Davidson Environmental Limited

# Post-remediation monitoring of sediments and biota from estuarine sites located adjacent to the former Fruitgrowers Chemical Company (FCC) site, Mapua, Nelson (sample 2)

Research, survey and monitoring report number 680

A report prepared for:
Tasman District Council and Ministry for the Environment
C/o Tasman District Council
189 Queen Street
Richmond
Nelson

By
Rob Davidson, Laura Richards & Jenny Easton

**Bibliographic reference:**

Davidson, R.J.; Richards, L.A.; Easton, J. 2011. Post-remediation monitoring of sediments and biota from estuarine sites located adjacent to the former Fruitgrowers Chemical Company (FCC) site, Mapua, Nelson (sample 2). Prepared by Davidson Environmental Limited for Tasman District Council and Ministry for the Environment. Survey and monitoring report 680.



**Prepared by:**

Davidson Environmental Limited
P.O. Box 958
Nelson 7040
Phone 03 5452600
Mobile 027 4453 352
e-mail davidson@xtra.co.nz

April 2011

# Contents

# Summary

Following the completion of the remediation project, the marine areas adjacent to the former Fruitgrowers Chemical Company (FCC) site were first sampled in Spring 2009 (Davidson et al., 2010). The present report presents data from the second post remediation sampling event in Spring 2010.

Sampling in the present study comprised:

- Pesticides in sediments (shallow 0-2 cm, deep 10-20 cm);
- Redox assessment of sediments;
- Pesticides in molluscs (mudflat snail, topshell snail, cockle);
- Invertebrate community composition and abundance from surface and within sediment samples; and
- Macroalgal distribution and percentage cover.

The sampling regime was based on recommendations made in the site auditor's report (Pattle Delamore, 2009). In 2009, sites that had been previously sampled were adopted for on-going monitoring. The present study re-sampled 2009 sites sampled by Davidson et al. (2010).

In the present study, 10 of the 16 shallow impact samples achieved the Soil Acceptance Criteria (SAC) for ADL (aldrin, dieldrin, lindane) (<0.01 mg/kg dry weight) compared to nine in the previous 2009 sample. In deeper sediments, seven sites achieved the SAC for ADL in 2010 compared to nine in 2009. Failure of more deep samples in the present study was due to an increase in ADL at East FCC sites.

For DDX (DDT, DDE, DDD), no sites achieved the SAC (<0.01 mg/kg dry weight) in 2009 or 2010. At West FCC sites, DDX levels in shallow sediments in 2010 remained comparable to levels recorded in 2009. For deep West FCC sediments, five sites showed small declines in DDX levels since 2009 and two showed small increases. In 2010, two West FCC deep sites achieved the SAC compared to three in 2009.

At the East FCC shore DDX values remained comparable or dropped between 2009 and 2010. DDX in most deep sediments, however, increased beyond levels that could be explained by natural environmental variation.

Two of the shallow samples collected from the tidal-influenced freshwater stream at the West FCC shore, also showed increases in ADL and DDX beyond normal environmental

variability. Deep stream sediments did not achieve the SAC for ADL or DDX, although values were considerably lower than recorded for shallow sediments.

ADL and DDX levels in cockles were comparable to other areas in New Zealand close to large cities with associated contamination of estuarine areas. Contaminants in cockles were, however, relatively low when compared to many contaminated sites overseas and were below the US and Canadian limits for the protection of human health.

ADL and DDX levels in mudflat snails were the highest of any mollusc sampled in the present study. This makes these snails the best indicator of contamination in molluscs. Levels of contaminants in mudflat snails dropped in 2010 compared to the 2009 sample.

A moderate level of nutrient enrichment was indicated by redox assessments in Eastern and Western FCC marine sediments. Enrichment of sediment is probably from water runoff via the numerous seepages flowing from the FCC site. Enrichment has not resulted in anaerobic conditions or a change in community composition. No increase or high abundance of pollution indicating organisms were recorded in 2009 or 2010. Present levels of ADL and DDX in marine sediments do not appear to have resulted in a decrease in invertebrate community diversity or abundance.

Recommendations with regard to future monitoring conclude the present report.

# 1.0 Background

Historic environmental investigations carried out at Mapua reported elevated concentrations of contaminants in marine sediments adjacent to the FCC site (e.g. CH2M HILL, 2007). The major contaminants of concern were organochlorine pesticides (OCPs), which include DDT, DDD and DDE (collectively known as DDX), and aldrin, dieldrin and lindane (collectively known as ADL). A decision was made to remediate the site to prevent further effects on the marine environment. Following initial trials, remediation works commenced in October 2004 and were completed in early 2008. The remediation Validation Report was submitted to MfE in December 2008. The site has remained vacant since remediation was completed.

During the works, two areas of foreshore adjacent to the FCC site were included in the remediation:

- the tidal beach in Mapua Channel located to the east of FCC East; and
- the tidal mudflats in Waimea Inlet located to the south of FCC Landfill, including a tidal channel that crosses the mudflats (the "swale"). Also included was a section of the tidal creek running along the north-west edge of FCC Landfill. This stream carries storm-water from adjacent housing developments.

The extent of contamination at these locations was broadly defined by previous investigation results and additional sampling during the remediation works. Based on the pre-remediation results, a surface layer of contaminated sediment was excavated down to the low tide contour in East FCC. In the west, the creek (for most of its length adjacent to the site), part of the foreshore, and part of the tidal swale were excavated and backfilled. The removal of contaminated sediments was completed in a series of cells, each backfilled with imported gravels after validation sampling from the base of the excavation. The resource consent required that excavated cells were sampled and backfilled within one tide. Consequently, the excavations were backfilled before the validation test results were received.

In June 2009, the audit report for the remediation of the former Fruitgrowers Chemical Company site, Mapua, was completed (Pattle Delamore, 2009). The auditor provided a comprehensive document that included a variety of recommendations with respect to monitoring marine sediments and biota. The general recommendations are outlined below, while the full recommendations can be viewed in Chapter 6 of the audit report.

The auditor has stated with respect to the marine sediments that:

"*It is considered that remediation to the extent practicable has been broadly achieved in the marine foreshore areas. The benefits of further remediation are likely to be outweighed by the additional disruption and impacts to the environment. It is clear that the remediation in these areas has not been successful in meeting the SACs for DDX and ADL. However, re-deposition of non-complying sediment from the surrounding marine environment probably meant that compliance with the SACs could not be achieved within the foreshore surface sediments. In addition, re-contamination of the deeper backfill material has occurred during the remediation works. The mechanism(s) for this are not clear, but site runoff is probably a major contributor. While contamination remains within the backfilled material, there is evidence that the surface sediment quality has been improving since completion of the remediation. A key aspect of the foreshore remediation is the removal of the site as a source of ongoing sediment contamination. This will allow natural attenuation processes to slowly improve the foreshore sediment quality over the coming years. Apart from localised effects on the marine ecosystem, the effects of the residual sediment contamination on other receptors are not likely to be significant. In the case of risks to human health via seafood consumption, additional data is required to confirm this as the current dataset is limited."*

The auditor stated with respect to monitoring that:

*"Sediment and snail sampling should continue, following a review of the sampling design to ensure it is adequately quantifying the risk via seafood consumption and is properly representing the quality of the surface sediments. The health and diversity of the foreshore ecosystems should be benchmarked relative to suitable control sites elsewhere in the Waimea Inlet. The information will contribute to assessing the significance of the residual contamination in the foreshore sediments and the local effects of contaminated groundwater discharge. The current annual monitoring of sediment and biota by TDC should be continued and expanded.*

*The aim of the monitoring will be to:*

1. *confirm OCP concentrations in snails (as appropriate bio-indicators) remain below levels that might present an unacceptable risk to human health;*
2. *confirm apparent improving trends in the chemical quality of shallow sediment using a larger sample set; and*
3. *provide additional information on localised effects of nutrients in groundwater discharges on the foreshores (see Section 7.10.2 of the audit report)."*

The present document is the second sample event (Spring 2010) after the completion of the remediation. The first sample event was conducted in Spring 2009 and was reported in

Davidson et al. (2010). The present sampling regime is a subset of the Davidson et al. (2010) sampling regime. Both sampling events follow recommendations by the site auditor.

## 2.0 Site history

The following section on the history of operations at the site has been extracted from the auditor's report.

FCC operated an agrichemical formulation plant on FCC East and West from 1932 until 1988, producing pesticides, herbicides and fungicides that were used throughout the country. The north-eastern portion of FCC East was operated by a subsidiary company, originally known as Lime and Marble Limited and later as Mintech Ltd. The Mintech site was generally used for processing non-toxic minerals but also included the FCC micronising plant and some biocide preparation. Facilities used for agrichemical formulation and storage were operated on both FCC East and West.

From the 1950s, a number of areas were either in-filled or reclaimed, including: low lying areas of FCC East; the area now known as FCC Landfill, reclaimed from the Waimea Inlet; and the eastern portions of FCC East, reclaimed from the Mapua Channel. The fill material used contained waste material from site operations.

FCC ceased operations in 1988 and by 1996 TDC had either inherited or acquired the FCC portions of the site, i.e. FCC Landfill, FCC West and FCC East. FCC Landfill was inherited first, in the early 1990s. In May 1992, TDC installed a clay cut-off wall along the southern edge of FCC Landfill to reduce leachate migration into the Waimea Inlet. From the early 1990s onwards, the site was the subject of a number of environmental investigations and assessments. It was clear from the investigation results that some form of remediation or management of residual contamination at the site was required. Elevated contaminant concentrations were detected in soil on and adjacent to the site, groundwater and in nearby marine sediments. The major contaminants of concern which drove the need for remediation were organochlorine pesticides. Other contaminants included heavy metals, organonitrogen pesticides, organophosphorous pesticides, petroleum hydrocarbons, acid herbicides and elemental sulphur.

The peak soil concentrations were typically found in the vicinity of historical process areas. Marine sediments appear to have been contaminated from site runoff and drainage, including from the landfill, to the nearby estuary and Mapua Channel – see next section.

A decision was made to remediate the site after initial plans for capping the site were set aside. Soil treatment trials to select an appropriate technology were carried out in 1999 – 2000. Resource consents for the remediation were granted in November 2003.

## 3.0 Previous estuarine contaminant studies

Woodward Clyde (1996) presented contaminant monitoring data for a variety of biota sampled from estuarine habitats adjacent to the FCC site (east, west and general area). The species sampled included mudflat snail (*Amphibola crenata*), cockle (*Austrovenus stutchburyi*), green-lipped mussel (*Perna canaliculus*), and Pacific oyster (*Crassostrea gigas).* Most sampling occurred from areas adjacent to the FCC site between 1993 and 1996.

Landcare Research scientists sampled contaminants from sediments at upper and lower catchment positions of the western mudflat channel, as well as a western mudflat site (Tahi Street) and eastern site located adjacent to the FCC site (O'Halloran and Cavanagh, 2002; Cavanagh and O'Halloran, 2003). These authors also sampled contaminants from mudflat snail (*Amphibola crenata*), crab (Grapsid family), short-finned eel (*Anguilla australis*), cockle (*Austrovenus stutchburyi*), and Pacific oyster (*Crassostrea gigas*). They also collected samples from a control channel and a control mudflat site.

The authors reported that crabs and cockles did not accumulate high levels of organochlorine contaminants compared to snails (*Amphibola*). The authors reported that, apart from eels, snails accumulated much higher concentrations of organochlorine contaminants compared to other organisms sampled. Cavanagh and O'Halloran (2003) recommended that snail (*Amphibola*) was the most appropriate bioindicator to assess the success of remediation of the FCC site and its associated contaminated areas. The authors also recommended that some "opportunistic sampling be conducted of higher animals such as eels inhabiting the drain".

TDC has sampled contaminants from sediments and snails on a number of occasions since 2005 (Easton, 2005; 2007a; 2007b; 2008; 2009; 2009a, 2010). Two sets of sampling sites have been used in repeat monitoring programmes. Sample of sediment and snail contamination were collected along the western estuary parallel to Tahi Street (Easton, 2007b; 2009). Another set of sample sites were repeat monitored for snail and sediment contamination as part of the consent condition 522/19 requiring testing of the sediments and macroinvertebrates 12, 24 and 36 months after the coastal marine area remediation (Easton, 2007a; 2008; 2009a). It is the latter set of samples that the site auditor suggested should be repeat sampled on at least two more occasions prior to a review of monitoring.

TDC sampled snails (*Amphibola crenata*) from the West FCC site and from a control site located further westward in the Waimea Inlet. Following remediation of the east FCC tidal shore, mudflat snails failed to recolonise. The author instead sampled a topshell (*Diloma subrostrata*). This species was also sampled from a control area located further eastwards in Waimea Inlet. *D. subrostrata* lives on a combination of rock, shell and soft substrata. Bioaccumulation levels recorded for this species were consistently lower than levels recorded for *Amphibola* samples collected from the west FCC site.

In Spring 2009, Davidson et al. (2010) sampled sediments for contaminant levels, organic content and a grain size analysis was conducted. The authors also recorded macroalgal cover, surface dwelling macroinvertebrates and infaunal invertebrates from East and West estuarine areas adjacent to the FCC site. The same parameters were also sampled from two control sites well distant to the remediated area.

In response to results from the Davidson et al. (2010) study, TDC sampled sediment and mudflat snail contaminants from one site of concern (JMB 084) located at the West FCC shore in January 2010 (Easton, 2010).

# 4.0 Review of biological sampling in 2009

The auditor recommended that:

Prior to undertaking the first post-remediation snail monitoring sample event, a review by Davidson (2009) was conducted to confirm that the sampling programme was sufficient and appropriate given the altered habitat and different species that had re-colonised East FCC habitats. The review assessed previous reports on the subject, including that by Landcare Research (2002), and took into account recent monitoring data. Consideration was given to sampling of alternative species of biota and extending the programme to improve its statistical robustness. The review also considered whether the sampling was properly representing the quality of the surface sediments.

In the review document, Davidson (2009) concluded that:

1. West FCC site: no change to the existing sampling protocol.
2. East FCC site: (1) collect an additional one or up to two mudflat snail composite samples; (2) at present, one topshell sample is collected from the East FCC site. It is recommended that two topshell samples from the East FCC site be collected on the first sample occasion (i.e. one sample from hard substrata and one sample from soft substrata).

3. East FCC site: one cockle sample should be collected from the East FCC site on each sample event.

# 5.0 Methods (present study)

Three broad types of monitoring were conducted in the marine environment adjacent to the FCC site, Mapua: (1) Contaminant sampling of macroinvertebrates and sediment (OPC's), (2) environmental variable sampling (redox cores), and (3) biological community sampling (invertebrate density and size, macroalgal cover). A summary of the laboratory methods and tests are displayed in Appendix 6.

## 5.1 Mollusc and sediment contaminant sampling

On 15th November 2010, sediment for contaminant analysis was collected from the surface layer (0-2 cm) and deep layer (10-20 cm) from estuarine soft sediments adjacent to the FCC site and at control sites (Table 1, Figures 1 and 2). The same surface sites were sampled as those sampled by Davidson et al. (2010). An additional deep sediment sample was collected from each of the three stream sites during the present study (Table 1). Sediment was collected using a stainless steel sampler from undisturbed substratum at each sample site. Samples were placed in containers supplied by Hill Laboratories. Stainless steel collection devices were washed between each replicate sample and between each site.

A variety of macroinvertebrates were also collected for contaminant analysis from FCC impact and Waimea Inlet control sites (Table 2, Figures 3 and 4). At one control site and two impact sites (West FCC and East FCC), the mudflat snail (*A. crenata*) was collected. The topshell (*Diloma subrostrata*) was sampled from an East FCC impact site. Based on the review by Davidson (2009), impact topshells living on (a) mud or (b) rock substratum were collected and kept separate for analysis. One sample of topshell snails were also collected from an eastern control site. In addition, a cockle sample was collected from the East FCC site and the same eastern control site some 1.4 km south-east of Mapua (Table 2, Figures 3 and 4).

Invertebrates were collected by hand using a haphazard sampling technique from an area of approximately $10m^2$ at each site. The only exception was the composite mudflat snail sample collected at the East FCC site (see yellow area in Figure 3). At this site, mudflat snails were relatively rare; therefore the whole shoreline was used to provide sufficient snail specimens for analysis. It is noted that Davidson et al. (2010) removed approximately 50 mudflat snails from the East FCC site for their sample. The authors stated that this was virtually all of the snails at this site. In response, the authors seeded the area with 50 snails collected from the western control site. It is impossible to know whether the snails sampled during the present sample were those transferred or new snails that had migrated or settled into the East FCC area.

All macroinvertebrates were kept in seawater for a period of 24 hours prior to transportation to Hill Laboratories to enable sediment purging from their digestive tracts prior to analysis. Seawater was regularly replaced during this period to ensure their survival during this process.

Macroinvertebrates (7) and sediment samples (18 shallow, 18 deep) were sent to Hill Laboratories for analysis on the day following collection.

**Table 1. Sediment contaminant and redox monitoring sites located at East and West (FCC) impact and control sites (November 2010).**

| Type | Site number | Coordinates | Strata | OCP surface | OCP deep | Redox |
|---|---|---|---|---|---|---|
| West control | JME 080 | 41° 15.482'S, 173° 5.540'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (west) | JME 083 | 41° 15.463'S, 173° 5.819'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (west) | JME 081 | 41° 15.484'S, 173° 5.821'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (west) | JME 082 | 41° 15.501'S, 173° 5.825'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (west) | West FCC new 1 (west) | 41° 15.471'S, 173° 5.849'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (west) | West FCC new 2 (middle) | 41° 15.473'S, 173° 5.867'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (west) | West FCC new 3 (east) | 41° 15.480'S, 173° 5.879'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (west) | JME 084 | 41° 15.484'S, 173° 5.859'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (west) | West FCC Stream 1 (lower) | 41° 15.446'S, 173° 5.839'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (west) | West FCC Stream 2 (middle) | 41° 15.433'S, 173° 5.863'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (west) | West FCC Stream 1 (upper) | 41° 15.425'S, 173° 5.877'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (east) | JME 088 | 41° 15.418'S, 173° 6.089'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (east) | JME 087 | 41° 15.421'S, 173° 6.093'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (east) | JME 086 | 41° 15.423'S, 173° 6.097'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (east) | East FCC New 1 (north) | 41° 15.410'S, 173° 6.097'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (east) | East FCC New 2 (south) | 41° 15.428'S, 173° 6.083'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| Impact (east) | JME 090 | 41° 15.436'S, 173° 6.079'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| East control | Hunter-Brown | 41° 16.187'S, 173° 6.497'E | 0-2 cm & 10-20 cm | 1 | 1 | 1 |
| TOTAL SAMPLES | | | | 18 | 18 | 18 |


**Figure 1. Location of sediment contaminant sites at West FCC location. Insert is West control site (1st bay to the west of West FCC).**


**Figure 2. Location of sediment contaminant sites at East FCC location. Insert is East control site at Hunter-Brown Reserve.**


**Figure 3. Location of invertebrate contaminant samples collected from West FCC site and West control site.**


**Figure 4. Location of invertebrate contaminant samples collected from East FCC site. Yellow area indicates the composite *Amphibola* collection area. Insert map is East control cockle sample site located at Hunter-Brown Reserve.**

**Table 2. Invertebrate contaminant sample sites located at impact (FCC) and control sites.**

| Type | Site number | Coordinates | Samples per site |
|---|---|---|---|
| West control | JME 080 (*Amphibola*) | 41° 15.482'S, 173° 5.540'E | 1 |
| West FCC | JME 084 (*Amphibola*) | 41° 15.484'S, 173° 5.859'E | 1 |
| East FCC (soft) | East FCC New 2 (south soft) (*Diloma*) | 41° 15.438'S, 173° 6.076'E | 1 |
| East FCC (rocky) | East FCC New 2 (south rocky) (*Diloma*) | 41° 15.438'S, 173° 6.076'E | 1 |
| East FCC (composite) | East FCC (*Amphibola*) | see Figure 4 | 1 |
| East FCC (JME 090) | East FCC (cockle) | 41° 15.436'S, 173° 6.079'E | 1 |
| East control | Hunter-Brown (cockle) | 41° 16.190'S, 173° 6.497'E | 1 |
| TOTAL SAMPLES | | | 7 |

## 5.2 Environmental variable sampling

Redox data from estuarine sediments were collected on the 15th November 2010 (Table 1, Figures 1 and 2). At each contaminant sample site (18), a 15 cm deep by 15 cm wide core sample was collected to assess the redox layer. Each core was photographed and notes taken on colour and odour.

## 5.3 Biological community sampling

A variety of biological sampling was conducted at FCC and control sites in Spring 2010. Sampling was a repeat of biological sampling conducted by Davidson et al. (2010) approximately one year earlier.

### 5.3.1 Macroalgae cover

On the 16th November 2010 photographs of macroalgae cover were collected from impact and control sites. At each site, reference points selected by Davidson et al. (2010) were relocated and used as photopoint sites. At the West FCC site, a total of three fixed point locations were selected, while two fixed points were chosen at the East FCC site (Table 3, Figure 5). Photos were also collected at the two control sites.

At each site, a series of photographs were collected spanning the adjacent estuarine area. Photographs were rendered into a panoramic photograph using the software program Autostitch. It is noted that this process may result in a small level of distortion and image-bending.

Percentage cover estimates of macroalgae on the substratum were collected from a series of contiguous 1m$^2$ quadrats deployed perpendicular to the shoreline from fixed points (Table 4, Figure 6). Apart from the East control site, the start of the series of quadrats was positioned near or at mean high water or at the foot of the rock embankments. The series of quadrats extended 14 m distance from the point of origin. A photograph of representative quadrats was collected from each series of quadrats at each site.

### 5.3.2 Epifauna and infauna invertebrate density and size

Macroinvertebrates were sampled from four impact and two control sites on 16th November 2010 (Table 5, Figure 7). At each site, surface counts of conspicuous macroinvertebrates were collected from 14 replicate, haphazardly deployed 1m$^2$ quadrats. Only macroinvertebrates that were living on the surface or partially visible on the surface were counted.

Three replicate core samples (13 cm wide by 15 cm deep) were collected at each site (Table 5). Cores were processed on-site through a 1 mm mesh size sieve and the contents preserved in 70% isopropyl alcohol (IPA) for sorting and identification. Macroinvertebrates were identified to the most practical taxonomic level by Rod Asher of the Cawthron Institute. All cockles obtained from core samples were measured for maximum length. To increase the sample size, additional cockles were collected and a representative sub-sample was also measured.

**Table 3. Macroalgae photo-points at Mapua FCC impact and control sites.**

| Location | Site | Description | Coordinates |
|---|---|---|---|
| West control | North | Located at seaward edge of rushes | 41° 15.487'S, 173° 5.544'E |
| West FCC | Western | At embedded marble rocks at foot of bank | 41° 15.458'S, 173° 5.825'E |
| West FCC | Middle | At embedded marble rocks at foot of bank | 41° 15.461'S, 173° 5.859'E |
| West FCC | Eastern | At embedded marble rocks at foot of bank | 41° 15.463'S, 173° 5.897'E |
| East FCC | Drain | On top of storm water pipe | 41° 15.408'S, 173° 6.095'E |
| East FCC | South | At southern end of shoreline rock wall | 41° 15.442'S, 173° 6.072'E |
| East control | | 12 m seaward of large tree lucerne | 41° 16.187'S, 173° 6.492'E |

**Table 4. Macroalgae transects at Mapua FCC impact and control sites.**

| Location | Site | Description | Coordinates | Quadrats in series |
|---|---|---|---|---|
| West control | North | Transect located north side of rushes, start at rush edge | 41° 15.487'S, 173° 5.544'E | 10 |
| West control | South | Transect located south side of rushes, start at rush edge | 41° 15.494'S, 173° 5.545'E | 10 |
| West FCC | West | Start on imbedded marble rock | 41° 15.461'S, 173° 5.859'E | 13 |
| West FCC | East | Start on imbedded marble rock | 41° 15.461'S, 173° 5.884'E | 14 |
| East FCC | North | 16 m south of storm water pipe | 41° 15.414'S, 173° 6.093'E | 13 |
| East FCC | South | 16 m north from end of shoreline rock wall | 41° 15.430'S, 173° 6.081'E | 13 |
| East control | West | 12 m seaward of large tree lucerne | 41° 16.187'S, 173° 6.492'E | 13 |
| East control | East | 12 m seaward of large tree lucerne | 41° 16.189'S, 173° 6.496'E | 13 |
| TOTAL QUADRATS | | | | 99 |

**Table 5. Invertebrate infaunal and epifaunal sites from FCC impact and control sites.**

| Location | Site | Core replicates | Surface $m^2$ replicates | Coordinates |
|---|---|---|---|---|
| West control | JME 080 | 3 | 14 | 41° 15.482'S, 173° 5.540'E |
| West FCC | West FCC (new2) | 3 | 14 | 41° 15.473'S, 173° 5.867'E |
| West FCC | West FCC (new3) | 3 | 14 | 41° 15.480'S, 173° 5.879'E |
| | | | | |
| East FCC | East FCC (new1) | 3 | 14 | 41° 15.408'S, 173° 6.098'E |
| East FCC | East FCC (new 2) | 3 | 14 | 41° 15.428'S, 173° 6.083'E |
| | | | | |
| Huunter-Brown | East Control | 3 | 14 | 41° 16.187'S, 173° 6.497'E |



**Figure 5. Location of macroalgae photo points. Insert is East control (Hunter-Brown Reserve).**



**Figure 6. Location of macroalgae transects at impact and control sites. Insert is East control.**


**Figure 7. Location of invertebrate infaunal and epifaunal impact and control sites.**

# 6.0 Results

## 6.1 Mollusc and sediment contaminant sampling

### 6.1.1 Contaminants in sediment

Contaminants in estuarine and stream sediments varied with depth, both between and at the same sites, as well as the same depth between sites (Figure 8, Table 6, Appendix 6). ADL (aldrin, dieldrin, lindane) exceeded the Soil Acceptance Criteria (SAC) at six of 16 shallow impact sites and nine of 16 deep impact sites. No elevated ADL values were recorded from control sites at either depth strata. In 2009 and 2010 the highest ADL was recorded from deep JME 090 located close to the rock wall at the southern East FCC shore (Figures 2 & 8). Shallow ADL dropped in 2010 compared to 2009 at this site. Other elevated values for ADL were also recorded from deep sediments at East FCC new2 (south), JME 087, JME088 and JME 086. These sites were from the East FCC shore (Figures 2 & 8). Deep ADL values in 2010 for the latter three sites were considerably higher compared to 2009.

All three shallow West FCC stream sites had ADL between 0.068 and 0.17 mg/kg dry weight. Two sites increased from 2009. ADL at deep stream sites were sampled for the first time in the present study and exhibited ADL values lower than surface sediments (Figure 8).

Both shallow and deep DDX (2,4 DDT; 4,4 DDT; 2,4 DDD; 4,4 DDD; 2,4 DDE; 4,4 DDE) values at West FCC sites in November 2010 remained comparable to September 2009 samples. Similarly shallow DDX values remained comparable at East FCC sites between sample years. In contrast, deep DDX values at four of the East FCC sites increased from 2009 and were well above the SAC (Table 6, Figure 8). Similarly shallow West FCC stream sites exhibited elevated DDX values comparable to, or higher than 2009 samples (Figure 8).

Comparison of DDX, dieldrin and lindane levels sampled from the same sites on six occasions (2005 to 2010) had high values at particular sites in 2005 and 2007. Samples collected in 2008 and 2009 showed dramatically lower values (Figure 9, Table 7). Average DDX and dieldrin values peaked in 2005, while the highest lindane level was recorded in 2007 (Figure 10). For the three sample events between 2008, 2009 and 2010, mean values for DDX, dieldrin and lindane were dramatically lower than 2005 and 2007. Despite this large decline, mean values for DDX in 2010 (0.2 mg/kg) remained above the SAC. The mean concentration of dieldrin (0.01 mg/kg) reached the SAC in November 2010 for the first time since 2005. Lindane was below the SAC in 2008, 2009a, 2009b and 2010 (Table 7). Aldrin was not reported as concentrations were typically below laboratory detection limits.

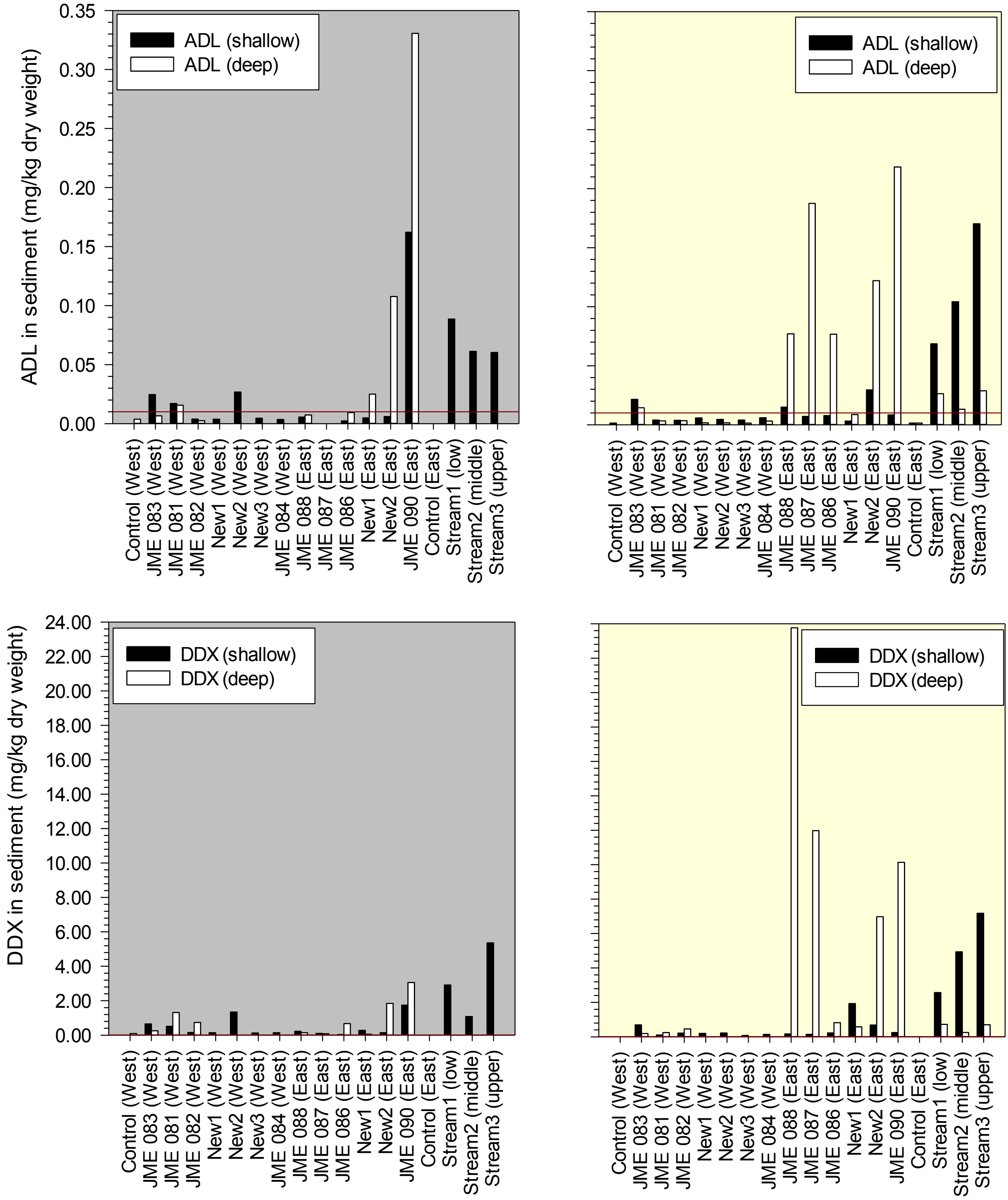



**Figure 8. Levels of ADL (aldrin, dieldrin, lindane) and DDX (2,4DDT; 4,4DDT; 2,4DDD; 4,4DDD; 2,4DDE; 4,4DDE) (mg/kg dry weight) recorded from sediment samples collected at control and impact sites in 2009 (left, grey) and 2010 (right, yellow). Note: deep stream sediments were not sampled in 2009. Red line is SAC (0.01 mg/kg dry weight).**

**Table 6a. Summary of shallow sediment ADL and DDX levels and their component analytes sampled in 2009 from impact (FCC sites) and control sites.**

**September 2009**

| SURFACE (0 - 2 cm) 2009 Test | SAC | West Control | West FCC JME 083 | West FCC JME 081 | West FCC JME 082 | West FCC new1 (west) | West FCC new2 (middle) | West FCC new3 (east) | West FCC JME 084 | East FCC JME 088 | East FCC JME 087 | East FCC JME 086 | East FCC new1 (north) | East FCC new2 (south) | East FCC JME 090 | East Control | West FCC Stream1 (low) | West FCC Stream2 (middle) | West FCC Stream3 (upper) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aldrin | | < 0.0010 | < 0.0011 | 0.001 | < 0.0010 | < 0.00099 | < 0.0011 | < 0.00099 | < 0.00099 | < 0.0011 | < 0.00098 | < 0.0010 | < 0.0010 | < 0.00099 | 0.0016 | < 0.00099 | 0.0088 | 0.0047 | 0.0075 |
| Dieldrin | | < 0.0010 | 0.023 | 0.015 | 0.0028 | 0.0027 | 0.024 | 0.0036 | 0.0025 | 0.0044 | < 0.00098 | 0.0013 | 0.0038 | 0.005 | 0.16 | < 0.00099 | 0.076 | 0.054 | 0.05 |
| gamma-BHC (Lindane) | | < 0.0010 | 0.001 | 0.001 | < 0.0010 | < 0.00099 | 0.0022 | < 0.00099 | < 0.00099 | < 0.0011 | < 0.00098 | < 0.0010 | < 0.0010 | < 0.00099 | < 0.0010 | < 0.00099 | 0.0038 | 0.0025 | 0.0028 |
| 2,4-DDD | | < 0.0010 | 0.084 | 0.065 | 0.018 | 0.014 | 0.19 | 0.014 | 0.014 | 0.014 | 0.0038 | 0.0031 | 0.014 | 0.0073 | 0.39 | < 0.00099 | 0.34 | 0.19 | 0.36 |
| 4,4 DDD | | < 0.0010 | 0.2 | 0.16 | 0.046 | 0.033 | 0.53 | 0.031 | 0.051 | 0.033 | 0.015 | 0.014 | 0.038 | 0.025 | 1 | < 0.00099 | 0.93 | 0.3 | 1.1 |
| 2,4 DDE | | < 0.0010 | 0.038 | 0.027 | 0.0062 | 0.0039 | 0.041 | 0.006 | 0.0038 | 0.0021 | < 0.00098 | < 0.0010 | < 0.0010 | < 0.00099 | < 0.0010 | < 0.00099 | 0.2 | 0.11 | 0.18 |
| 4,4 DDE | | < 0.0010 | 0.21 | 0.16 | 0.039 | 0.057 | 0.48 | 0.047 | 0.054 | 0.037 | 0.011 | 0.0068 | 0.038 | 0.018 | 0.11 | < 0.00099 | 1.2 | 0.32 | 1.2 |
| 2,4 DDT | | < 0.0010 | 0.025 | 0.091 | 0.0073 | 0.002 | 0.008 | 0.0032 | 0.0028 | 0.019 | 0.015 | 0.0018 | 0.034 | 0.01 | 0.029 | < 0.00099 | 0.041 | 0.027 | 0.12 |
| 4,4 DDT | | 0.0014 | 0.1 | 0.015 | 0.04 | 0.031 | 0.094 | 0.023 | 0.016 | 0.12 | 0.059 | 0.014 | 0.16 | 0.084 | 0.21 | < 0.00099 | 0.2 | 0.14 | 2.4 |
| ADL (aldrin, dieldrin, lindane) [1] | 0.01 | 0.0015 | 0.02455 | 0.017 | 0.0038 | 0.00369 | 0.02675 | 0.00459 | 0.00349 | 0.0055 | 0.00147 | 0.0023 | 0.0048 | 0.00599 | 0.1621 | 0.001485 | 0.0886 | 0.0612 | 0.0603 |
| DDX [1] | 0.01 | 0.0039 | 0.657 | 0.518 | 0.1565 | 0.1409 | 1.343 | 0.1242 | 0.1416 | 0.2251 | 0.10429 | 0.0402 | 0.2843 | 0.1448 | 1.7395 | 0.00297 | 2.911 | 1.087 | 5.36 |

**November 2010**

| SURFACE (0 - 2 cm) 2010 Test | SAC | West Control | West FCC JME 083 | West FCC JME 081 | West FCC JME 082 | West FCC new1 (west) | West FCC new2 (middle) | West FCC new3 (east) | West FCC JME 084 | East FCC JME 088 | East FCC JME 087 | East FCC JME 086 | East FCC new1 (north) | East FCC new2 (south) | East FCC JME 090 | East Control | West FCC Stream1 (low) | West FCC Stream2 (middle) | West FCC Stream3 (upper) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aldrin | | <0.0011 | 0.0017 | <0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | 0.0021 | <0.0010 | <0.0010 | 0.005 | 0.0051 | 0.0065 |
| Dieldrin | | <0.0011 | 0.0193 | 0.003 | 0.0027 | 0.0048 | 0.0036 | 0.0029 | 0.0049 | 0.014 | 0.006 | 0.0068 | 0.0022 | 0.027 | 0.0074 | <0.0010 | 0.061 | 0.095 | 0.16 |
| gamma-BHC (Lindane) | | <0.0011 | <0.0010 | <0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | <0.0010 | <0.0010 | <0.0010 | 0.0026 | 0.0041 | 0.0038 |
| 2,4-DDD | | <0.0011 | 0.071 | 0.0142 | 0.0135 | 0.02 | 0.03 | 0.0071 | 0.0162 | 0.0175 | 0.0102 | 0.0106 | 0.038 | 0.032 | 0.02 | <0.0010 | 0.39 | 0.7 | 1.18 |
| 4,4 DDD | | 0.0029 | 0.172 | 0.034 | 0.036 | 0.051 | 0.076 | 0.0139 | 0.048 | 0.041 | 0.023 | 0.025 | 0.081 | 0.079 | 0.046 | 0.0012 | 0.79 | 1.5 | 2.4 |
| 2,4 DDE | | <0.0011 | 0.028 | 0.0052 | 0.0042 | 0.0048 | 0.0086 | 0.0017 | 0.0047 | 0.0024 | 0.0013 | 0.0013 | <0.010 | 0.007 | 0.0022 | <0.0010 | 0.23 | 0.42 | 0.59 |
| 4,4 DDE | | 0.0036 | 0.28 | 0.037 | 0.031 | 0.048 | 0.084 | 0.021 | 0.054 | 0.026 | 0.0185 | 0.0165 | 0.089 | 0.12 | 0.031 | 0.0012 | 1.02 | 1.91 | 2.7 |
| 2,4 DDT | | <0.0011 | 0.0131 | 0.0026 | 0.0061 | 0.0168 | 0.0055 | 0.0063 | 0.0024 | 0.0151 | 0.0109 | 0.033 | 0.164 | 0.109 | 0.037 | 0.0012 | 0.03 | 0.08 | 0.051 |
| 4,4 DDT | | 0.0019 | 0.129 | 0.0134 | 0.121 | 0.057 | 0.0189 | 0.026 | 0.0187 | 0.067 | 0.076 | 0.148 | 1.55 | 0.34 | 0.113 | 0.0091 | 0.115 | 0.33 | 0.26 |
| ADL (aldrin, dieldrin, lindane) [1] | 0.01 | 0.0015 | 0.0215 | 0.004 | 0.0037 | 0.0058 | 0.0046 | 0.004 | 0.006 | 0.015 | 0.007 | 0.0078 | 0.0032 | 0.0296 | 0.0084 | 0.0015 | 0.0686 | 0.1042 | 0.1703 |
| Comparison 2009 to 2010 | | No change | Decline | Decline | Decline | Increase | Decline | Decline | Increase | Increase | Increase | Increase | Decline | Increase | Decline | Increase | Decline | Increase | Increase |
| DDX [1] | 0.01 | 0.01005 | 0.6931 | 0.1064 | 0.2118 | 0.1976 | 0.223 | 0.076 | 0.144 | 0.169 | 0.1399 | 0.2344 | 1.927 | 0.687 | 0.2492 | 0.0137 | 2.575 | 4.94 | 7.181 |
| Comparison 2009 to 2010 | | Increase | Increase | Decline | Increase | Increase | Decline | Decline | Increase | Decline | Increase | Increase | Increase | Increase | Decline | Increase | Decline | Increase | Increase |

| Notes: | |
|---|---|
| 1 | For multiple analyte totals, the concentration detected below the LOR is assumed to have a concentration of 0.5 the LOR |
| SAC | Soil acceptance criteria |
| LOR | Limit of laboratory reporting |
| ND | Not detected above LOR's |
| (shaded) | Value exceeds Soil Acceptance Criteria (SAC) |

**Table 6b. Summary of deep sediment ADL and DDX levels and their component analytes sampled in 2009 from impact (FCC sites) and control sites.**

**September 2009**

| DEEP (15 - 20 cm) Test | SAC | West Control | West FCC JME 083 | West FCC JME 081 | West FCC JME 082 | West FCC new1 (west) | West FCC new2 (middle) | West FCC new3 (east) | West FCC JME 084 | East FCC JME 088 | East FCC JME 087 | East FCC JME 086 | East FCC new1 (north) | East FCC new2 (south) | East FCC JME 090 | East Control |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aldrin | | < 0.00098 | < 0.0011 | 0.0025 | < 0.00099 | < 0.0011 | < 0.0011 | < 0.00099 | < 0.00099 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | 0.0072 | 0.028 | < 0.0010 |
| Dieldrin | | 0.0027 | 0.0055 | 0.011 | 0.0015 | < 0.0011 | < 0.0011 | < 0.00099 | < 0.00099 | 0.0063 | < 0.0010 | 0.0083 | 0.024 | 0.1 | 0.3 | < 0.0010 |
| gamma-BHC (Lindane) | | < 0.00098 | < 0.0011 | 0.0021 | < 0.00099 | < 0.0011 | < 0.0011 | < 0.00099 | < 0.00099 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | 0.0026 | < 0.0010 |
| 2,4-DDD | | < 0.00098 | 0.022 | 0.081 | 0.044 | < 0.0011 | 0.0012 | < 0.00099 | < 0.00099 | 0.0049 | 0.0028 | 0.016 | 0.0035 | 0.086 | 0.47 | < 0.0010 |
| 4,4 DDD | | 0.0071 | 0.054 | 0.15 | 0.15 | 0.012 | 0.0025 | < 0.00099 | 0.0021 | 0.0062 | 0.0036 | 0.035 | 0.0069 | 0.11 | 1.2 | 0.0026 |
| 2,4 DDE | | 0.024 | 0.0075 | 0.031 | 0.013 | < 0.0011 | < 0.0010 | < 0.00099 | < 0.00099 | 0.0044 | 0.0011 | 0.0046 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| 4,4 DDE | | 0.001 | 0.046 | 0.18 | 0.11 | 0.0026 | 0.0029 | 0.0013 | 0.0036 | 0.031 | 0.013 | 0.2 | 0.014 | 0.31 | 0.37 | 0.0011 |
| 2,4 DDT | | 0.056 | 0.017 | 0.15 | 0.022 | < 0.0011 | < 0.0010 | < 0.00099 | < 0.00099 | 0.014 | 0.011 | 0.091 | 0.004 | 0.35 | 0.17 | < 0.0010 |
| 4,4 DDT | | 0.0015 | 0.11 | 0.72 | 0.4 | 0.0035 | 0.0014 | < 0.00099 | 0.001 | 0.078 | 0.053 | 0.32 | 0.024 | 0.99 | 0.85 | 0.002 |
| ADL (aldrin, dieldrin, lindane) [1] | 0.01 | 0.00368 | 0.0066 | 0.0156 | 0.00249 | 0.00165 | 0.0016 | 0.001485 | 0.001485 | 0.0073 | 0.0015 | 0.0093 | 0.025 | 0.1077 | 0.3306 | 0.0015 |
| DDX [1] | 0.01 | 0.09009 | 0.2565 | 1.312 | 0.739 | 0.01975 | 0.00855 | 0.003775 | 0.008185 | 0.1385 | 0.0845 | 0.6666 | 0.0529 | 1.8465 | 3.0605 | 0.0072 |

**November 2010**

| DEEP (15 - 20 cm) Test | SAC | West Control | West FCC JME 083 | West FCC JME 081 | West FCC JME 082 | West FCC new1 (west) | West FCC new2 (middle) | West FCC new3 (east) | West FCC JME 084 | East FCC JME 088 | East FCC JME 087 | East FCC JME 086 | East FCC new1 (north) | East FCC new2 (south) | East FCC JME 090 | East Control | West FCC Stream1 (low) | West FCC Stream2 (middle) | West FCC Stream3 (upper) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aldrin | | < 0.0011 | 0.0019 | <0.0010 | < 0.0011 | < 0.0011 | < 0.0011 | <0.0010 | < 0.0011 | 0.0073 | 0.0111 | 0.0182 | 0.001 | 0.0063 | 0.033 | < 0.0010 | 0.0021 | 0.0018 | 0.0018 |
| Dieldrin | | < 0.0011 | 0.012 | 0.0023 | 0.0023 | < 0.0011 | < 0.0011 | <0.0010 | 0.0021 | 0.068 | 0.16 | 0.058 | 0.0071 | 0.111 | 0.183 | < 0.0010 | 0.023 | 0.0113 | 0.027 |
| gamma-BHC (Lindane) | | < 0.0011 | < 0.0010 | <0.0010 | < 0.0011 | < 0.0011 | < 0.0011 | <0.0010 | < 0.0011 | 0.0017 | 0.0165 | <0.0010 | <0.0010 | 0.0047 | 0.0024 | < 0.0010 | 0.0011 | <0.0010 | <0.0010 |
| 2,4-DDD | | < 0.0011 | 0.034 | 0.026 | 0.029 | < 0.0011 | < 0.0011 | 0.0013 | 0.0016 | 0.188 | 0.21 | 0.118 | 0.0194 | 0.27 | 0.4 | 0.0011 | 0.107 | 0.04 | 0.112 |
| 4,4 DDD | | < 0.0011 | 0.077 | 0.077 | 0.086 | 0.003 | 0.0017 | 0.0023 | 0.0038 | 2.1 | 0.98 | 0.39 | 0.021 | 0.53 | 1.04 | 0.0011 | 0.21 | 0.082 | 0.24 |
| 2,4 DDE | | < 0.0011 | 0.0102 | 0.0055 | 0.0098 | < 0.0011 | < 0.0011 | <0.0010 | <0.0011 | 0.0199 | 0.029 | 0.0119 | 0.0153 | 0.068 | <0.10 | <0.0010 | 0.043 | 0.025 | 0.062 |
| 4,4 DDE | | < 0.0011 | 0.058 | 0.063 | 0.07 | 0.0039 | 0.0019 | 0.0027 | 0.0054 | 0.25 | 0.39 | 0.08 | 0.118 | 0.89 | 0.55 | 0.0012 | 0.24 | 0.09 | 0.24 |
| 2,4 DDT | | < 0.0011 | 0.0107 | 0.0042 | 0.092 | < 0.0011 | < 0.0011 | <0.0010 | <0.0011 | 3.1 | 1.77 | 0.033 | 0.08 | 1.12 | 1.5 | 0.0015 | 0.021 | 0.0035 | 0.0059 |
| 4,4 DDT | | 0.0013 | 0.112 | 0.069 | 0.171 | 0.0011 | 0.001 | 0.0031 | 0.0019 | 18.1 | 8.6 | 0.191 | 0.33 | 4.1 | 6.6 | 0.0046 | 0.107 | 0.0166 | 0.047 |
| ADL (aldrin, dieldrin, lindane) [1] | 0.01 | < 0.0011 | 0.0144 | 0.0033 | 0.0034 | 0.00165 | 0.0016 | 0.0015 | 0.0032 | 0.077 | 0.1876 | 0.0767 | 0.0086 | 0.122 | 0.2184 | 0.0015 | 0.0262 | 0.0131 | 0.0288 |
| Comparison 2009 to 2010 | | Decline | Increase | Decline | Increase | No change | No change | Increase | Increase | Increase | Increase | Increase | Decline | Increase | Decline | No change | | | |
| DDX [1] | 0.01 | 0.01005 | 0.1909 | 0.2447 | 0.4578 | 0.00965 | 0.00625 | 0.0104 | 0.0138 | 23.7579 | 11.979 | 0.8239 | 0.5837 | 6.978 | 10.14 | 0.01 | 0.728 | 0.2571 | 0.7069 |
| Comparison 2009 to 2010 | | Decline | Decline | Decline | Decline | Decline | Decline | Increase | Increase | Increase | Increase | Increase | Increase | Increase | Increase | Increase | | | |

| Notes: | |
|---|---|
| 1 | For multiple analyte totals, the concentration detected below the LOR is assumed to have a concentration of 0.5 the LOR |
| SAC | Soil acceptance criteria |
| LOR | Limit of laboratory reporting |
| ND | Not detected above LOR's |
| (shaded) | Value exceeds Soil Acceptance Criteria (SAC) |

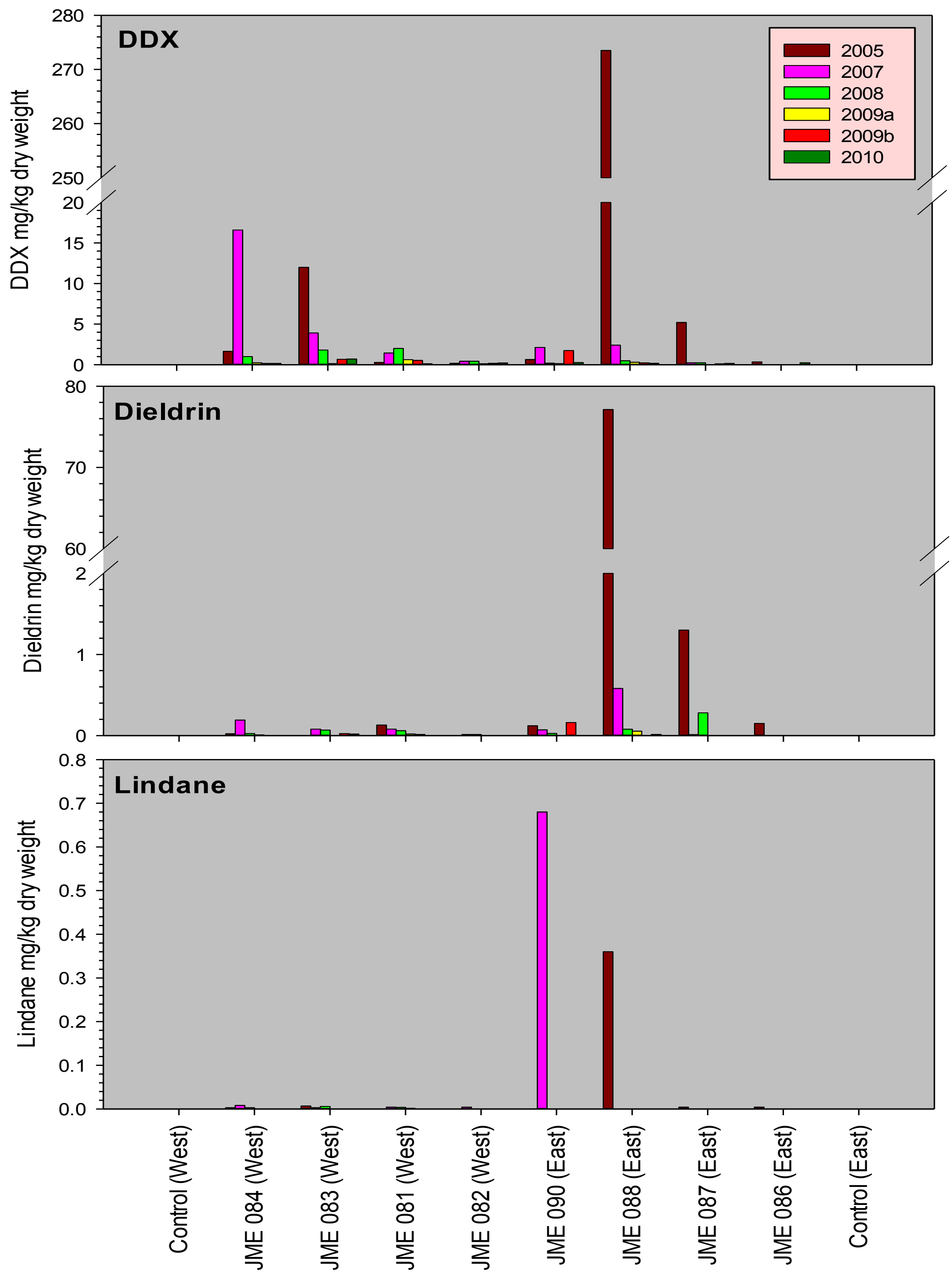



**Figure 9. Levels of DDX (2,4DDT; 4,4DDT; 2,4DDD; 4,4DDD; 2,4DDE; 4,4DDE), dieldrin and lindane (mg/kg dry weight) recorded from the same control and impact sites in 2005, 2007, 2008, 2009a, 2009b and 2010 (present study).**

**Table 7. Summary of DDX, dieldrin and lindane levels from surface samples collected between 2005 and November 2010 from impact (FCC) and control sites. Note: in most cases only sites common to all studies have been included. A number of new sites sampled in 2009 and 2010 are therefore not included in the table.**

| Location | Area | DDX (mg/kg) | | | | | | | Dieldrin (mg/kg) | | | | | | | Lindane (mg/kg) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2005 | 2007 | 2008 | 2009a | 2009b | 2010a | 2010b | 2005 | 2007 | 2008 | 2009a | 2009b | 2010a | 2010b | 2005 | 2007 | 2008 | 2009a | 2009b | 2010b |
| Control | West (1 bay west of FCC) | 0.0056 | ND | ND | 0.005 | 0.0015 | | 0.0015 | - | ND | ND | ND | ND | | ND | - | ND | ND | ND | ND | ND |
| JME 084 (West FCC snail sample site) 10m (2005, 2007), 40 m (2008), 45m (2009) from MHWS | West FCC | 1.64 | 16.6 | 0.987 | 0.23 | 0.1416 | 0.49 | 0.144 | 0.022 | 0.19 | 0.025 | 0.009 | 0.0025 | 0.014 | 0.0049 | 0.003 | 0.008 | 0.003 | ND | ND | ND |
| JME 083 (at concrete bridge) | West FCC | 12 | 3.9 | 1.8 | 0.129 | 0.657 | | 0.6931 | 0.0018 | 0.08 | 0.067 | 0.005 | 0.023 | | 0.0193 | 0.007 | 0.003 | 0.0057 | ND | 0.001 | ND |
| JME 081 (40 m down ditch) | West FCC | 0.26 | 1.43 | 2 | 0.62 | 0.518 | | 0.1064 | 0.129 | 0.08 | 0.06 | 0.02 | 0.015 | | 0.003 | - | 0.004 | 0.0039 | 0.0016 | 0.001 | ND |
| JME 082 (80 m down ditch) | West FCC | 0.17 | 0.42 | 0.41 | 0.12 | 0.1565 | | 0.2118 | 0.0035 | 0.013 | 0.013 | 0.004 | 0.0028 | | 0.0027 | 0.0005 | 0.004 | ND | ND | ND | ND |
| JME 090 | East FCC | 0.63 | 2.12 | 0.187 | 0.13 | 1.7395 | | 0.2492 | 0.12 | 0.071 | 0.026 | 0.006 | 0.16 | | 0.0074 | - | 0.68 | ND | ND | ND | ND |
| JME 088 (top of beach) | East FCC | 273.5 | 2.4 | 0.477 | 0.3 | 0.2251 | | 0.169 | 77.13 | 0.58 | 0.078 | 0.054 | 0.0044 | | 0.014 | 0.36 | ND | ND | ND | ND | ND |
| JME 087 (10 m down beach) [1] | East FCC | 5.2 | 0.24 | 0.24 | 0.016 | 0.1043 | | 0.1399 | 1.3 | 0.0108 | 0.28 | 0.005 | ND | | 0.006 | 0.004 | ND | ND | ND | ND | ND |
| JME 086 (15 m down beach) [2] | East FCC | 0.34 | 0.023 | 0.044 | 0.013 | 0.0402 | | 0.2344 | 0.15 | 0.0057 | 0.004 | ND | 0.0013 | | 0.0068 | 0.004 | ND | ND | ND | ND | ND |
| Control | East (Hunter-Brown) | - | - | - | - | 0.00148 | | 0.0015 | - | - | - | - | ND | | ND | - | - | - | - | ND | ND |

| Notes: | |
|---|---|
| 1 | 10m (2005, 2009b), 5m (2007), 4.8m (2008), 8m (2009a) |
| 2 | 22m (2005), 15m (2007, 2009a, 2009b), 10.5m (2008) |
| 2009a | Easton (2009) (sample February and October 2009) |
| 2009b | Davidson et al., (2010) (Sample October 2009) |
| 2010a | Easton (2010) (sample January 2010) |
| 2010b | Present report (sample November 2010) |
| (orange shading) | Values greater than Soil Acceptance Criteria (SAC) |

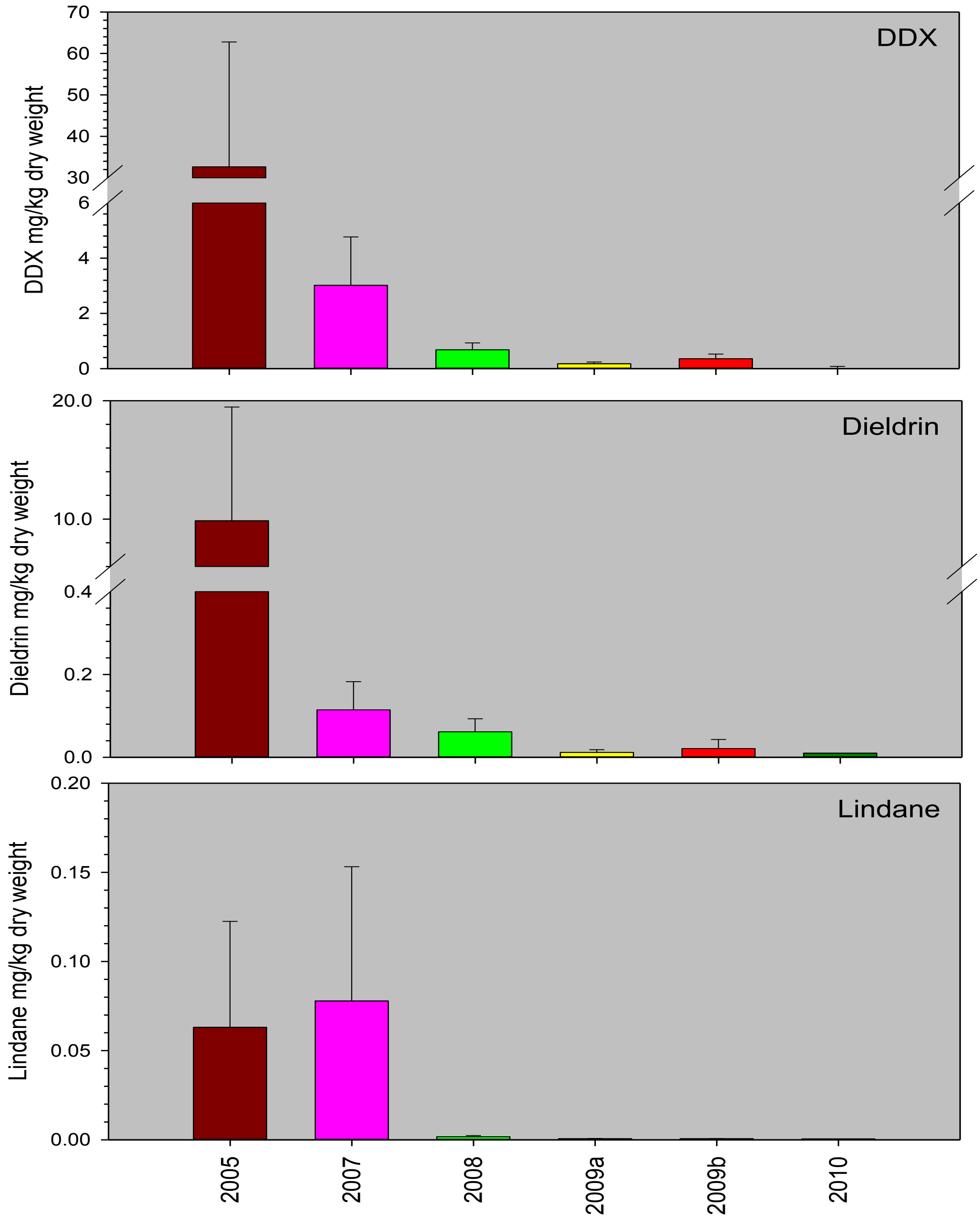



**Figure 10. Mean DDX (2,4DDT; 4,4DDT; 2,4DDD; 4,4DDD; 2,4DDE; 4,4DDE), aldrin and lindane (mg/kg dry weight) pooled from the same control and impact sites where data was available for 2005, 2007, 2008, 2009a, 2009b and 2010. Note: x axis values are variable between graphs. Error bars +/- 1 se.**

### 6.1.2 Mollusc contaminants

A variety of mollusc species were tested for pesticide contamination from five impact and two control samples (Table 8). Levels of ADL in cockles sampled at the East FCC impact site were relatively low (0.0033 mg/kg in 1999 and 0.0026 mg/kg in 2010). DDX levels for impact cockles were higher than control cockles, but not on the same scale as values recorded for mudflat snail (Table 8). Mudflat snail ADL and DDX concentrations from the West FCC site (JME 084) were the highest values recorded in the present study in 2009 and 2010, however, values dropped between 2009 and 2010. For example the DDX value in 2009 was the second highest since 2005 (i.e. 22.09 mg/kg) and well above the November 2010 sample (4.716 mg/kg) (Table 9).

Dieldrin at the same site for *Amphibola* also showed a decrease from 2009 to 2010. Lindane was not detectable in either 2009 or 2010 samples. Samples collected by TDC in January 2010 recorded intermediate values (Table 9).

Topshells (*Diloma*) living on rock and soft substrata were sampled during 2009 and the present study. Slightly higher values of DDX were recorded from topshells living on soft substrata in both years (Table 8). ADL and DDX levels for topshells were lower than levels recorded for mudflat snails at the East FCC beach. DDX levels in topshells at the East FCC remained relatively consistent between to two sample events (Table 9).

**Table 8. Pesticide concentrations in molluscs sampled from impact and control sites on 20 October 2009 (top) and 16 November 2010 (bottom).**

| 2009 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Location | West | West FCC | East FCC | East FCC | East FCC | East FCC | East |
| Site | Control | JME 084 | Composite | new2 (north) | new2 (south) | JME 090 | Control |
| Species | Amphibola | Amphibola | Amphibola | Diloma | Diloma | Cockle | Cockle |
| Substrata | Soft | Soft | Soft | Rocky | Soft | Soft | Soft |
| Pesticides (mg/kg) | | | | | | | |
| Aldrin | < 0.00050 | < 0.0015 | < 0.00050 | < 0.00050 | < 0.00050 | < 0.00050 | < 0.00050 |
| Dieldrin | 0.002 | 0.52 | 0.23 | 0.031 | 0.027 | 0.0028 | < 0.00050 |
| gamma-BHC (Lindane) | < 0.00050 | < 0.0015 | < 0.00050 | < 0.00050 | < 0.00050 | < 0.00050 | < 0.00050 |
| | | | | | | | |
| 2,4-DDD | < 0.00050 | 1.8 | 0.12 | 0.0095 | 0.013 | 0.0012 | < 0.00050 |
| 4,4 DDD | 0.015 | 5.9 | 0.46 | 0.067 | 0.082 | 0.0044 | 0.00069 |
| 2,4 DDE | < 0.00050 | 0.18 | 0.0069 | 0.0019 | 0.0036 | < 0.00050 | < 0.00050 |
| 4,4 DDE | 0.068 | 11 | 0.013 | 0.058 | 0.08 | 0.0041 | 0.0011 |
| 2,4 DDT | < 0.00050 | 0.11 | 0.31 | 0.0011 | 0.0017 | < 0.00050 | < 0.00050 |
| 4,4 DDT | 0.012 | 3.1 | 0.23 | 0.009 | 0.0088 | 0.00081 | < 0.00050 |
| | | | | | | | |
| ADL (aldrin, dieldrin, lindane) [1] | 0.0025 | 0.5215 | 0.2305 | 0.0315 | 0.0275 | 0.0033 | ND |
| DDX [1] | 0.09575 | 22.09 | 1.1399 | 0.1465 | 0.1891 | 0.01101 | 0.00279 |

| 2010 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Location | West | West FCC | East FCC | East FCC | East FCC | East FCC | East |
| Site | Control | JME 084 | Composite | new2 (north) | new2 (south) | JME 090 | Control |
| Species | Amphibola | Amphibola | Amphibola | Diloma | Diloma | Cockle | Cockle |
| Substrata | Soft | Soft | Soft | Rocky | Soft | Soft | Soft |
| Pesticides (mg/kg) | | | | | | | |
| Aldrin | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 |
| Dieldrin | 0.0016 | 0.139 | 0.141 | 0.0128 | 0.0121 | 0.0021 | <0.0005 |
| gamma-BHC (Lindane) | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 |
| | | | | | | | |
| 2,4-DDD | 0.0018 | 0.39 | 0.087 | 0.0042 | 0.0054 | 0.0014 | <0.0005 |
| 4,4 DDD | 0.0111 | 1.15 | 0.42 | 0.03 | 0.044 | 0.0047 | <0.0005 |
| 2,4 DDE | <0.0005 | 0.04 | 0.005 | 0.0012 | 0.0016 | <0.0005 | <0.0005 |
| 4,4 DDE | 0.038 | 2.6 | 0.54 | 0.038 | 0.052 | 0.004 | <0.0005 |
| 2,4 DDT | <0.0005 | 0.036 | 0.0049 | 0.0018 | 0.0013 | 0.001 | <0.0005 |
| 4,4 DDT | 0.0079 | 0.5 | 0.136 | 0.0173 | 0.0175 | 0.0033 | <0.0005 |
| | | | | | | | |
| ADL (aldrin, dieldrin, lindane) [1] | 0.0021 | 0.1395 | 0.1415 | 0.0133 | 0.0126 | 0.0026 | ND |
| DDX [1] | 0.0593 | 4.716 | 1.1929 | 0.0925 | 0.1218 | 0.01465 | ND |

| Notes: | |
|---|---|
| 1 | For multiple analyte totals, if below the LOR it is assumed to have a concentration of 0.5 the LOR |
| ND | Not detected above LOR's |
| Scale | All values presented as mg/kg |
| LOR | Limit of laboratory reporting |

**Table 9. Historical pesticide concentrations in molluscs recorded from impact and control sites sampled by a variety of authors from 2002 to 2010 (present study).**

| Site | Location | Species | Substrata | DDX (mg/kg) | | | | | | | Dieldrin (mg/kg) | | | | | | | Lindane (mg/kg) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2005 | 2007 | 2008 | 2009a | 2009b | 2010 | Present | 2005 | 2007 | 2008 | 2009a | 2009b | 2010 | Present | 2005 | 2007 | 2008 | 2009a | 2009b | Present |
| Control | West | Amphibola | Soft | 0.11 | - | - | - | 0.09575 | - | 0.0598 | 0.007 | - | - | - | 0.002 | - | 0.0016 | - | - | - | - | ND | ND |
| JME 084 | West FCC | Amphibola | Soft | 6.2 | 51.14 | 10.34 | 3.5 | 22.09 | 13 [2] | 4.716 | 0.364 | 2.18 | 0.48 | 0.22 | 0.52 | 0.39 [2] | 0.139 | - | - | - | - | ND | ND |
| Composite | East FCC | Amphibola | Soft | 3.96 | - | - | - | 1.1399 | - | 1.1929 | 1 | - | - | - | 0.23 | - | 0.141 | - | - | - | - | ND | ND |
| New2 (north) | East FCC | Diloma | Rocky | - | 0.543 | 0.078 | 0.025 | 0.1465 | - | 0.0925 | - | 0.027 | 0.01 | 0.005 | 0.0031 | - | 0.0128 | - | 0.001 | ND | ND | ND | ND |
| New2 (south) | East FCC | Diloma | Soft | - | - | - | - | 0.1891 | - | 0.1218 | - | - | - | - | 0.0027 | - | 0.0121 | - | - | - | - | ND | ND |
| JME 090 | East FCC | Cockle | Soft | - | - | - | - | 0.01101 | - | 0.0149 | - | - | - | - | 0.0028 | - | 0.0021 | - | - | - | - | ND | ND |
| Control | East | Cockle | Soft | <0.01 [1] | - | - | - | 0.00279 | - | ND | - | - | - | - | ND | - | ND | - | - | - | - | ND | ND |

| Note: | |
|---|---|
| 1 | O'Halloran and Cavanagh (2002) |
| - | No data supplied |
| 2 | Easton (2010) |

## 6.2 Environmental variable sampling

### 6.2.1 Redox

One redox core sample was collected from each of the 18 sediment contaminant sampling sites (Table 1, Figures 1 and 2, Appendix 5). One core sample was collected from each of the two control sites (i.e. West and East controls). The West Control site showed no sign of any redox layer (i.e. no distinct black colouration or layer), while the East Control site showed a mild discolouration, but no defined redox or anaerobic layer (Photo 1). No anaerobic smell was detected from either control sample.

**Photo 1. Core samples collected from West Control site (left) and East Control site (Hunter-Brown; right) in November 2010.**

A total of ten redox core samples were collected from the West FCC impact shore including three from the stream upstream of its confluence with the estuary proper (one per site; Appendix 5).

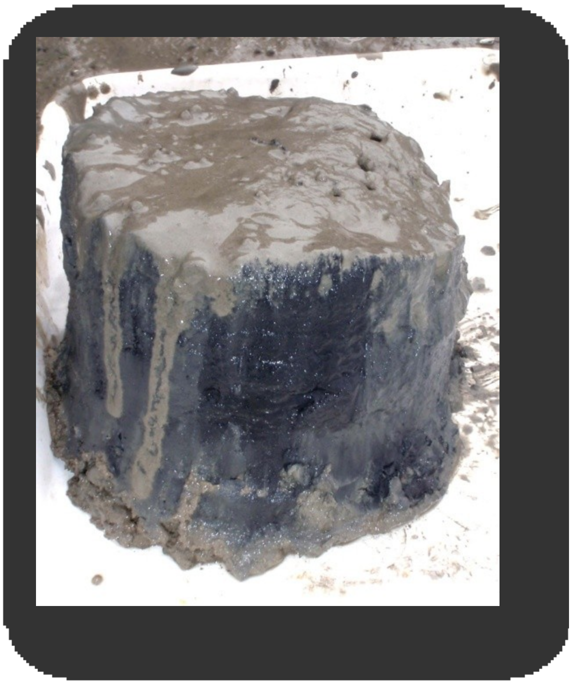
Sites JME 081, JME 083, JME 084, and West FCC (New3) showed low levels of discolouration, while all other samples showed mild to moderate discolouration. Site JME 082 showed the strongest discolouration of any West FCC impact estuary site (Photo 2). This site was the further-most site into the estuary on the edges of the tidal parts of the stream channel located within the estuary proper (Figure 1). The core showed a relatively even discolouration from near the surface to the bottom of the core, however, no strong smell was associated with the core indicating only a moderate level of enrichment.

**Photo 2. Core samples collected from West FCC (JME 082; left) and West FCC (new3; right) in November 2010.**

The three core samples collected from the freshwater stream showed some discolouration even close to the surface. No strongly anaerobic smell was associated with these samples. These core samples were characterised by small coarse sediment material from the remediation (i.e. small cobbles, pebbles, gravels with fine substrata between).

A total of six redox core samples were collected from the East FCC impact shore (one per site; Appendix 5). All cores apart from JME 090 located at the southern end of the beach showed discolouration, but at relatively low levels (Photo 3). JME 088 and JME 090 were located in an area of the shore where sediments were dominated by fine substrata. The anaerobic layer was apparent very close to the surface and was represented by a relatively strong black colour and a characteristic enriched odour (Photo 3).

Substratum within many of the East FCC cores were mixes of fine sediment deposited during each tide after remediation (i.e. silts and clay) and a base of pebble and small cobbles or stones introduced to the site during remediation activities. The depth and overall amount of fine surface sediments appeared greater in the 2010 sample compared to the 2009 sample.



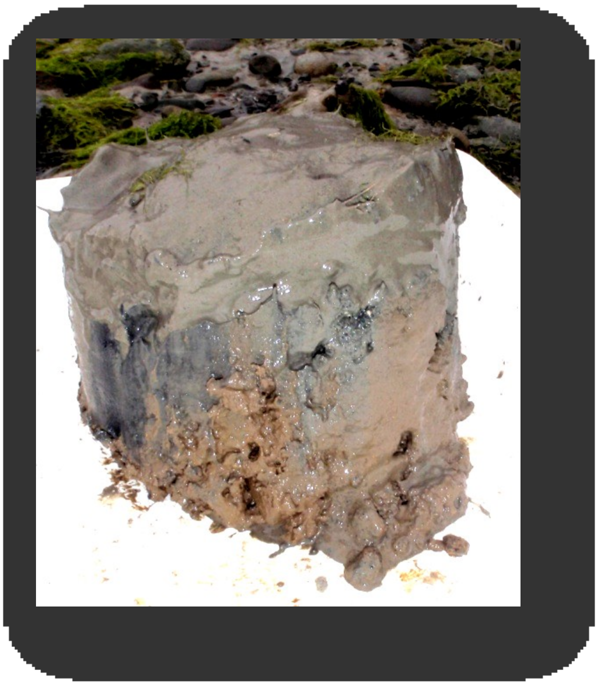


**Photo 3. Core samples collected from East FCC (JME 088) (left) and JME 090 (right) in November 2010.**

## 6.3 Biological community sampling

### 6.3.1 Macroalgae cover

Photographs collected from comparable tidal heights at impact and control sites in October 2009 and November 2010 have been displayed in photos 4-7.

**Photo 4. Macroalgae panoramic photos from West control. Top is September 2009 and bottom is November 2010.**

**Photo 5. Macroalgae panoramic photos from East control (Hunter-Brown). Top is September 2009 and bottom is November 2010.**

**Photo 6. Macroalgae photos from West FCC (middle). Top: Nov. 2009, bottom Nov. 2010.**

**Photo 7. Macroalgae panoramic photos from East FCC (south). Top is September 2009 and bottom is November 2010.**

Macroalgal cover was absent or at low levels at both control sites (photos 4 and 5). In 2009, macroalgae dominated by *Enteromorpha* sp. was widespread and abundant close to the cobble bank at the West FCC new2 (middle) site (Photo 6 top). In 2010, this macroalgae was present but at reduced levels compared to 2009.

At the East FCC sites, macroalgae was present at levels higher than the controls but at lower levels than the West FCC site. Little difference between 2009 and 2010 macroalgal levels was apparent at East FCC sites (Photo 7).

The cover of vascular plants at the West FCC (east) site increased between November 2009 and November 2010 (Photo 8). This increase in cover was predominantly due to the spread and growth of glasswort and bachelors button. Colonisation by sea rush plants was also occurred between 2009 and 2010.

**Photo 7. Vascular plants from West FCC (east). Top is November 2009 and bottom is November 2010.**

Mean percentage cover values recorded from the four impact and four control series of quadrats also showed greater cover of macroalgae at impact sites compared to control sites (Figure 13, Appendix 1). The West FCC sites (middle) and East FCC (south) had the highest mean values (Figure 13), ranging from 0-95% cover for individual quadrats (Appendix 1). Values at the two control sites were low, with the highest individual quadrat value of 20%

cover. Macroalgae percentage cover values at both impact and control sites all declined between the September 2009 sample and the November 2010 event.

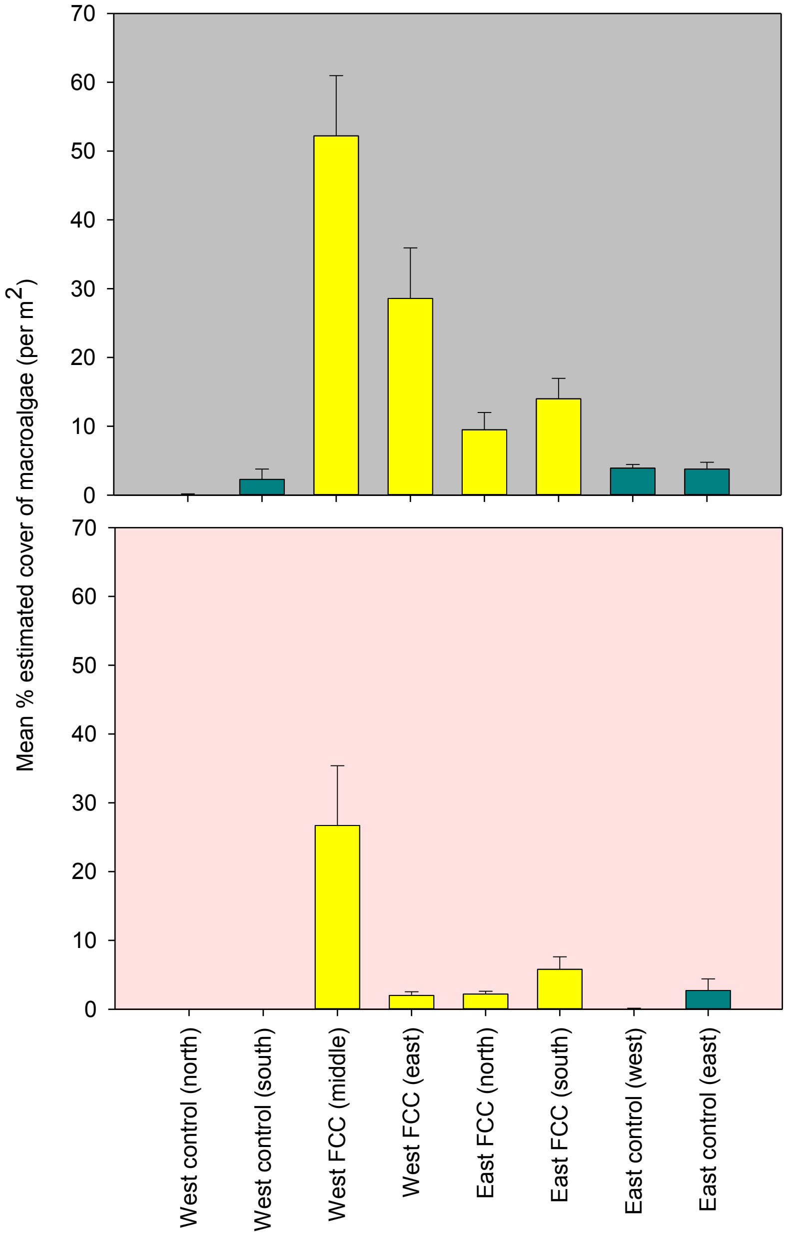



**Figure 13. Mean percentage cover of macroalgae recorded from 14 contiguous $1m^2$ quadrats deployed at each impact and control site. Error bars are +/- 1 standard error. Top graph is 2009, bottom is 2010.**

### 6.3.2 Epifauna and infauna invertebrate density and size

#### Invertebrate infaunal core samples

The mean number of infaunal macroinvertebrate species recorded from three replicate core samples collected at sites varied from 2 to 6 species in September 2009 and 1.3-5 species in November 2010 (Figure 14, Appendix 2). In 2009, the highest number of species occurred at the East control site and at the East FCC (new1). In 2010, the highest number of species was recorded from East FCC (new2) with a total of 11 species and a mean number of 5 species and the East control site with a total of 10 species and a mean number of 3.33 species (Appendix 2).

In 2009, the lowest number of species was recorded from the second east impact site, East FCC (new2). In 2010, the lowest number of species were recorded from the second East FCC site (mean 1.33 species) and the West impact sites (mean 1.67 and 2 species total), but these values were close to the number of species recorded from the West control site (mean 3.33 species).

The mean number of individual infaunal macroinvertebrates recorded from impact and control sites varied between years and between sites in the same years (Figure 14, Appendix 2). In 2010, highest values were recorded from East FCC impact sites and one impact site (West FCC (new2)), followed by the control sites. Lowest number of individuals was recorded from the West FCC impact sites. Apart from the East FCC site where number of individuals increased, most sites remained relatively consistent between sample years.

#### Invertebrate surface counts

The mean density and composition of macroinvertebrates recorded from surface counts at East and West FCC sites exhibited distinct differences (Figure 15, Appendix 3a and 3b). In both years, eastern sites were dominated by cockle (*C. stutchburyi*) and topshell (*D. subrostrata*), while western sites were dominated by mudflat snail (*A. crenata*) and spire shell (*Zeacumantus lutulentus*). Some species were present at both West and East FCC sites. These species were, however, more abundant at either East or West FCC sites, but not both.

Densities of topshell remained relatively consistent between one East impact site, East FCC (new1), and the East control site whereas densities of mudflat snail were higher from both West impact sites compared to the West control site (Figure 15, Appendix 3). In both years the spire shell was more abundant at the West control site compared to the West impact sites.

## Invertebrate size

The mean size of cockles collected from the East FCC impact and East control sites in 2009 was virtually identical (Table 10). In 2010, cockles at the same impact and control sites were on average smaller. Cockles at both sites and in both years were relatively small with no individuals over 30 mm recorded in either year.

In 2009, the mean size of mudflat snails at West FCC impact site (JME 084) was nearly half that of the West control and East FCC impact site. This result was reflected in the size ranges, with the West impact site supporting a smaller range of individuals down to 6 mm compared to the smallest size at the other two sites being 14-15 mm. During the present study no measurements of mudflat snails were collected, however, observations confirm that the snails at the West FCC site were consistently smaller than those recorded from the East FCC impact sites and the West control site.

**Table 10. Cockle size data collected from east control and impact sites in 2009 and 2010.**

| | East control 2009 | East FCC 2009 | East control 2010 | East FCC 2010 |
|---|---|---|---|---|
| Total | 104 | 112 | 37 | 38 |
| Mean size (mm) | 19.29 | 19.26 | 15.31 | 10.84 |
| SD | 5.61 | 7.57 | 6.10 | 5.74 |
| Std error | 0.55 | 0.72 | 1.00 | 0.93 |
| Size range (mm) | 3-29 mm | 2.5-32 mm | 3-24 mm | 2.5-23 mm |

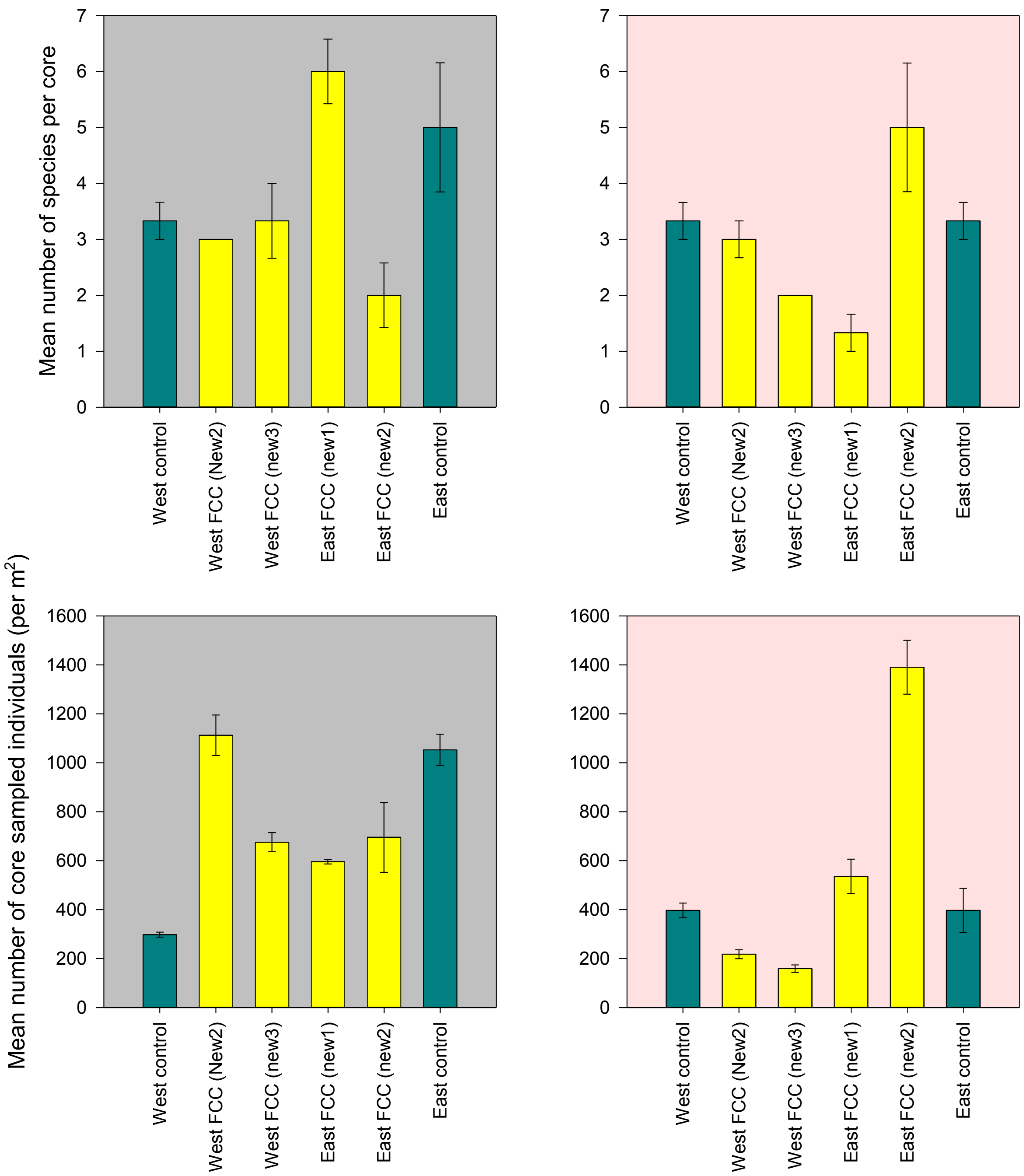



**Figure 14. Mean number of invertebrate species (top) and mean number of individual invertebrates per $m^2$ averaged from three replicate core samples collected at impact (yellow) and control (green) sites sampled on 16 September 2009 (left, grey) and 16 November 2010 (right, pink).**

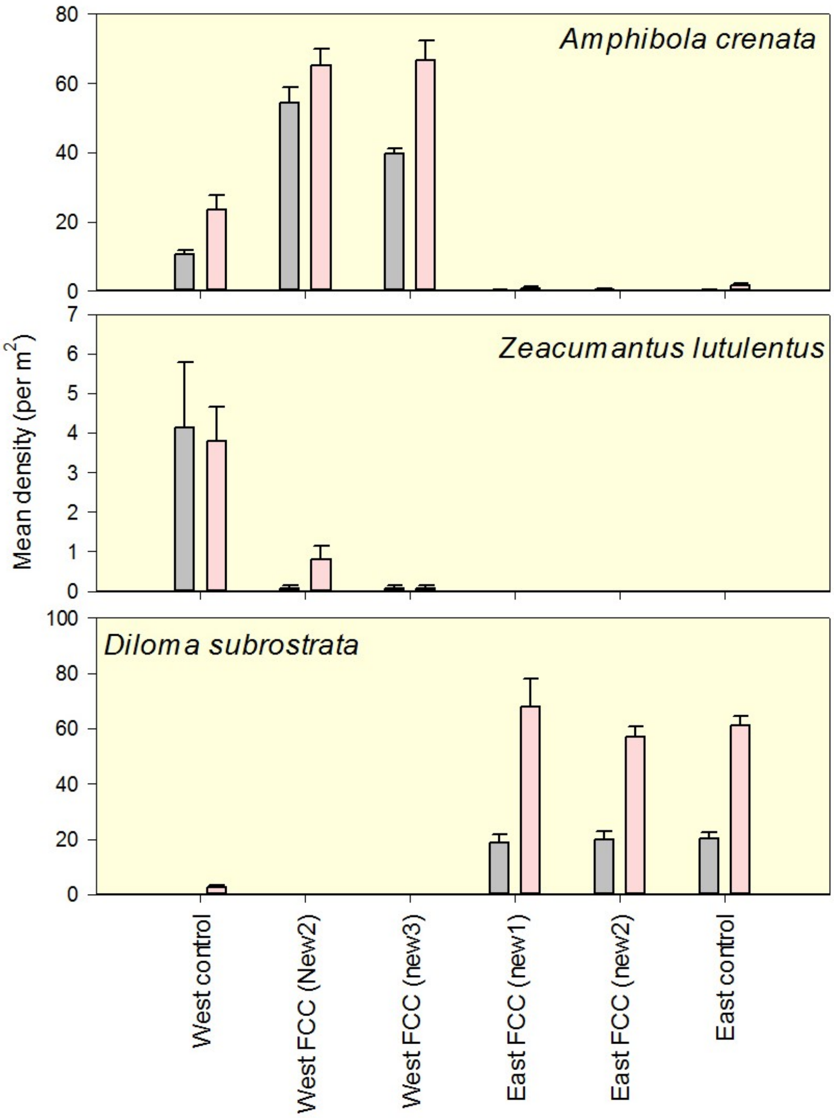



**Figure 15. Mean number of conspicuous invertebrates recorded from surface 1m² counts at impact and control sites sampled in September 2009 (grey) and November 2010 (pink).**

# 7.0 Discussion

## 7.1 Organism and sediment contaminant sampling

### Surface sediment contaminant levels

In 2009 and 2010, DDX and ADL in surface sediments varied depending on location. In 2009, ADL SAC levels were exceeded at three of the seven West FCC sites. In 2010, the SAC ADL criterion was exceeded at only one of the seven sites sampled. The SAC criterion for DDX in both 2009 and 2010 was exceeded at all West FCC sites. Three sites showed declines between 2009 and 2010, the largest being at West FCC (new2) dropping from 1.343 to 0.223 mg/kg dry wt. Of the four increases in DDX, none were large and outside levels that would be expected due to environmental variability.

For the tidal freshwater stream, all surface sediments sampled exceeded DDX and ADL SAC criteria in both years. The West FCC (stream1 low) site showed a minor drop for both contaminant groups, however, at the middle and upper sites both ADL and DDX levels increased. Of particular note was the concentrations of DDX at the middle and upper stream sites (4.94 and 7.18 mg/kg respectively). These levels are above those recorded in 2009 and during the CH2M Hill (2007) study. CH2M Hill (2007) sampled sediment OCP's from three sites along the stream. Authors reported the SAC was exceeded at all sites and reported highest concentrations of DDX and ADL near the mouth of the stream where it entered the estuary (DDX 3.296 mg/kg, ADL 0.105 mg/kg).

Based on results in 2009 and the present study, it is probable that DDX in stream surface sediments are elevated due to seepage from adjacent terrestrial sediments. In the Auditors report a contaminant "hotspot" buried close to the stream edge was suspected (see Auditors report, section 6.7.3.2). The auditor stated that such "hotspots" could be remediated, however, he stated that this was not warranted as they presented no particular risk as creek-bed gravel and vegetative cover prevents sediment mobilisation and hence the pathway to potential receptors. The auditor recommended that the Site Management Plan ensure measures be established to control excavation in the area and to prevent the creek from being eroded. Due to the increase in DDX at these stream sites, it is recommended that the auditor be asked for comment on the latest results.

At the East FCC site, ADL SAC criterion in surface sediments was exceeded at one of the six sites in 2009 and two of the six in 2010. These exceeded levels were, however, relatively close to the SAC and therefore within levels of normal environmental variability. For DDX, all surface samples exceeded the SAC in both sample occasions. Two decreases and four increases were recorded from surface sediments at the East FCC sites. Largest DDX increases were observed from East FCC (new1) 0.2843 to 1.927 mg/kg; East FCC (new 2) 0.1448 to 0.687 mg/kg and JME (086) 0.0402 to 0.2344 mg/kg.

### Deep sediment contaminant levels

For deep sediments at West FCC sites, ADL levels remained relatively consistent with some small drops and some small increases recorded between years. In contrast, ADL at East FCC sites was recorded above the SAC from five of the six sites in 2010 compared to only one in 2009.

DDX concentrations at deep West FCC sites remained at relatively low levels between sample years, especially when compared to East FCC sites. DDX levels declined slightly at many deep West FCC sites.

In contrast, DDX levels at all deep East FCC sites increased between 2009 and 2010, with some increases being relatively large. For example, JME (088) increased from 0.13855 in 2009 to 23.7579 mg/kg in 2010. Similarly, at JME (087), JME (090) and East FCC (new2) all showed relatively large scale increases for deep sediment DDX.

Water seepage channels arising from the foot of the East FCC rock wall occur regularly along this shore and carry water from the adjacent FCC site into and onto the mudflats. The relatively large increase in contaminants from deep sediments at the East FCC shore suggests that surface or subsurface seepage is probably carrying contaminants into this shore. The surface layer at the East FCC shore comprises new silt and clay substratum that is probably deposited with the tidal cycles. This relatively new substratum was less contaminated than the underlying deep sediment.

### Overall patterns of contamination

Apart from surface sediments at the western freshwater tidal stream and deep sediments at the East FCC, most sites showed some small improvement, little change, or small increases for ADL and DDX. Only one site in the western estuary had ADL levels above the SAC with most shallow sites being below the SAC in 2010.

In the 2009 auditor report, it was stated that the SAC for DDX and ADL in estuarine sediments was not met (Pattle Delamore, 2009). In contrast, the present study confirms that most of the shallow and deep sediments (excluding the West FCC stream and East FCC deep sites) now meet the SAC for ADL. Apart from the West FCC stream and East FCC deep sediments, most sites although not meeting the SAC for DDX have values of <0.5 mg/kg.

The only areas of concern in the present study were the increase of DDX at shallow sites in the freshwater stream and East FCC deep sediments contaminant levels for both ADL and

DDX. At both these locations, sediment recontamination has occurred and has probably come from “hot spots” in the adjacent FCC site.

The auditor stated that re-deposition from adjacent non-complying sediment from the surrounding marine environment was one of the primary reasons for recontamination of remediated estuarine sediments. Sampling of the West FCC from areas located offshore of the remediated beach (site JME 084) confirmed that the surface layer of estuary sediments has DDX above the SAC (0.1416 mg/kg in 2009 and 0.144 mg/kg in 2010). Sampling of these offshore non-remediated sediments showed deeper material often achieved the SAC. Based on the concentrations found at this non-remediated site, it is unlikely that redistribution of surface sediment to the West FCC stream sites would explain their increase in DDX. Further these sites are physically separated with stream sites receiving estuarine water only on the larger tides.

The auditor also stated that there was evidence that re-contamination of deeper backfill material had occurred during remediation works and that this may have been due to runoff from the site during remediation works. CH2M Hill (2007) first raised the issue of runoff from the FCC land during remediation works and recommended a variety of measures to minimise recontamination of the estuary sediments. Davidson et al. (2010) stated that based on DDX levels recorded from particular remediated sites, it appeared that some recontamination of sediments had occurred. These authors documented increases for DDX compared to previous samples at the West FCC stream, the East FCC site (JME 090) and for mudflat snails at West FCC (JME 084). They suggested that DDX levels above estuarine background concentrations indicated that runoff from FCC land had occurred. Davidson et al. (2010) proposed possible mechanisms for this increase including: (a) runoff during remediation works after the CH2M Hill (2007) data were collected, (b) variable OCP concentrations in sediments resulting in variable results, (c) groundwater seepage from the FCC site into the stream and low lying estuarine flats, and (d) recontamination from adjacent non-remediated marine sediments. Data collected from the shallow West FCC stream sites and the deep East FCC sites during the present study strongly suggest recontamination from “hotspots” in the adjacent FCC site has occurred.

Davidson et al. (2010) reported DDX exceeding the SAC at the deep sediment West control site. They stated this was unexpected and was not due to cross contamination during sampling as this site was sampled prior to sampling of contaminated sites. They suggested that elevated DDX was possibly due to historic contamination of Waimea Inlet over a large spatial scale. In the present study, DDX was recorded above the SAC for deep and shallow sediments. Further, DDX levels at the shallow and deep East control sites also exceeded the SAC. Cross-contamination cannot explain these results as both control sites were sampled prior to sampling of impact sites. It is likely that the contamination at deep control sites is due to historic contamination of the wider estuary. The contamination of shallow sediments at control sites may be due to the relocation of contaminated sediments from the non-remediated sediments close to the FCC site. These results highlight the problems associated with contaminant sampling in semi-enclosed bodies of water.

### Shellfish and snail contaminant levels

DDX and ADL in cockles at the East FCC shore were elevated above the control values, but were comparable to values recorded from other studies located in estuaries close to large cities such as the Avon Heathcote (Thomson and Davies, 1993) and Manukau Harbour (Hickey et al., 1995). At the East FCC shore, both cockles and topshells had lower levels of DDX and ADL compared to mudflat snails. This confirms the conclusion by O'Halloran and Cavanagh (2002) that mudflat snails represent the best mollusc to monitor for contaminants. Davidson et al. (2010) noted an increase in DDX and dieldrin in mudflat snails at the West FCC site between February 2009 and October 2009. The authors recorded DDX in October 2009 (JME 084 at 22.09 mg/kg), representing the second highest value since 2007 (51.15 mg/kg), while dieldrin was also relatively high (0.52 mg/kg) compared to previous samples. In the present study, ADL and DDX declined well below the 2009 levels at all sites where cockles and topshells were sampled.

For mudflat snails, ADL and DDX also declined in the present study relative to previous years. At JME (084) for example, DDX values have declined from 51.14 mg/kg in 2007 to 4.7 mg/kg in the present study. As these are mostly juvenile snails, it is unlikely they have migrated into this area from elsewhere, therefore the OCP concentrations in the flesh will have been received from the surface layer of estuarine sediment. The reason for the increase in ADL and DDX between 2008 and early 2009 followed by a drop in the present study are unknown.

The increase in ADL and DDX from deep sediments at the East FCC shore was not reflected in any increase in mollusc contaminant levels in 2010. Cockle, topshell and mudflat snails all feed from the surface layers of sediment and are therefore unlikely to come into contact with the deeper contaminated sediments.

## 7.2 Surface and infaunal invertebrate density and size

Distinct differences between the environmental variables that operate at western and eastern sites largely determine invertebrate community composition and abundance. For example, eastern impact and control sites are located on the edge of a main estuarine channel, swept by very strong and regular tidal currents, whereas western impact and control sites are located in sheltered embayments. Further, eastern impact and control sites are located at a range of lower tidal levels compared to western sites that are located near mean high water. It is therefore probable that most biological differences observed between western and eastern sites were due to these environmental differences rather than OCP's or organic enrichment. Differences between impact sites and their associated control site are, however, potentially more related to biological factors such as enrichment and, to a lesser extent, contaminants.

It is difficult to distinguish between the importance of environmental factors and the potential effect of pesticides on invertebrate density, presence/absence, and size (Liess and Carsten, 2005). Each site has a unique set of environmental variables that largely determine species composition and abundance. In addition, estuarine environments are notoriously patchy, with relatively high variation being common place, even between sites situated in close proximity (Robertson et al., 2002). Further compounding this variability is the vulnerability of species to pesticides and a lack of information on the effects of pesticides on marine invertebrates.

Based on invertebrate data collected by Davidson et al. (2010) and the present study, sites exhibited both differences and similarities between impact and control locations. The number of species recorded from one East FCC site was comparable to the eastern control site, while the other East FCC site supported dramatically less species. This occurred for both studies but the location where high numbers occurred varied between years. The difference in abundance and number of species between sites and years highlights the problems associated with the natural variability of estuarine mudflats.

The number of species and their abundance at the West impact and West control site was comparable. Davidson et al. (2010) reported high numbers of mudflat snail and estuarine snail (*Potamopyrgus estuarinus*) from the impact sites. Although mudflat snails were abundant in the present study, no *Potamopyrgus* were recorded from the impact sites or control sites in the present study. The small size of mudflat snails at western impact sites may be related to differences in habitat composition and tidal height, with the impact site located at a slightly higher tidal level.

Overall, the composition, abundance and size of macroinvertebrates were distinctly different between East and West sites due to the very different shore types. Differences between impact and control sites in East and West locations were most likely due to natural environmental variation between sites. Despite this environmental variability, some components of the invertebrate community were strikingly similar. The presence of contaminants and nutrient enrichment as indicated by redox results shows that sites adjacent to the FCC site are not natural when compared with the control sites, however, contaminant and enrichment was not at levels that resulted in a mass reduction in the diversity, abundance and size of macroinvertebrates or, alternatively, the biological population being dominated by enrichment-indicating species.

## 7.3 Macroalgae cover

Macroalgae blooms are traditionally indicative of nutrient enrichment. Davidson et al. (2010) recorded a localised macroalgae bloom from the West FCC site with relatively minor levels of macroalgae being recorded from the East FCC shore. This was the case in the present study; however, levels of observed macroalgae were reduced in the present sample. This reduction also occurred at control sites and may be due to the very dry and hot conditions in Spring 2010.

The macroalgae present in the West FCC shore was dominated by *Enteromorpha* sp., a species usually associated with freshwater flows into a marine environment. This species therefore confirms the presence of freshwater seepage from the West FCC site into the estuary. The spatial scale and the quantity of macroalgal growth was best described as a localised bloom with a high percentage cover at particular locations. This was, however, a relatively low biomass bloom of macroalgae when compared to some blooms in estuaries around New Zealand. In particular locations, these blooms can become a nuisance as algae decompose and smell pungent. The relatively small spatial scale and low biomass suggest that nutrient enrichment is not excessive in this area. It is probable that the macroalgal bloom will be seasonal at the West FCC site, with biomass declining in the hot summer and lower light and cooler winter months.

## 7.4 Recommendations for future monitoring

Two sample events (Spring 2009 and 2010) have occurred in relation to the post remediation biological and sediment contamination monitoring programme. Based on results from those sampling events combined with results from previous sampling of this area, the following monitoring recommendations are suggested.

- Collection of surface and within sediment invertebrate data in 2009 and 2010 has provided a baseline dataset that could be used for any future comparison. Further sampling is unnecessary unless contaminant levels increase to levels of concern. Data collected in 2009 and 2010 did not show any major impacts from present contaminant levels and results between years remained relatively stable.
- Collection of sediment grain size was provided in Spring 2009. It is unlikely that grain size data will alter to any large degree therefore no further data collection of grain size is suggested.

- Ongoing monitoring of total organic carbon (TOC), redox and macroalgae is unnecessary unless contaminant levels increase to levels of concern or nuisance blooms occur. Data collected over 2009 and 2010 suggests that enrichment is stable and possibly declining at these sites.
- Collection of deep and shallow contaminant data has indicated two areas of concern. Contaminant levels have increased beyond levels that could be considered part of normal sampling variability at (1) West FCC freshwater tidal stream and (2) East FCC. The levels of contamination recorded in these areas suggest that recontamination has occurred. It is therefore recommended that annual monitoring of contaminants from all sites at shallow and deep strata be continued. A periodic review of any new data is suggested to assess the need for ongoing monitoring.
- Based on evidence that the West FCC stream is influenced by a contaminant "hot spot", it is recommended that four additional sites be sampled within the stream in an effort to better identify the source. At present, all stream samples are collected on the southern bank. It is recommended that three new sites on the northern bank be sampled. It is also recommended that one new site located upstream of the present sites be sampled.
- Due to increased fine sediment located at the East FCC site, there are now sufficient numbers of *Amphibola* to obtain a sample. As mudflat snails are a better indicator of mollusc contamination than *Diloma* it is therefore recommended that *Diloma* sampling be terminated during any future monitoring. Cockle sampling should be continued during any ongoing monitoring.

# References

**Cavanagh, J.E.; O'Halloran, K. 2003.** Investigation of organochlorine contamination in mud snails (Amphibola sp.) and sediment collected from mudflats adjacent to the Fruit Chemical Company (FCC) site at Mapua – summary of results. Landcare Research Contract Report prepared for Tasman District Council.

**CH2M HILL, 2007.** Groundwater and sediment investigation report, former Fruitgrower Chemical Company site, Mapua. Report prepared for Ministry for the Environment.

**Davidson, R.J. 2009.** Review of snail sampling protocols for the east intertidal shore adjacent to the FCC remediation site, Mapua. Prepared by Davidson Environmental Ltd. for Tasman District Council and Ministry for the Environment. Survey and monitoring report no. 607.

**Davidson, R. J.; Richards, L.A.; Easton, J. 2010.** Post-remediation monitoring of sediments and biota from estuarine sites located adjacent to the former Fruitgrowers Chemical Company (FCC) site, Mapua, Nelson. Prepared by Davidson Environmental Limited for Tasman District Council and Ministry for the Environment. Survey and monitoring report no. 616.

**Easton, J. 2005.** Report on macroinvertebrate and sediment quality monitoring for FCC site remediation. Samples 22 February 2005. Prepared by Tasman District Council.

**Easton, J. 2007a.** Report on snails and sediment a year after East and West beach remediation. Samples 25 & 31 January, 23 April and 22 May 2007 Prepared by Tasman District Council.

**Easton, J. 2007b.** Report on assessment of mud snail and estuarine sediments: west side of Grossi Point Peninsula: 24 October 2007. Prepared by Tasman District Council.

**Easton, J. 2008.** Report on snails and sediment, second round after west and east beach remediation, April 2008. Prepared by Tasman District Council.

**Easton, J. 2009.** Report on snail and sediment quality on the west side of Grossi Point, Mapua. Sample June 2009. Prepared by Tasman District Council.

**Easton, J. 2009a.** Report on snail and sediment quality, third annual round after FCC west and east beach remediation. Sample 3 February 2009. Prepared by Tasman District Council.

**Easton, J. 2010.** Report on West FCC snails and sediment: repeat sampling on 18 January 2010. Prepared by Tasman District Council.

**Hickey, C.W.; Roper, D.S.; Holland, P.T.; Trower, T.M. 1995.** Accumulation of organic contaminants in two sediment-dwelling shellfish with contrasting feeding modes: Deposit- (*Macomona liliana*) and filter-feeding (*Austrovenus stutchburyi*). *Archives of Environmental Contamination and Toxicology*, 29, 221-231.

**Liess, M.; Carsten, P. 2005.** Analyzing effects of pesticides on invertebrate communities in streams. *Environmental Toxicology and Chemistry*, Vol. 24, 954-965.

**O'Halloran, K.; Cavanagh, J.E. 2002.** Investigation of organochlorine contamination in biota and sediment collected from mudflats adjacent to the Fruit Chemical Company (FCC) site at Mapua. Environmental Toxicology, Landcare Research, Lincoln, March 2002.

**Pattle Delamore Partners Ltd. 2009.** Audit of the remediation of the former Fruitgrowers Chemical Company site, Mapua. A report prepared by Mike Clyde and Graeme Proffitt for the Ministry of the Environment. File W01738100 R01.

**Robertson, B.M.; Gillespie, P.A.; Asher, R.A.; Frisk, S.; Keeley, N.B.; Hopkins, G.A.; Thompson, S.J.; Tuckey, B.J. 2002.** Estuarine Environmental Assessment and Monitoring: A National Protocol. Part A. Development, Part B. Appendices, and Part C. Application. Prepared for supporting Councils and the Ministry for the Environment, Sustainable Management Fund Contract No. 5096. Part A. 93p. Part B. 159p. Part C. 40p plus field sheets.

**Scobie, S.; Buckland, S.; Ellis, H.; Salter, R. 1998.** Organochlorines in New Zealand: Ambient concentrations of selected organochlorines in estuaries. Organochlorines Programme, Ministry for the Environment.

**Thomson, B.; Davies, J. 1993.** Interpretation of organochlorine and hydrocarbon contaminants in the Avon and Heathcote river and estuary system. Report to the Canterbury Regional Council, Christchurch, New Zealand.

**Woodward-Clyde. 1996.** Mapua site remediation, assessment of environmental effects. Report prepared for Tasman District Council.

**Appendix 1. Estimated percentage cover of macroalgae present at impact and control sites in 16th September 2009 (top) and 16th November 2010 (bottom).**

| Meters | West control | | West FCC | | East FCC | | East control (Hunter-Brown) | |
|---|---|---|---|---|---|---|---|---|
| | North | South | Middle | East | North | South | West | East |
| 0 | 1 | 20 | 60 | 75 | 30 | 20 | 3 | 0 |
| 1 | 0 | 8 | 80 | 65 | 15 | 10 | 3 | 1 |
| 2 | 0 | 4 | 75 | 65 | 10 | 10 | 2 | 0 |
| 3 | 0 | 0 | 75 | 50 | 25 | 20 | 6 | 1 |
| 4 | 0 | 0 | 98 | 60 | 5 | 8 | 6 | 1 |
| 5 | 0 | 0 | 65 | 20 | 8 | 1 | 2 | 1 |
| 6 | 0 | 0 | 65 | 15 | 20 | 20 | 2 | 1 |
| 7 | 0 | 0 | 50 | 15 | 5 | 35 | 2 | 2 |
| 8 | 0 | 0 | 75 | 5 | 1 | 30 | 8 | 8 |
| 9 | 0 | 0 | 65 | 8 | 2 | 25 | 6 | 8 |
| 10 | 0 | 0 | 20 | 10 | 3 | 10 | 4 | 8 |
| 11 | 0 | 0 | 3 | 5 | 2 | 5 | 4 | 8 |
| 12 | 0 | 0 | 0 | 1 | 3 | 2 | 2 | 10 |
| 13 | 0 | 0 | 0 | 6 | 4 | 0 | 5 | 4 |
| Mean % | 0.07 | 2.29 | 52.21 | 28.57 | 9.50 | 14.00 | 3.93 | 3.79 |
| Range | 0-1% | 0-20% | 0-98% | 1-75% | 1-30% | 0-30% | 2-8% | 0-10% |
| N | 14.00 | 14.00 | 14.00 | 14.00 | 14.00 | 14.00 | 14.00 | 14.00 |
| SD | 0.27 | 5.59 | 32.69 | 27.52 | 9.38 | 11.09 | 1.98 | 3.72 |
| Std. error | 0.07 | 1.50 | 8.74 | 7.36 | 2.51 | 2.96 | 0.53 | 1.00 |

Photo points

| Meters | West control | | West FCC | | East FCC | | East control (Hunter-Brown) | |
|---|---|---|---|---|---|---|---|---|
| | North | South | Middle | East | North | South | West | East |
| 0 | 0 | 0 | 0 | 1 | 5 | 20 | 0 | 0 |
| 1 | 0 | 0 | 5 | 1 | 2 | 6 | 0 | 0 |
| 2 | 0 | 0 | 15 | 5 | 2 | 18 | 0 | 0 |
| 3 | 0 | 0 | 15 | 3 | 2 | 3 | 0 | 0 |
| 4 | 0 | 0 | 1 | 2 | 2 | 4 | 0 | 1 |
| 5 | 0 | 0 | 10 | 5 | 3 | 6 | 0 | 1 |
| 6 | 0 | 0 | 18 | 5 | 6 | 15 | 0 | 0 |
| 7 | 0 | 0 | 70 | 3 | 1 | 4 | 0 | 0 |
| 8 | 0 | 0 | 75 | 3 | 1 | 3 | 0 | 0 |
| 9 | 0 | 0 | 15 | 0 | 2 | 1 | 0 | 0 |
| 10 | 0 | 0 | 95 | 0 | 2 | 1 | 1 | 0 |
| 11 | 0 | 0 | 55 | 0 | 1 | 0 | 0 | 1 |
| 12 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 15 |
| 13 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 20 |
| Mean % | 0.00 | 0.00 | 26.71 | 2.00 | 2.21 | 5.79 | 0.07 | 2.71 |
| Range | 0-0% | 0-0% | 0-75% | 1-5% | 1-6% | 0-20% | 1-1% | 0-20% |
| N | 14.00 | 14.00 | 14.00 | 14.00 | 14.00 | 14.00 | 14.00 | 14.00 |
| SD | 0.00 | 0.00 | 32.47 | 2.00 | 1.53 | 6.82 | 0.27 | 6.35 |
| Std. error | 0.00 | 0.00 | 8.68 | 0.53 | 0.41 | 1.82 | 0.07 | 1.70 |

## Appendix 2. Infaunal macroinvertebrates from samples (top September 2009; bottom November 2010). Densities converted to per m$^2$ values.

| Taxa | Common Name | East control | | | East FCC | | | East FCC | | | West control | | | West FCC | | | West FCC | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Per m$^2$ | Std. dev. | 95% | Per m$^2$ | Std. dev. | 95% | Per m$^2$ | Std. dev. | 95% | Per m$^2$ | Std. dev. | 95% | Per m$^2$ | Std. dev. | 95% | Per m$^2$ | Std. dev. | 95% |
| *Themiste* sp. (ex *Dendrostomium*) | Peanut worm | 39.73 | 34.40 | 19.86 | 79.45 | 91.03 | 52.55 | | | | | | | | | | | | |
| *Potamopyrgus estuarinus* | Estuarine snail | | | | | | | | | | | | | 417.13 | 449.89 | 259.75 | 258.22 | 268.71 | 155.14 |
| *Amphibola crenata* | Mud snail | | | | | | | 19.86 | 34.40 | 19.86 | 79.45 | 91.03 | 52.55 | 556.17 | 137.62 | 79.45 | 278.09 | 91.03 | 52.55 |
| *Diloma subrostrata* | Top shell | 39.73 | 68.81 | 39.73 | | | | | | | | | | | | | | | |
| *Diloma zealandica* | Top shell | 19.86 | 34.40 | 19.86 | | | | | | | | | | | | | | | |
| *Cominella glandiformis* | Mud flat whelk | 19.86 | 34.40 | 19.86 | | | | | | | | | | | | | | | |
| *Austrovenus stutchburyi* | Cockle | 734.94 | 396.77 | 229.08 | 119.18 | 157.66 | 91.03 | 635.63 | 396.77 | 229.08 | | | | 99.32 | 91.03 | 52.55 | 59.59 | 59.59 | 34.40 |
| *Scolecolepides benhami* | Worm | | | | | | | 39.73 | 34.40 | 19.86 | 19.86 | 34.40 | 19.86 | | | | | | |
| *Boccardia acus* | Worm | | | | 99.32 | 34.40 | 19.86 | | | | 19.86 | 34.40 | 19.86 | | | | | | |
| Nereidae (juvenile) | Rag worms | | | | 39.73 | 34.40 | 19.86 | | | | 19.86 | 34.40 | 19.86 | | | | | | |
| Nereidae (unidentified) | Rag worms | | | | 19.86 | 34.40 | 19.86 | | | | | | | | | | | | |
| *Nicon aestuariensis* | Rag worms | | | | | | | | | | 19.86 | 34.40 | 19.86 | 19.86 | 34.40 | 19.86 | | | |
| *Nereis cricognatha* | Rag worms | | | | | | | | | | 19.86 | 34.40 | 19.86 | | | | | | |
| Maldanidae | Bamboo worm | | | | | | | | | | | | | 19.86 | 34.40 | 19.86 | | | |
| *Pectinaria australis* | Worm | | | | 59.59 | 59.59 | 34.40 | | | | | | | | | | | | |
| *Eurylana cookii* | Isopod | 19.86 | 34.40 | 19.86 | | | | | | | | | | | | | | | |
| Amphipoda A (Phoxocephalidae) | Hopper | | | | 39.73 | 34.40 | 19.86 | | | | | | | | | | 59.59 | 59.59 | 34.40 |
| *Helice crassa* | Mud crab | 99.32 | 68.81 | 39.73 | 119.18 | 0.00 | 0.00 | | | | 99.32 | 124.05 | 71.62 | | | | 19.86 | 34.40 | 19.86 |
| *Austrominius modestus* (ex *Elminius*) | Barnacle | 79.45 | 34.40 | 19.86 | | | | | | | | | | | | | | | |
| Dolichopodidae larvae | Fly larvae | | | | | | | | | | 19.86 | 34.40 | 19.86 | | | | | | |
| Spider (terrestrial) | Spider | | | | 19.86 | 34.40 | 19.86 | | | | | | | | | | | | |
| Number of species | | 8 | | | 9 | | | 3 | | | 8 | | | 5 | | | 5 | | |
| Mean number of species | | 5.00 | | | 6.00 | | | 2.00 | | | 3.33 | | | 3.00 | | | 3.33 | | |
| N | | 3 | | | 3 | | | 3 | | | 3 | | | 3 | | | 3 | | |
| SD | | 2 | | | 1 | | | 1 | | | 0.58 | | | 0 | | | 1.15 | | |
| Standard error | | 1.15 | | | 0.58 | | | 0.58 | | | 0.33 | | | 0.00 | | | 0.67 | | |
| Mean number of individuals per m$^2$ | | 1053 | | | 596 | | | 695 | | | 298 | | | 1112 | | | 675 | | |
| N | | 15 | | | 18 | | | 6 | | | 10 | | | 9 | | | 10 | | |
| SD | | 245.57 | | | 39.73 | | | 349.92 | | | 32.62 | | | 248.25 | | | 122.77 | | |
| Standard error | | 63.41 | | | 9.36 | | | 142.85 | | | 10.31 | | | 82.75 | | | 38.82 | | |

| General Group | Taxa | Common Name | East control | | | East FCC (new 1) | | | East FCC (New 2) | | | West control | | | West FCC | | | West FCC | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Per m$^2$ | Std. dev. | 95% | Per m$^2$ | Std. dev. | 95% | Per m$^2$ | Std. dev. | 95% | Per m$^2$ | Std. dev. | 95% | Per m$^2$ | Std. dev. | 95% | Per m$^2$ | Std. dev. | 95% |
| Sipuncula | *Themiste* sp. (ex *Dendrostomium*) | Peanut worm | 0.00 | 0.00 | 0.00 | 0.33 | 0.58 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Gastropoda | *Amphibola crenata* | Mud snail | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.67 | 2.08 | 1.20 | 2.00 | 1.73 | 1.00 | 1.00 | 0.00 | 0.00 |
| Gastropoda | *Diloma subrostrata* | Top shell | 1.00 | 1.73 | 1.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.73 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Gastropoda | Micrelenchus tenebrosus | Top shell | 0.33 | 0.58 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Gastropoda | Notoacmea helmsi | Mud flat limpet | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Gastropoda | *Cominella glandiformis* | Mud flat whelk | 0.33 | 0.58 | 0.33 | 0.00 | 0.00 | 0.00 | 0.33 | 0.58 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Gastropoda | Zeacumantus lutulentus | Spiral shell | 0.33 | 0.58 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bivalvia | *Austrovenus stutchburyi* | Cockle | 11.33 | 4.73 | 2.73 | 8.67 | 8.33 | 4.81 | 13.67 | 10.97 | 6.33 | 3.33 | 1.53 | 0.88 | 1.00 | 1.73 | 1.00 | 0.00 | 0.00 | 0.00 |
| Bivalvia | Macomona liliana | Wedge shell | 1.00 | 1.73 | 1.00 | 0.00 | 0.00 | 0.00 | 2.00 | 3.46 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bivalvia | Nucula hartvigiana | Nut shell | 0.67 | 1.15 | 0.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Polychaeta: Nereidae | Nereidae (unidentified) | Rag worms | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.58 | 0.33 | 0.33 | 0.58 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Polychaeta: Nereidae | *Nicon aestuariensis* | Rag worms | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Polychaeta: Nereidae | Perinereis vallata | Rag worms | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.58 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Polychaeta: Maldanidae | Maldanidae | Bamboo worm | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.58 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.67 | 0.58 | 0.33 |
| Polychaeta: Pectinidae | *Pectinaria australis* | Worm | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 3.46 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Decapoda | *Helice crassa* | Mud crab | 1.00 | 1.00 | 0.58 | 0.00 | 0.00 | 0.00 | 0.33 | 0.58 | 0.33 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Decapoda | Macrophthalmus hirtipes | Stalk-eyed mud crab | 1.33 | 1.15 | 0.67 | 0.00 | 0.00 | 0.00 | 0.67 | 1.15 | 0.67 | 0.33 | 0.58 | 0.33 | 0.67 | 0.58 | 0.33 | 0.00 | 0.00 | 0.00 |
| Cirripedia | *Austrominius modestus* (ex *Elminius*) | Barnacle | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.33 | 2.31 | 1.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Total number of species | | 10 | | | 2 | | | 11 | | | 5 | | | 3 | | | 2 | | |
| | Mean number of species | | 3.33 | | | 1.33 | | | 5.00 | | | 3.33 | | | 1.67 | | | 2.00 | | |
| | N (sites) | | 3 | | | 3 | | | 3 | | | 3 | | | 3 | | | 3 | | |
| | SD | | 0.577350269 | | | 0.57735 | | | 2 | | | 0.58 | | | 0.5773503 | | | 0.00 | | |
| | Standard error | | 0.33 | | | 0.33 | | | 1.15 | | | 0.33 | | | 0.33 | | | 0.00 | | |
| | Mean number of individuals per m$^2$ | | 397 | | | 536 | | | 1390 | | | 397 | | | 218 | | | 159 | | |
| | N (individuals in cores) | | 16 | | | 4 | | | 15 | | | 10 | | | 5 | | | 6 | | |
| | SD | | 2.62 | | | 2.04 | | | 3.19 | | | 0.86 | | | 0.53 | | | 0.45 | | |
| | Standard error | | 90.00 | | | 70.17 | | | 109.85 | | | 29.67 | | | 18.09 | | | 15.35 | | |

## Appendix 3a. Surface 1m$^2$ quadrat counts of macroinvertbrates from impact and control sites (16th September 2009).

| General Group | Taxa | Common Name | West control | | | | | | | | | | | | | | Total | Mean density per m$^2$ | Std. dev. | Std. error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | | | |
| Gastropoda | *Amphibola crenata* | Mud flat snail | 15 | 4 | 6 | 6 | 5 | 17 | 8 | 13 | 10 | 10 | 11 | 16 | 15 | 13 | 149 | 10.64 | 4.34 | 1.16 |
| Gastropoda | *Zeacumantus lutulentus* | Spire shell | 0 | 2 | 1 | 2 | 0 | 2 | 0 | 3 | 2 | 9 | 23 | 5 | 9 | 0 | 58 | 4.14 | 6.21 | 1.66 |
| Bivalvia | *Austrovenus stutchburyi* | Cockle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0.07 | 0.27 | 0.07 |

| General Group | Taxa | Common Name | West FCC (new2) | | | | | | | | | | | | | | Total | Mean density per m$^2$ | Std. dev. | Std. error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | | | |
| Gastropoda | *Amphibola crenata* | Mud flat snail | 52 | 44 | 40 | 29 | 37 | 39 | 72 | 47 | 54 | 66 | 81 | 59 | 58 | 83 | 761 | 54.36 | 16.56 | 4.43 |
| Gastropoda | *Zeacumantus lutulentus* | Spire shell | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0.14 | 0.36 | 0.10 |

| General Group | Taxa | Common Name | West FCC (new3) | | | | | | | | | | | | | | Total | Mean density per m$^2$ | Std. dev. | Std. error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | | | |
| Gastropoda | *Amphibola crenata* | Mud flat snail | 45 | 37 | 47 | 43 | 36 | 43 | 37 | 45 | 25 | 36 | 35 | 49 | 38 | 38 | 554 | 39.57 | 6.22 | 1.66 |
| Gastropoda | *Zeacumantus lutulentus* | Spire shell | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0.07 | 0.27 | 0.07 |
| Bivalvia | *Zenostrobus pulex* | Little black mussel | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 5 | 0 | 2 | 0 | 0 | 0 | 0 | 11 | 0.79 | 1.67 | 0.45 |

| General Group | Taxa | Common Name | East control (Hunter-Brown) | | | | | | | | | | | | | | Total | Mean density per m$^2$ | Std. dev. | Std. error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | | | |
| Gastropoda | *Amphibola crenata* | Mud flat snail | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0.14 | 0.36 | 0.10 |
| Gastropoda | *Diloma subrostrata* | Top shell | 6 | 24 | 26 | 21 | 31 | 27 | 10 | 24 | 12 | 21 | 32 | 14 | 13 | 24 | 285 | 20.36 | 8.05 | 2.15 |
| Bivalvia | *Austrovenus stutchburyi* | Cockle | 1 | 0 | 3 | 58 | 6 | 5 | 0 | 0 | 0 | 0 | 3 | 0 | 2 | 17 | 95 | 6.79 | 15.42 | 4.12 |

| General Group | Taxa | Common Name | East FCC (new1) | | | | | | | | | | | | | | Total | Mean density per m$^2$ | Std. dev. | Std. error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | | | |
| Gastropoda | *Amphibola crenata* | Mud flat snail | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.14 | 0.36 | 0.10 |
| Gastropoda | *Diloma subrostrata* | Top shell | 8 | 14 | 19 | 10 | 26 | 4 | 44 | 8 | 36 | 25 | 5 | 17 | 23 | 21 | 260 | 18.57 | 11.73 | 3.14 |

| General Group | Taxa | Common Name | East FCC (new2) | | | | | | | | | | | | | | Total | Mean density per m$^2$ | Std. dev. | Std. error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | | | |
| Gastropoda | *Amphibola crenata* | Mud flat snail | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 5 | 0.36 | 1.34 | 0.36 |
| Gastropoda | *Diloma subrostrata* | Top shell | 11 | 12 | 18 | 32 | 38 | 44 | 13 | 37 | 15 | 12 | 12 | 12 | 9 | 11 | 276 | 19.71 | 12.24 | 3.27 |
| Bivalvia | *Austrovenus stutchburyi* | Cockle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 16 | 0 | 17 | 46 | 3.29 | 6.58 | 1.76 |

## Appendix 3b. Surface 1m$^2$ quadrat counts of macroinvertbrates from impact and control sites (16$^{th}$ November 2010).

| General Group | Taxa | Common Name | West control | | | | | | | | | | | | | | Total | Mean density per m$^2$ | Std. dev. | Std. error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | | | |
| Gastropoda | *Amphibola crenata* | Mud flat snail | 3 | 0 | 4 | 19 | 17 | 12 | 21 | 21 | 34 | 46 | 39 | 38 | 37 | 38 | 329 | 23.50 | 15.24 | 4.07 |
| Gastropoda | *Zeacumantus lutulentus* | Spire shell | 0 | 0 | 1 | 1 | 0 | 4 | 7 | 9 | 4 | 1 | 8 | 5 | 5 | 8 | 53 | 3.79 | 3.31 | 0.88 |
| Gastropoda | *Diloma subrostrata* | Top shell | 1 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 3 | 7 | 11 | 7 | 35 | 2.50 | 3.41 | 0.91 |

| General Group | Taxa | Common Name | West FCC (new2) | | | | | | | | | | | | | | Total | Mean density per m$^2$ | Std. dev. | Std. error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | | | |
| Gastropoda | *Amphibola crenata* | Mud flat snail | 98 | 70 | 58 | 50 | 64 | 68 | 76 | 60 | 64 | 80 | 72 | 84 | 24 | 44 | 912 | 65.14 | 18.19 | 4.86 |
| Gastropoda | *Zeacumantus lutulentus* | Spire shell | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 3 | 2 | | 11 | 0.79 | 1.31 | 0.35 |

| General Group | Taxa | Common Name | West FCC (new3) | | | | | | | | | | | | | | Total | Mean density per m$^2$ | Std. dev. | Std. error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | | | |
| Gastropoda | *Amphibola crenata* | Mud flat snail | 29 | 29 | 64 | 67 | 49 | 83 | 86 | 90 | 52 | 64 | 74 | 94 | 78 | 76 | 935 | 66.79 | 20.72 | 5.54 |
| Gastropoda | *Zeacumantus lutulentus* | Spire shell | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.07 | 0.27 | 0.07 |
| Bivalvia | *Zenostrobus pulex* | Little black mussel | 0 | 0 | 4 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 7 | 0.50 | 1.16 | 0.31 |

| General Group | Taxa | Common Name | East control (Hunter-Brown) | | | | | | | | | | | | | | Total | Mean density per m$^2$ | Std. dev. | Std. error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | | | |
| Gastropoda | *Amphibola crenata* | Mud flat snail | 6 | 2 | 0 | 0 | 0 | 0 | 8 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 20 | 1.43 | 2.53 | 0.68 |
| Gastropoda | *Diloma subrostrata* | Top shell | 68 | 58 | 68 | 54 | 56 | 78 | 84 | 56 | 44 | 52 | 42 | 64 | 64 | 70 | 858 | 61.29 | 11.94 | 3.19 |
| Gastropoda | *Cominella glandiformis* | Mudflat whelk | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.14 | 0.53 | 0.14 |
| Gastropoda | *Zeacumantus lutulentus* | Spire shell | 8 | 2 | 6 | 10 | 8 | 6 | 0 | 0 | 0 | 8 | 4 | 10 | 10 | 8 | 80 | 5.71 | 3.83 | 1.02 |

| General Group | Taxa | Common Name | East FCC (new1) | | | | | | | | | | | | | | Total | Mean density per m$^2$ | Std. dev. | Std. error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | | | |
| Gastropoda | *Amphibola crenata* | Mud flat snail | 0 | 0 | 8 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0.71 | 2.16 | 0.58 |
| Gastropoda | *Cominella glandiformis* | Mudflat whelk | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0.07 | 0.27 | 0.07 |
| Gastropoda | *Diloma subrostrata* | Top shell | 64 | 110 | 104 | 140 | 32 | 12 | 64 | 66 | 41 | 28 | 45 | 106 | 42 | 96 | 950 | 67.86 | 37.70 | 10.07 |

| General Group | Taxa | Common Name | East FCC (new2) | | | | | | | | | | | | | | Total | Mean density per m$^2$ | Std. dev. | Std. error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | | | |
| Gastropoda | *Diloma subrostrata* | Top shell | 40 | 56 | 58 | 48 | 70 | 48 | 32 | 86 | 62 | 56 | 64 | 56 | 74 | 50 | 800 | 57.14 | 13.87 | 3.71 |
| Gastropoda | *Cominella glandiformis* | Mudflat whelk | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 3 | 0.21 | 0.43 | 0.11 |

**Appendix 4. Cockle measurement summary (16th September 2009, 16th November 2010).**

| | East control | East FCC | East control | East FCC |
|---|---|---|---|---|
| | 2009 | 2009 | 2010 | 2010 |
| Total | 104 | 112 | 37 | 38 |
| Mean size (mm) | 19.29 | 19.26 | 15.31 | 10.84 |
| SD | 5.61 | 7.57 | 6.10 | 5.74 |
| Std error | 0.55 | 0.72 | 1.00 | 0.93 |
| Size range | 3-29 mm | 2.5-32 mm | 3-24 mm | 2.5-23 |

**Appendix 5. Redox photographs of core samples (16 November 2010).**

**West control (above)**

**West FCC JME 081**

**West FCC JME 082**

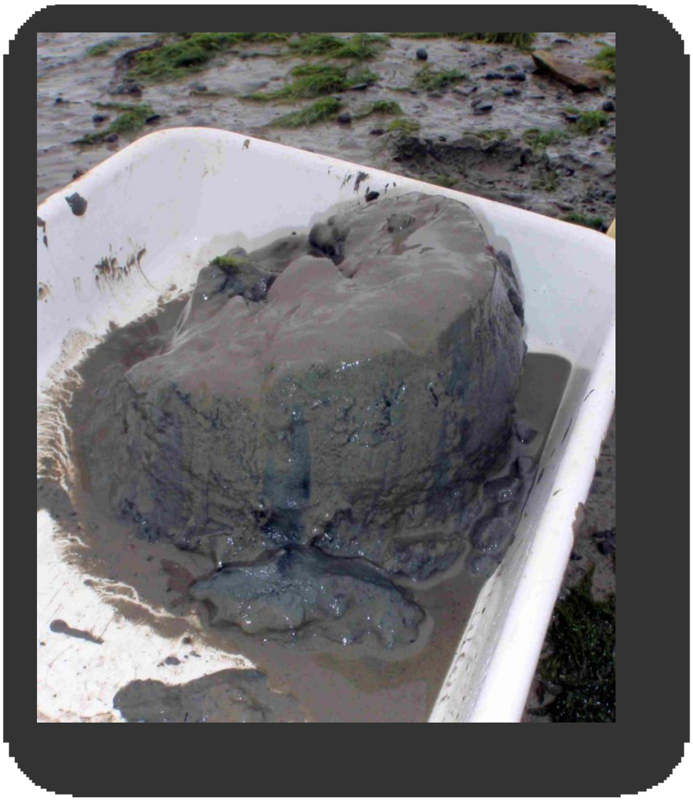
**West FCC JME 083**

**West FCC JME 084**

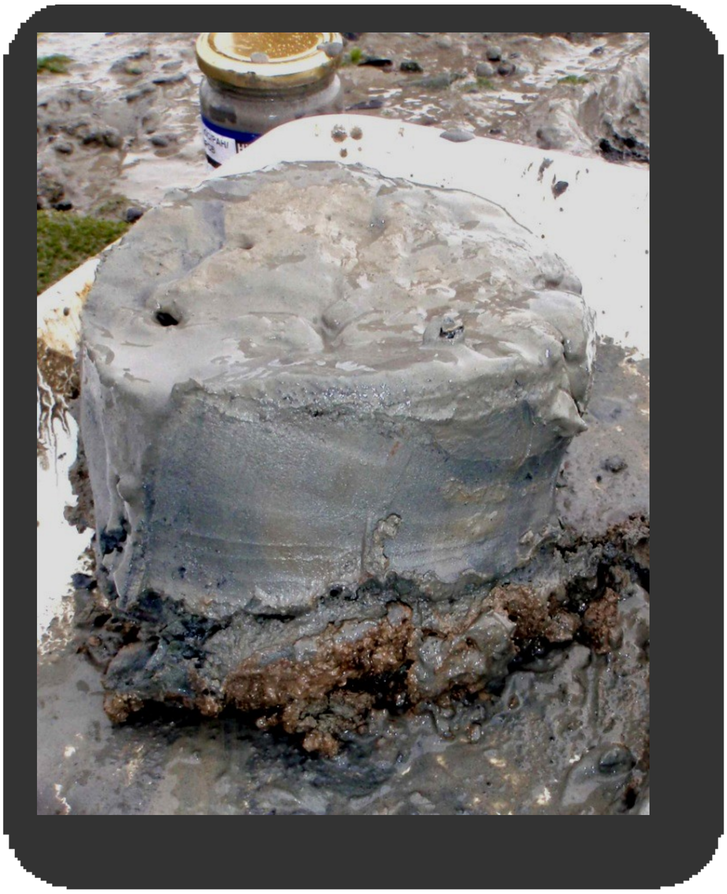
**West FCC (new1)**

**West FCC (new2)**

**West FCC (new3)**

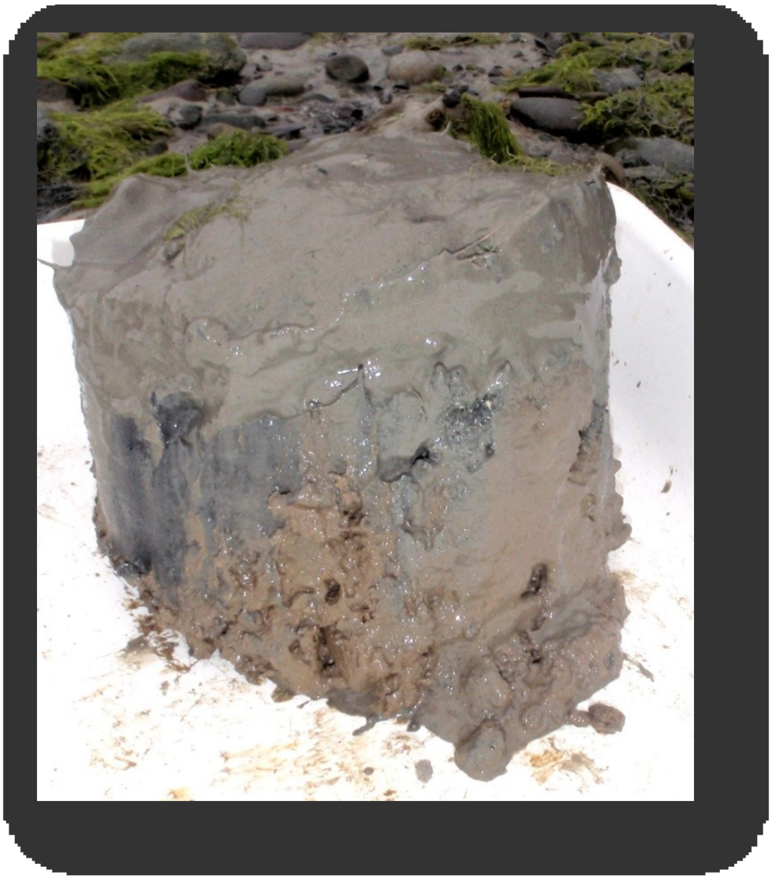


**East FCC (JME 086)**



**East FCC (JME 087)**

**East FCC (JME 088)**



**East FCC (JME 090)**

**East FCC (new1)**

**East FCC (new2)**

**East control (Hunter-Brown)**

**Stream (low)**

**Stream (middle)**

**Stream (upper)**

## Appendix 6. Hill Laboratories results sheets.

**Hill Laboratories**
BETTER TESTING BETTER RESULTS

R J Hill Laboratories Limited
1 Clyde Street
Private Bag 3205
Hamilton 3240, New Zealand
Tel +64 7 858 2000
Fax +64 7 858 2001
Email mail@hill-labs.co.nz
Web www.hill-labs.co.nz

# ANALYSIS REPORT



SPv1

| | | | |
|---|---|---|---|
| **Client:** | Davidson Environmental Ltd | **Lab No:** | 846275 |
| **Contact:** | R Davidson | **Date Registered:** | 18-Nov-2010 |
| | C/- Davidson Environmental Ltd | **Date Reported:** | 26-Nov-2010 |
| | PO Box 958 | **Quote No:** | 42753 |
| | NELSON 7040 | **Order No:** | |
| | | **Client Reference:** | Mapua samples |
| | | **Submitted By:** | R Davidson |

**Sample Type: Sediment**

| **Sample Name:** | | West Control Surface 15-Nov-2010 8:44 am | West Control Deep 15-Nov-2010 8:45 am | JME 083 Surface 15-Nov-2010 10:45 am | JME 083 Deep 15-Nov-2010 10:45 am | JME 081 Surface 15-Nov-2010 10:50 am |
|---|---|---|---|---|---|---|
| **Lab Number:** | | 846275.8 | 846275.9 | 846275.10 | 846275.11 | 846275.12 |
| Organochlorine Pesticides Trace in Soil | | | | | | |
| Aldrin | mg/kg dry wt | < 0.0011 | < 0.0011 | 0.0017 | 0.0019 | < 0.0010 |
| alpha-BHC | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| beta-BHC | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| delta-BHC | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| gamma-BHC (Lindane) | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| cis-Chlordane | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| trans-Chlordane | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| 2,4'-DDD | mg/kg dry wt | < 0.0011 | < 0.0011 | 0.071 | 0.034 | 0.0142 |
| 4,4'-DDD | mg/kg dry wt | 0.0029 | < 0.0011 | 0.172 | 0.077 | 0.034 |
| 2,4'-DDE | mg/kg dry wt | < 0.0011 | < 0.0011 | 0.028 | 0.0102 | 0.0052 |
| 4,4'-DDE | mg/kg dry wt | 0.0036 | < 0.0011 | 0.153 | 0.058 | 0.037 |
| 2,4'-DDT | mg/kg dry wt | < 0.0011 | < 0.0011 | 0.0131 | 0.0107 | 0.0026 |
| 4,4'-DDT | mg/kg dry wt | 0.0019 | 0.0013 | 0.129 | 0.112 | 0.0134 |
| Dieldrin | mg/kg dry wt | < 0.0011 | < 0.0011 | 0.0193 | 0.0120 | 0.0030 |
| Endosulfan I | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endosulfan II | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endosulfan sulphate | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endrin | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endrin Aldehyde | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endrin ketone | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Heptachlor | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Heptachlor epoxide | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Hexachlorobenzene | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Methoxychlor | mg/kg dry wt | < 0.0011 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Total Chlordane [(cis+trans)* 100/42] | mg/kg dry wt | < 0.002 | < 0.002 | < 0.002 | < 0.002 | < 0.002 |

| **Sample Name:** | | JME 081 Deep 15-Nov-2010 10:50 am | JME 082 Surface 15-Nov-2010 10:55 am | JME 082 Deep 15-Nov-2010 10:55 am | West FCC New 1 Surface 15-Nov-2010 11:00 am | West FCC New 1 Deep 15-Nov-2010 11:00 am |
|---|---|---|---|---|---|---|
| **Lab Number:** | | 846275.13 | 846275.14 | 846275.15 | 846275.16 | 846275.17 |
| Organochlorine Pesticides Trace in Soil | | | | | | |
| Aldrin | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| alpha-BHC | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| beta-BHC | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| delta-BHC | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| gamma-BHC (Lindane) | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |

**Sample Type: Sediment**

| Sample Name: | | JME 081 Deep 15-Nov-2010 10:50 am | JME 082 Surface 15-Nov-2010 10:55 am | JME 082 Deep 15-Nov-2010 10:55 am | West FCC New 1 Surface 15-Nov-2010 11:00 am | West FCC New 1 Deep 15-Nov-2010 11:00 am |
|---|---|---|---|---|---|---|
| Lab Number: | | 846275.13 | 846275.14 | 846275.15 | 846275.16 | 846275.17 |
| Organochlorine Pesticides Trace in Soil | | | | | | |
| cis-Chlordane | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| trans-Chlordane | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| 2,4'-DDD | mg/kg dry wt | 0.026 | 0.0135 | 0.029 | 0.020 | 0.0011 |
| 4,4'-DDD | mg/kg dry wt | 0.077 | 0.036 | 0.086 | 0.051 | 0.0030 |
| 2,4'-DDE | mg/kg dry wt | 0.0055 | 0.0042 | 0.0098 | 0.0048 | < 0.0011 |
| 4,4'-DDE | mg/kg dry wt | 0.063 | 0.031 | 0.070 | 0.048 | 0.0039 |
| 2,4'-DDT | mg/kg dry wt | 0.0042 | 0.0061 | 0.092 | 0.0168 | < 0.0011 |
| 4,4'-DDT | mg/kg dry wt | 0.069 | 0.121 | 0.171 | 0.057 | 0.0011 |
| Dieldrin | mg/kg dry wt | 0.0023 | 0.0027 | 0.0023 | 0.0048 | < 0.0011 |
| Endosulfan I | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| Endosulfan II | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| Endosulfan sulphate | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| Endrin | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| Endrin Aldehyde | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| Endrin ketone | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| Heptachlor | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| Heptachlor epoxide | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| Hexachlorobenzene | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| Methoxychlor | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 |
| Total Chlordane [(cis+trans)* 100/42] | mg/kg dry wt | < 0.002 | < 0.002 | < 0.002 | < 0.002 | < 0.002 |

| Sample Name: | | West FCC New 2 Surface 15-Nov-2010 11:10 am | West FCC New 2 Deep 15-Nov-2010 11:10 am | West FCC New 3 Surface 15-Nov-2010 11:30 am | West FCC New 3 Deep 15-Nov-2010 11:30 am | JME 084 Surface 15-Nov-2010 11:15 am |
|---|---|---|---|---|---|---|
| Lab Number: | | 846275.18 | 846275.19 | 846275.20 | 846275.21 | 846275.22 |
| Organochlorine Pesticides Trace in Soil | | | | | | |
| Aldrin | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| alpha-BHC | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| beta-BHC | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| delta-BHC | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| gamma-BHC (Lindane) | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| cis-Chlordane | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| trans-Chlordane | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| 2,4'-DDD | mg/kg dry wt | 0.030 | < 0.0011 | 0.0071 | 0.0013 | 0.0162 |
| 4,4'-DDD | mg/kg dry wt | 0.076 | 0.0017 | 0.0139 | 0.0023 | 0.048 |
| 2,4'-DDE | mg/kg dry wt | 0.0086 | < 0.0011 | 0.0017 | < 0.0010 | 0.0047 |
| 4,4'-DDE | mg/kg dry wt | 0.084 | 0.0019 | 0.021 | 0.0027 | 0.054 |
| 2,4'-DDT | mg/kg dry wt | 0.0055 | < 0.0011 | 0.0063 | < 0.0010 | 0.0024 |
| 4,4'-DDT | mg/kg dry wt | 0.0189 | 0.0010 | 0.026 | 0.0031 | 0.0187 |
| Dieldrin | mg/kg dry wt | 0.0036 | < 0.0011 | 0.0029 | < 0.0010 | 0.0049 |
| Endosulfan I | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endosulfan II | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endosulfan sulphate | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endrin | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endrin Aldehyde | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endrin ketone | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Heptachlor | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Heptachlor epoxide | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Hexachlorobenzene | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Methoxychlor | mg/kg dry wt | < 0.0010 | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 |
| Total Chlordane [(cis+trans)* 100/42] | mg/kg dry wt | < 0.002 | < 0.002 | < 0.002 | < 0.002 | < 0.002 |

| Sample Type: Sediment | | | | | | |
|---|---|---|---|---|---|---|
| Sample Name: | | JME 084 Deep 15-Nov-2010 11:15 am | West Stream Low Surface 15-Nov-2010 11:50 am | West Stream Low Deep 15-Nov-2010 11:50 am | West Stream Middle Surface 15-Nov-2010 11:55 am | West Stream Middle Deep 15-Nov-2010 11:55 am |
| Lab Number: | | 846275.23 | 846275.24 | 846275.25 | 846275.26 | 846275.27 |
| Organochlorine Pesticides Trace in Soil | | | | | | |
| Aldrin | mg/kg dry wt | < 0.0011 | 0.0050 | 0.0021 | 0.0051 | 0.0018 |
| alpha-BHC | mg/kg dry wt | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| beta-BHC | mg/kg dry wt | < 0.0011 | 0.0012 | < 0.0010 | < 0.0010 | < 0.0010 |
| delta-BHC | mg/kg dry wt | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| gamma-BHC (Lindane) | mg/kg dry wt | < 0.0011 | 0.0026 | 0.0011 | 0.0041 | < 0.0010 |
| cis-Chlordane | mg/kg dry wt | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| trans-Chlordane | mg/kg dry wt | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| 2,4'-DDD | mg/kg dry wt | 0.0016 | 0.39 | 0.107 | 0.70 | 0.040 |
| 4,4'-DDD | mg/kg dry wt | 0.0038 | 0.79 | 0.21 | 1.50 | 0.082 |
| 2,4'-DDE | mg/kg dry wt | < 0.0011 | 0.23 | 0.043 | 0.42 | 0.025 |
| 4,4'-DDE | mg/kg dry wt | 0.0054 | 1.02 | 0.24 | 1.91 | 0.090 |
| 2,4'-DDT | mg/kg dry wt | < 0.0011 | 0.030 | 0.021 | 0.080 | 0.0035 |
| 4,4'-DDT | mg/kg dry wt | 0.0019 | 0.115 | 0.107 | 0.33 | 0.0166 |
| Dieldrin | mg/kg dry wt | 0.0012 | 0.061 | 0.023 | 0.095 | 0.0113 |
| Endosulfan I | mg/kg dry wt | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endosulfan II | mg/kg dry wt | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endosulfan sulphate | mg/kg dry wt | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endrin | mg/kg dry wt | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endrin Aldehyde | mg/kg dry wt | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endrin ketone | mg/kg dry wt | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Heptachlor | mg/kg dry wt | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Heptachlor epoxide | mg/kg dry wt | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Hexachlorobenzene | mg/kg dry wt | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Methoxychlor | mg/kg dry wt | < 0.0011 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Total Chlordane [(cis+trans)* 100/42] | mg/kg dry wt | < 0.002 | < 0.002 | < 0.002 | < 0.002 | < 0.002 |

| Sample Name: | | West Stream Upper Surface 15-Nov-2010 12:00 pm | West Stream Upper Deep 15-Nov-2010 12:00 pm | JME 088 Surface 15-Nov-2010 9:40 am | JME 088 Deep 15-Nov-2010 9:41 am | JME 087 Surface 15-Nov-2010 9:35 am |
|---|---|---|---|---|---|---|
| Lab Number: | | 846275.28 | 846275.29 | 846275.30 | 846275.31 | 846275.32 |
| Organochlorine Pesticides Trace in Soil | | | | | | |
| Aldrin | mg/kg dry wt | 0.0065 | 0.0018 | < 0.0010 | 0.0073 | < 0.0010 |
| alpha-BHC | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0010 |
| beta-BHC | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0010 |
| delta-BHC | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0010 |
| gamma-BHC (Lindane) | mg/kg dry wt | 0.0038 | < 0.0010 | < 0.0010 | 0.0017 | < 0.0010 |
| cis-Chlordane | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0010 |
| trans-Chlordane | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0010 |
| 2,4'-DDD | mg/kg dry wt | 1.18 | 0.112 | 0.0175 | 0.188 | 0.0102 |
| 4,4'-DDD | mg/kg dry wt | 2.4 | 0.24 | 0.041 | 2.1 | 0.023 |
| 2,4'-DDE | mg/kg dry wt | 0.59 | 0.062 | 0.0024 | 0.0199 | 0.0013 |
| 4,4'-DDE | mg/kg dry wt | 2.7 | 0.24 | 0.026 | 0.25 | 0.0185 |
| 2,4'-DDT | mg/kg dry wt | 0.051 | 0.0059 | 0.0151 | 3.1 | 0.0109 |
| 4,4'-DDT | mg/kg dry wt | 0.26 | 0.047 | 0.067 | 18.1 | 0.076 |
| Dieldrin | mg/kg dry wt | 0.160 | 0.027 | 0.0140 | 0.068 | 0.0060 |
| Endosulfan I | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0010 |
| Endosulfan II | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0010 |
| Endosulfan sulphate | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0010 |
| Endrin | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0010 |
| Endrin Aldehyde | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0010 |
| Endrin ketone | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0010 |
| Heptachlor | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0010 |
| Heptachlor epoxide | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0010 |

| Sample Type: Sediment | | | | | | |
|---|---|---|---|---|---|---|
| Sample Name: | | West Stream Upper Surface 15-Nov-2010 12:00 pm | West Stream Upper Deep 15-Nov-2010 12:00 pm | JME 088 Surface 15-Nov-2010 9:40 am | JME 088 Deep 15-Nov-2010 9:41 am | JME 087 Surface 15-Nov-2010 9:35 am |
| Lab Number: | | 846275.28 | 846275.29 | 846275.30 | 846275.31 | 846275.32 |
| Organochlorine Pesticides Trace in Soil | | | | | | |
| Hexachlorobenzene | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0010 |
| Methoxychlor | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0011 | < 0.0010 |
| Total Chlordane [(cis+trans)* 100/42] | mg/kg dry wt | < 0.002 | < 0.002 | < 0.002 | < 0.002 | < 0.002 |

| Sample Name: | | JME 087 Deep 15-Nov-2010 9:36 am | JME 086 Surface 15-Nov-2010 9:30 am | JME 086 Deep 15-Nov-2010 9:32 am | East FCC New 1 Surface 15-Nov-2010 9:46 am | East FCC New 1 Deep 15-Nov-2010 9:47 am |
|---|---|---|---|---|---|---|
| Lab Number: | | 846275.33 | 846275.34 | 846275.35 | 846275.36 | 846275.37 |
| Organochlorine Pesticides Trace in Soil | | | | | | |
| Aldrin | mg/kg dry wt | 0.0111 | < 0.0010 | 0.0182 | < 0.0010 | 0.0010 |
| alpha-BHC | mg/kg dry wt | 0.0013 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| beta-BHC | mg/kg dry wt | 0.0022 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| delta-BHC | mg/kg dry wt | 0.0012 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| gamma-BHC (Lindane) | mg/kg dry wt | 0.0165 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| cis-Chlordane | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| trans-Chlordane | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| 2,4'-DDD | mg/kg dry wt | 0.21 | 0.0106 | 0.118 | 0.038 | 0.0194 |
| 4,4'-DDD | mg/kg dry wt | 0.98 | 0.025 | 0.39 | 0.081 | 0.021 |
| 2,4'-DDE | mg/kg dry wt | 0.029 | 0.0013 | 0.0119 | < 0.010 | 0.0153 |
| 4,4'-DDE | mg/kg dry wt | 0.39 | 0.0165 | 0.080 | 0.089 | 0.118 |
| 2,4'-DDT | mg/kg dry wt | 1.77 | 0.033 | 0.033 | 0.164 | 0.080 |
| 4,4'-DDT | mg/kg dry wt | 8.6 | 0.148 | 0.191 | 1.55 | 0.33 |
| Dieldrin | mg/kg dry wt | 0.160 | 0.0068 | 0.058 | 0.0022 | 0.0071 |
| Endosulfan I | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endosulfan II | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endosulfan sulphate | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endrin | mg/kg dry wt | 0.0153 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endrin Aldehyde | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endrin ketone | mg/kg dry wt | 0.0068 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Heptachlor | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Heptachlor epoxide | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Hexachlorobenzene | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Methoxychlor | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Total Chlordane [(cis+trans)* 100/42] | mg/kg dry wt | < 0.002 | < 0.002 | < 0.002 | < 0.002 | < 0.002 |

| Sample Name: | | East FCC New 2 Surface 15-Nov-2010 9:22 am | East FCC New 2 Deep 15-Nov-2010 9:23 am | JME 090 Surface 15-Nov-2010 9:13 am | JME 090 Deep 15-Nov-2010 9:15 am | Hunter-Brown Surface 15-Nov-2010 7:36 am |
|---|---|---|---|---|---|---|
| Lab Number: | | 846275.38 | 846275.39 | 846275.40 | 846275.41 | 846275.42 |
| Organochlorine Pesticides Trace in Soil | | | | | | |
| Aldrin | mg/kg dry wt | 0.0021 | 0.0063 | < 0.0010 | 0.033 | < 0.0010 |
| alpha-BHC | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| beta-BHC | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| delta-BHC | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| gamma-BHC (Lindane) | mg/kg dry wt | < 0.0010 | 0.0047 | < 0.0010 | 0.0024 | < 0.0010 |
| cis-Chlordane | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| trans-Chlordane | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| 2,4'-DDD | mg/kg dry wt | 0.032 | 0.27 | 0.020 | 0.40 | < 0.0010 |
| 4,4'-DDD | mg/kg dry wt | 0.079 | 0.53 | 0.046 | 1.04 | 0.0012 |
| 2,4'-DDE | mg/kg dry wt | 0.0070 | 0.068 | 0.0022 | < 0.10 | < 0.0010 |
| 4,4'-DDE | mg/kg dry wt | 0.120 | 0.89 | 0.031 | 0.55 | 0.0012 |
| 2,4'-DDT | mg/kg dry wt | 0.109 | 1.12 | 0.037 | 1.50 | 0.0012 |
| 4,4'-DDT | mg/kg dry wt | 0.34 | 4.1 | 0.113 | 6.6 | 0.0091 |

| Sample Type: Sediment | | | | | | |
|---|---|---|---|---|---|---|
| | **Sample Name:** | East FCC New 2 Surface 15-Nov-2010 9:22 am | East FCC New 2 Deep 15-Nov-2010 9:23 am | JME 090 Surface 15-Nov-2010 9:13 am | JME 090 Deep 15-Nov-2010 9:15 am | Hunter-Brown Surface 15-Nov-2010 7:36 am |
| | **Lab Number:** | 846275.38 | 846275.39 | 846275.40 | 846275.41 | 846275.42 |
| Organochlorine Pesticides Trace in Soil | | | | | | |
| Dieldrin | mg/kg dry wt | 0.027 | 0.111 | 0.0074 | 0.183 | < 0.0010 |
| Endosulfan I | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endosulfan II | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endosulfan sulphate | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endrin | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endrin Aldehyde | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Endrin ketone | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Heptachlor | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Heptachlor epoxide | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Hexachlorobenzene | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Methoxychlor | mg/kg dry wt | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 | < 0.0010 |
| Total Chlordane [(cis+trans)* 100/42] | mg/kg dry wt | < 0.002 | < 0.002 | < 0.002 | < 0.002 | < 0.002 |

| | **Sample Name:** | Hunter-Brown Deep 15-Nov-2010 7:39 am | | | | |
|---|---|---|---|---|---|---|
| | **Lab Number:** | 846275.43 | | | | |
| Organochlorine Pesticides Trace in Soil | | | | | | |
| Aldrin | mg/kg dry wt | < 0.0010 | - | - | - | - |
| alpha-BHC | mg/kg dry wt | < 0.0010 | - | - | - | - |
| beta-BHC | mg/kg dry wt | < 0.0010 | - | - | - | - |
| delta-BHC | mg/kg dry wt | < 0.0010 | - | - | - | - |
| gamma-BHC (Lindane) | mg/kg dry wt | < 0.0010 | - | - | - | - |
| cis-Chlordane | mg/kg dry wt | < 0.0010 | - | - | - | - |
| trans-Chlordane | mg/kg dry wt | < 0.0010 | - | - | - | - |
| 2,4'-DDD | mg/kg dry wt | 0.0011 | - | - | - | - |
| 4,4'-DDD | mg/kg dry wt | 0.0011 | - | - | - | - |
| 2,4'-DDE | mg/kg dry wt | < 0.0010 | - | - | - | - |
| 4,4'-DDE | mg/kg dry wt | 0.0012 | - | - | - | - |
| 2,4'-DDT | mg/kg dry wt | 0.0015 | - | - | - | - |
| 4,4'-DDT | mg/kg dry wt | 0.0046 | - | - | - | - |
| Dieldrin | mg/kg dry wt | < 0.0010 | - | - | - | - |
| Endosulfan I | mg/kg dry wt | < 0.0010 | - | - | - | - |
| Endosulfan II | mg/kg dry wt | < 0.0010 | - | - | - | - |
| Endosulfan sulphate | mg/kg dry wt | < 0.0010 | - | - | - | - |
| Endrin | mg/kg dry wt | < 0.0010 | - | - | - | - |
| Endrin Aldehyde | mg/kg dry wt | < 0.0010 | - | - | - | - |
| Endrin ketone | mg/kg dry wt | < 0.0010 | - | - | - | - |
| Heptachlor | mg/kg dry wt | < 0.0010 | - | - | - | - |
| Heptachlor epoxide | mg/kg dry wt | < 0.0010 | - | - | - | - |
| Hexachlorobenzene | mg/kg dry wt | < 0.0010 | - | - | - | - |
| Methoxychlor | mg/kg dry wt | < 0.0010 | - | - | - | - |
| Total Chlordane [(cis+trans)* 100/42] | mg/kg dry wt | < 0.002 | - | - | - | - |

| Sample Type: Shellfish | | | | | | |
|---|---|---|---|---|---|---|
| | **Sample Name:** | East FCC New 2 (Soft) 15-Nov-2010 | East FCC New 2 (Rocky) 15-Nov-2010 | JME 090 (East FCC) 15-Nov-2010 | Hunter-Brown 15-Nov-2010 | |
| | **Lab Number:** | 846275.3 | 846275.4 | 846275.6 | 846275.7 | |
| Individual Tests | | | | | | |
| Dry Matter | g/100g as rcvd | 21 | 23 | 10.7 | 9.3 | - |
| Organochlorine Pesticides in Biomatter | | | | | | |
| Aldrin | mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |

| Sample Type: Shellfish | | | | | |
|---|---|---|---|---|---|
| Sample Name: | East FCC New 2 (Soft) 15-Nov-2010 | East FCC New 2 (Rocky) 15-Nov-2010 | JME 090 (East FCC) 15-Nov-2010 | Hunter-Brown 15-Nov-2010 | |
| Lab Number: | 846275.3 | 846275.4 | 846275.6 | 846275.7 | |
| Organochlorine Pesticides in Biomatter | | | | | |
| alpha-BHC mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| beta-BHC mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| delta-BHC mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| gamma-BHC (Lindane) mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| cis-Chlordane mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| trans-chlordane mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| 2,4'-DDD mg/kg | 0.0054 | 0.0042 | 0.0014 | < 0.0005 | - |
| 4,4'-DDD mg/kg | 0.044 | 0.030 | 0.0047 | < 0.0005 | - |
| 2,4'-DDE mg/kg | 0.0016 | 0.0012 | < 0.0005 | < 0.0005 | - |
| 4,4'-DDE mg/kg | 0.052 | 0.038 | 0.0040 | < 0.0005 | - |
| 2,4'-DDT mg/kg | 0.0013 | 0.0018 | 0.0010 | < 0.0005 | - |
| 4,4'-DDT mg/kg | 0.0175 | 0.0173 | 0.0033 | < 0.0005 | - |
| Dieldrin mg/kg | 0.0121 | 0.0128 | 0.0021 | < 0.0005 | - |
| Endosulfan I mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| Endosulfan II mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| Endosulfan sulfate mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| Endrin mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| Endrin Aldehyde mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| Endrin ketone mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| Heptachlor mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| Heptachlor epoxide mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| Hexachlorobenzene mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| Methoxychlor mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | < 0.0005 | - |
| Total Chlordane [(cis+trans)*100/42] mg/kg | < 0.002 | < 0.002 | < 0.002 | < 0.002 | - |

| Sample Type: Snails | | | | | |
|---|---|---|---|---|---|
| Sample Name: | JME 080 West Control 15-Nov-2010 | JME 084 West FCC 15-Nov-2010 | East FCC (Composite) 15-Nov-2010 | | |
| Lab Number: | 846275.1 | 846275.2 | 846275.5 | | |
| Individual Tests | | | | | |
| Dry Matter g/100g as rcvd | 13.2 | 11.6 | 14.6 | - | - |
| Organochlorine Pesticides in Biomatter | | | | | |
| Aldrin mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| alpha-BHC mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| beta-BHC mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| delta-BHC mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| gamma-BHC (Lindane) mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| cis-Chlordane mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| trans-chlordane mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| 2,4'-DDD mg/kg | 0.0018 | 0.39 | 0.087 | - | - |
| 4,4'-DDD mg/kg | 0.0111 | 1.15 | 0.42 | - | - |
| 2,4'-DDE mg/kg | < 0.0005 | 0.040 | 0.0050 | - | - |
| 4,4'-DDE mg/kg | 0.038 | 2.6 | 0.54 | - | - |
| 2,4'-DDT mg/kg | < 0.0005 | 0.036 | 0.0049 | - | - |
| 4,4'-DDT mg/kg | 0.0079 | 0.50 | 0.136 | - | - |
| Dieldrin mg/kg | 0.0016 | 0.139 | 0.141 | - | - |
| Endosulfan I mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| Endosulfan II mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| Endosulfan sulfate mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| Endrin mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| Endrin Aldehyde mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| Endrin ketone mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| Heptachlor mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| Heptachlor epoxide mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |

| Sample Type: Snails | | | | | | |
|---|---|---|---|---|---|---|
| Sample Name: | | JME 080 West Control 15-Nov-2010 | JME 084 West FCC 15-Nov-2010 | East FCC (Composite) 15-Nov-2010 | | |
| Lab Number: | | 846275.1 | 846275.2 | 846275.5 | | |
| Organochlorine Pesticides in Biomatter | | | | | | |
| Hexachlorobenzene | mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| Methoxychlor | mg/kg | < 0.0005 | < 0.0005 | < 0.0005 | - | - |
| Total Chlordane [(cis+trans)*100/42] | mg/kg | < 0.002 | < 0.002 | < 0.002 | - | - |

## Analyst's Comments

It has been noted that the duplicate for the OCP analysis on sample 846275.8, which was run as part of our in-house QC procedure, showed greater variation than would normally be expected. This may reflect the heterogeneity of the sample.

# SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

**Sample Type: Sediment**

| Test | Method Description | Default Detection Limit | Samples |
|---|---|---|---|
| Organochlorine Pesticides Trace in Soil | Sonication extraction, SPE cleanup, GPC cleanup (if required), dual column GC-ECD analysis. Tested on dried sample | - | 8-43 |

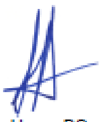
**Sample Type: Snails**

| Test | Method Description | Default Detection Limit | Samples |
|---|---|---|---|
| Homogenisation of Biological samples for Organics Tests* | Mincing, chopping, or blending of sample to form homogenous sample fraction. | - | 1-7 |
| Shucking of Shellfish* | Removal of tissue from shell. Analysis performed at Hill Laboratories - Food & Bioanalytical Division, Waikato Innovation Park, Ruakura Lane, Hamilton. | - | 1-7 |
| Organochlorine Pesticides in Biomatter | Sonication extraction, alumina cleanup, GPC cleanup, dual column GC-ECD analysis | - | 1-7 |
| Dry Matter (Env) | Dried at 103°C (removes 3-5% more water than air dry) for 18hr, gravimetry. US EPA 3550. | 0.10 g/100g as rcvd | 1-7 |

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

This report must not be reproduced, except in full, without the written consent of the signatory.



Ara Heron BSc (Tech)
Client Services Manager - Environmental Division