Davidson Environmental Limited

Post-remediation contaminant monitoring of sediments and biota from estuarine sites located adjacent to the former Fruitgrowers Chemical Company (FCC) site, Mapua, Nelson (sample 3)

Research, survey and monitoring report number 710

A report prepared for:
Tasman District Council and Ministry for the Environment
C/o Tasman District Council
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Bibliographic reference:

Davidson, R.J.; Richards, L.A.; Easton, J. 2012. Post-remediation contaminant monitoring of sediments and biota from estuarine sites located adjacent to the former Fruitgrowers Chemical Company (FCC) site, Mapua, Nelson (sample 3). Prepared by Davidson Environmental Limited for Tasman District Council and Ministry for the Environment. Survey and monitoring report 710.

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January 2012

Contents

Summary

Following the completion of the remediation project, the marine areas adjacent to the former Fruitgrowers Chemical Company (FCC) site were sampled in Spring 2009 (Davidson et al., 2010). The same sampling regime was repeated in Spring 2010 (Davidson et al., 2011). The present report presents data collected during the third post remediation sampling event (Spring 2011).

Sampling in the present study comprised a reduced sampling regime compared to the first two sampling events. The following data were collected in Spring 2011:

- Pesticides in sediments (shallow 0-2 cm, deep 6-10 cm);
- Pesticides in molluscs (mudflat snail, topshell snail, cockle); and
- Macroalgal photopoints.

The first two sampling events followed recommendations by the site auditor (Pattle Delamore, 2009). The present sample event adopted additional recommendations made in a review after the first two year sample events and was conducted by Pattle Delamore (2011).

The following is a brief outline of results from these studies.

At the West FCC shore, the Soil Acceptance Criteria (SAC) for ADL (Aldrin, Dialdrin, Lindane) was exceeded at only one of the seven West FCC estuarine sites in 2010 and 2011. The SAC for DDX was exceeded at all West FCC sites in 2009 and 2010. For the first time in Spring 2011, one of the West FCC sites met the DDX SAC (West FCC new3). DDX in shallow estuarine sediments declined at all but one site between 2010 and 2011.

At the East FCC shore, the SAC for ADL in surface sediments was exceeded at one of the six sites in 2009 and two in 2010 and one site in 2011. These values were, however, relatively close to the SAC. For DDX, all East FCC surface samples exceeded the SAC on each sample occasion. In the present sample, all East FCC surface samples decreased below 2010 values.

For the West FCC tidal freshwater stream, all surface sediments sampled exceeded DDX and ADL SAC criteria for all years. The West FCC (stream1 low) site showed a decline for both contaminant groups since 2009, however, at the middle and upper sites, both ADL and DDX showed an increase. Of particular note was the concentrations of DDX at the middle and upper stream sites (4.604 and 3.093 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).

For deep sediments at West FCC sites, ADL levels remained relatively consistent with five small decreases and two small increases between 2010 and 2011. The increases were recorded in the estuarine ditch that drains the West FCC stream. Increases in deep DDX concentrations also occurred at estuarine sites along the ditch. It is probable that the elevated ADL and DDX concentrations found in the West FCC stream sites are responsible for the elevated levels found in the downstream estuarine ditch.

ADL and DDX levels in deep sediment samples at the West FCC stream increased from 2010. Highest values were recorded from the middle of the stream followed by the upper sample. Lowest values were recorded from the bottom of the stream. This is consistent with shallow contaminant values suggesting that contamination continues to enter the middle and upper parts of the stream.

DDX levels at all deep East FCC sites increased between 2009 and 2010 and declined between 2010 and 2011. Contaminant levels from the deep East FCC samples in 2011 are comparable to levels recorded in 2009 and well below 2010 levels.

Apart from sediments at the West FCC freshwater tidal stream, most sites showed some improvement, little change, or small increases for ADL and DDX. Only one site in the eastern estuary had ADL levels above the SAC, while western estuary sites above the SAC were located in a ditch draining the West FCC stream.

ADL and DDX levels in cockles were comparable to other areas in New Zealand located 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 molluscan indicator of contamination. Levels of contaminants in mudflat snails remained low, however, in the West FCC site, contaminants returned to 2009 levels.

The Spring of 2011 was very wet and should have been optimal for macroalgal growth. The decline of macroalgae compared to 2009 and 2010 samples is therefore most likely due to a decline in nutrients required for growth.

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 third sample event (Spring 2011) after the completion of the remediation. The first and second sample events were conducted in Spring 2009 and 2010, and were reported in Davidson et al. (2010, 2011). The first two sampling events followed recommendations by the site auditor (Pattle Delamore, 2009), while the present sample event followed additional recommendations made in a review of sampling by Pattle Delamore (2011).

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 DDX in mudflat snails from JMB 084 at the West FCC shore in January 2010 (see Easton, 2010). The author concluded the concentration of OCPs in mudflat snails and sediment from this site was lower than values recorded by Davidson et al. (2011) sample. Easton (2010) stated that this was, however, an increase compared to immediately after the remediation (i.e. 2009).

In Spring 2010, Davidson et al. (2011) again sampled sediments for contaminant levels. The authors also recorded macroalgal cover, surface dwelling macroinvertebrates and infaunal invertebrates from East and West FCC estuarine areas. The same parameters were also sampled from two control sites well distant to the remediated area. 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.

4.0 Review of sampling (Pattle Delamore, 2011)

The present document is the third sample event (Spring 2011) after the completion of the remediation. The first and second sample events were conducted in Spring 2009 and 2010, and were reported in Davidson et al. (2010, 2011). The first two sampling events followed recommendations by the site auditor (Pattle Delamore, 2009), while the present sample event followed additional recommendations made in a review of sampling by Pattle Delamore (2011). Based on their recommendations, the methodology for the Spring 2011 sampling was modified.

Changes to the biota and sediment monitoring protocol for Spring 2011 were:

1. Surface and within sediment monitoring of estuarine invertebrate species and their abundance were not collected in Spring 2011;

2. Macroalgae quadrats were not collected in Spring 2011 unless macroalgae levels increased above levels recorded in the previous two samples;

3. Deep OCP sediment samples were collected from 2-10 cm depth;

4. A visual description of sediments were collected from all OCP sample sites;

5. Redox photographs were not collected in Spring 2011;

6. An inspection of the West FCC stream was conducted in an effort to detect any seeps that may carry contaminants;

7. Top shells living on rocks at the East FCC site were not sampled in Spring 2011. Due to low numbers of mudflat snails, top shells on soft sediment were sampled in Spring 2011 in case insufficient numbers of mudflat snails were available for the lab.

5.0 Methods (present study)

Two 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), and (2) biological community sampling (macroalgal photographs). A summary of the laboratory methods and tests are displayed in Appendix 6.

5.1 Mollusc and sediment contaminant sampling

On 22nd November 2011, sediment for contaminant analysis was collected from the surface layer (0-2 cm) and deep layer (6-10 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 in Spring 2011 as those sampled by Davidson et al. (2011) in Spring 2010 (Table 1). Surface sediment for analyses was collected using a stainless steel scoop sampler from undisturbed substratum. Deep sediment samples were collected by first extracting a core of sediment to a depth of up to 10 cm. The depth varied depending on the substratum at each sample site. Some sites were characterised by soft sediment at all depths, while many, especially the remediated sites had high level of pebbles, granule and small cobble substrata making coring difficult. All deep sediment samples collected in the present study were collected from between 6 and 10 cm depth (Table 1). Once the core had been removed, a stainless steel scoop was used to extract soft sediment from the excavation. Notes on sediment composition, depth of the sample, colour and smell were collected at each site. Samples were placed in containers supplied by Hill Laboratories. Stainless steel collection devices were washed between each replicate samples and between each site.

A variety of macroinvertebrates were also collected for contaminant analysis from East and West FCC impact sites 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 (*Amphibola crenata*) was collected. Low numbers of mudflat snail were available at the East FCC site. As a precaution, topshell (*Diloma subrostrata*) living on soft sediment at the East FCC impact site were also collected. In addition, a cockle sample was collected from the East FCC site and the eastern control site, some 1.4 km south-east of Mapua (Table 2, Figures 3 and 4).

Mudflat snails were collected by hand using a haphazard sampling technique from an area of approximately 10m^2 at each site (Table 2). 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. Cockles were collected by shoveling sediment into a 40 mm aperture sieve, followed by washing to extract cockles. Cockles >20 mm width were collected from the sieve.

Table 1. Sediment contaminant monitoring sites located at East and West (FCC) impact and control sites (November 2011).

Type	Site number	Coordinates	Strata	OCP surface	OCP deep
West control	JME 080	41° 15.482'S, 173° 5.540'E	0-2 cm & 8-10 cm	1	1
Impact (west)	JME 083	41° 15.463'S, 173° 5.819'E	0-2 cm & 8-10 cm	1	1
Impact (west)	JME 081	41° 15.484'S, 173° 5.821'E	0-2 cm & 8-10 cm	1	1
Impact (west)	JME 082	41° 15.501'S, 173° 5.825'E	0-2 cm & 8-10 cm	1	1
Impact (west)	West FCC new 1 (west)	41° 15.471'S, 173° 5.849'E	0-2 cm & 8-10 cm	1	1
Impact (west)	West FCC new 2 (middle)	41° 15.473'S, 173° 5.867'E	0-2 cm & 8-10 cm	1	1
Impact (west)	West FCC new 3 (east)	41° 15.480'S, 173° 5.879'E	0-2 cm & 8-10 cm	1	1
Impact (west)	JME 084	41° 15.484'S, 173° 5.859'E	0-2 cm & 8-10 cm	1	1
Impact (west)	West FCC Stream 1 (lower)	41° 15.446'S, 173° 5.839'E	0-2 cm & 8-10 cm	1	1
Impact (west)	West FCC Stream 2 (middle)	41° 15.433'S, 173° 5.863'E	0-2 cm & 8-10 cm	1	1
Impact (west)	West FCC Stream 1 (upper)	41° 15.425'S, 173° 5.877'E	0-2 cm & 8-10 cm	1	1
Impact (east)	JME 088	41° 15.418'S, 173° 6.089'E	0-2 cm & 6-8 cm	1	1
Impact (east)	JME 087	41° 15.421'S, 173° 6.093'E	0-2 cm & 6-8 cm	1	1
Impact (east)	JME 086	41° 15.423'S, 173° 6.097'E	0-2 cm & 8-10 cm	1	1
Impact (east)	East FCC New 1 (north)	41° 15.410'S, 173° 6.097'E	0-2 cm & 6-8 cm	1	1
Impact (east)	East FCC New 2 (south)	41° 15.428'S, 173° 6.083'E	0-2 cm & 6-8 cm	1	1
Impact (east)	JME 090	41° 15.436'S, 173° 6.079'E	0-2 cm & 6-10 cm	1	1
East control	Hunter-Brown	41° 16.187'S, 173° 6.497'E	0-2 cm & 6-8 cm	1	1
TOTAL SAMPLES				18	18

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.

Mudflat snail (n = 3), topshell (n = 1), cockle (n = 2) and sediment samples (18 shallow, 18 deep) were sent to Hill Laboratories for analysis on the day following collection and the 24 hour sediment purging from invertebrates.

Both sediment and invertebrate samples were chilled during transportation.

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 (compos	East FCC (*Amphibola*)	Whole area	1
East FCC (JME 09	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			6

Figure 1. Location of sediment contaminant sites at West FCC location. Insert is West control site JME080 (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.

5.2 Macroalgae photographs

Macroalgae photographs were initially collected in October 2009 (Davidson et al. (2010). These were repeated in November 2010 (Davidson et al. 2011) and in the present study in November 2011).

On the 22nd November 2011, 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 resampled, while two fixed points were resampled at the East FCC site (Table 3, Figure 5). One set of panoramic 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.

Occasional close up photos were collected at these sites.

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

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

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 (Figures 8 and 9, Tables 6a and 6b, Appendix 1).

For shallow samples, ADL (aldrin, dieldrin, lindane) exceeded the Soil Acceptance Criteria (SAC) at five of 16 impact sites (Table 6a). For deep samples, ADL also exceeded the SAC for five of the 16 deep samples. No elevated ADL values were recorded from control sites at either depth strata. In 2011, highest ADL was recorded at both depth strata from the middle and upper West FCC stream sites (Tables 6a and 6b, Figures 1 & 8). One of the shallow and two of the deep samples represented an increase from 2010 samples (Tables 6a and 6b). Of the three stream samples, highest values were recorded from the middle site.

Only one East FCC site had elevated ADL (JME 088). Elevated ADL values were recorded from shallow and deep sediments at West FCC JME083 and deep samples at JME083 and JME081. Both of these West FCC sites are located in the estuarine ditch draining the West FCC stream (Figures 1 and 8). Apart from the West FCC stream, most ADL samples showed a decline from 2010 samples (Tables 6a and 6b).

Highest values for DDX (2,4 DDT; 4,4 DDT; 2,4 DDD; 4,4 DDD; 2,4 DDE; 4,4 DDE) were recorded at shallow and deep West FCC stream sites (Table 6a and 6b, Figure 9). Shallow stream samples showed higher levels of DDX compared to deep samples. Deep DDX levels increased compared to 2010, while shallow samples declined slightly compared to 2010.

Many of the deep East FCC sites that recorded relatively high DDX levels in 2010 exhibited relatively large declines in the 2011 sample event (Figure 9). Highest East FCC values were recorded from deep JME 090 and New2 sites located in central and southern parts of the shore close to the rock wall (Figure 2). West FCC values for DDX remained relatively stable between 2009, 2010 and 2011 (Figure 9).

Comparison of DDX, dieldrin and lindane levels sampled from the same sites on seven occasions (2005 to 2011) had high values at particular sites in 2005 and 2007. Samples collected in 2008 and 2009 showed dramatically lower values (Figure 10, Table 7). Average DDX and dieldrin values peaked in 2005, while the highest lindane level was recorded in

2007 (Figure 11). For the four most recent sample events (2008, 2009, 2010, 2011), mean values for DDX, dieldrin and lindane were dramatically lower compared to 2005 and 2007.

Despite these declines from large historic values, mean values for DDX in 2011 was 0.627 mg/kg for all shallow sites and 0.488 mg/kg for all deep sites. This was well above the SAC set at 0.01 mg/kg. The mean DDX for all sites excluding the West FCC stream sites was, however, 0.131 mg/kg and 0.2038 mg/kg for shallow and deep respectively.

At the two control sites, levels of contaminants remained low to not detectable on all occasions. Trace DDX levels have, however, been recorded in some years.

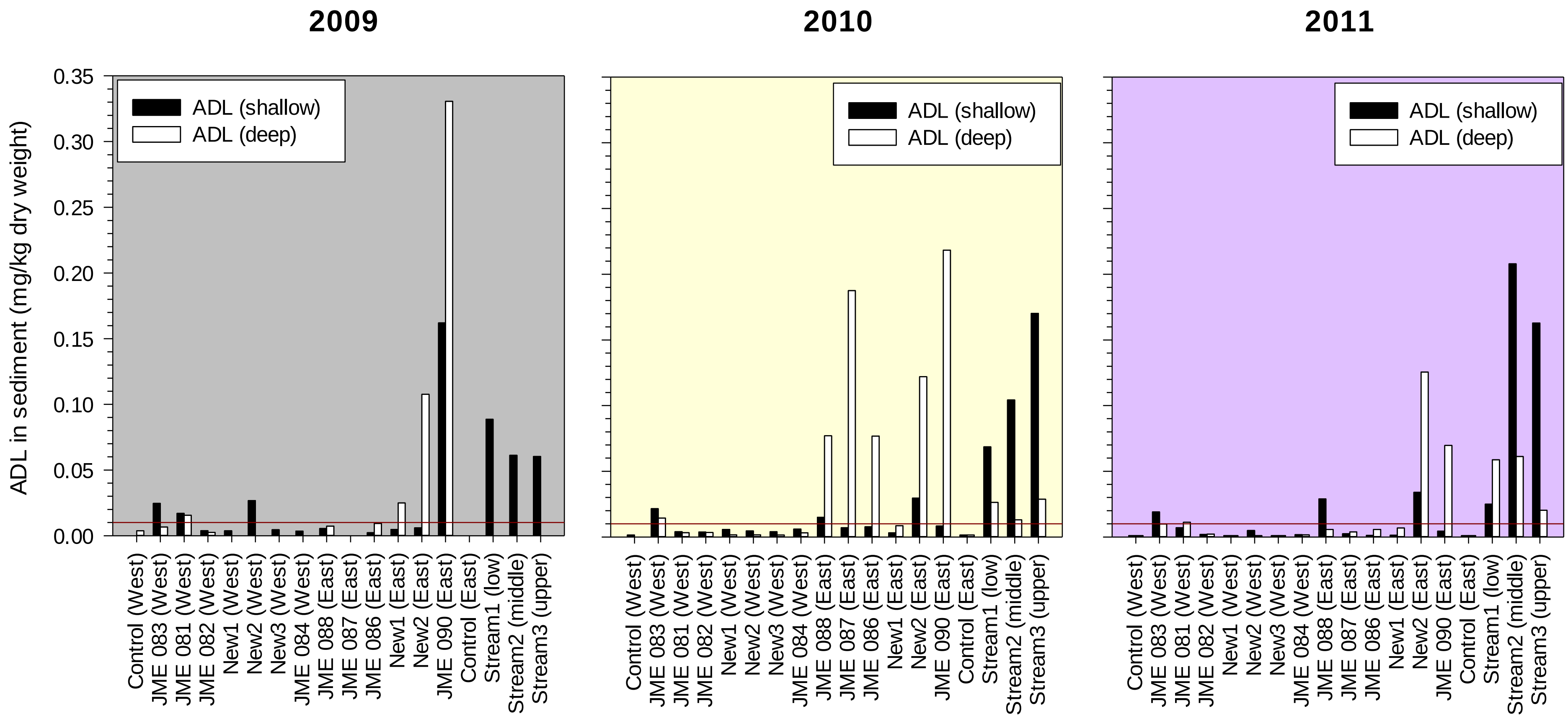

Figure 8. Levels of ADL (aldrin, dieldrin, lindane) (mg/kg dry weight) recorded from sediment samples collected at control and impact sites in 2009 (left, grey), 2010 (middle, yellow) and 2011 (right, purple). Note: deep stream sediments were not sampled in 2009. Red line is SAC (0.01 mg/kg dry weight).

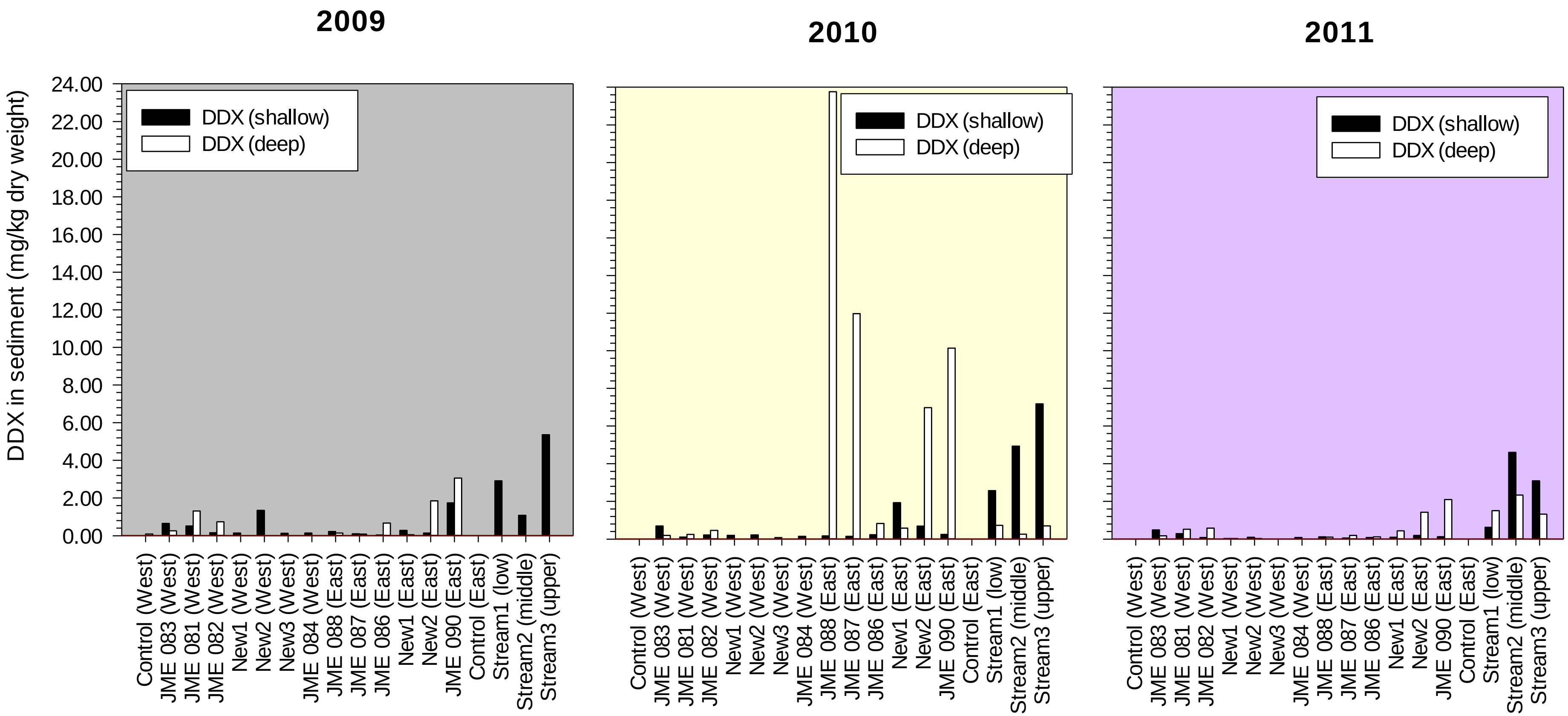

Figure 9. Levels of DDX (2,4DDT; 4,4DDT; 2,4DDD; 4,4DDD; 2,4DDE; 4,4DDE) (mg/kg dry weight) recorded from sediment samples collected at control and impact sites in 2009 (left, grey), 2010 (middle, yellow) and 2011 (right, purple). Note: deep stream sediments were not sampled in 2009. Red line is SAC (0.01 mg/kg dry weight).

Table 6a. Shallow sediment ADL and DDX levels and their component analytes sampled in 2009, 2010 and 2011 from FCC 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

November 2011

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	0.0021	<.0010	<.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010		0.0143	0.0036
Dieldrin		<0.0011	0.169	0.0071	0.002	<0.0010	0.0049	<0.0010	0.0017	0.029	0.0024	0.0012	0.0014	0.0038	0.0058	<0.0010	0.025	0.19	0.157
gamma-BHC (Lindane)		<0.0011	<0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010		0.0036	0.0023
2,4-DDD		<0.0011	0.064	0.041	0.0111	0.0032	0.0118	<0.0010	0.0094	0.0142	0.0061	0.0028	0.0076	0.0186	0.0107	<0.0010	0.085	0.66	0.5
4,4 DDD		<0.0011	0.141	0.092	0.033	0.0091	0.031	0.0027	0.025	0.027	0.0149	0.006	0.018	0.044	0.025	<0.0010	0.19	1.6	1.09
2,4 DDE		<0.0011	0.036	0.0158	0.0038	0.0011	0.0057	<0.0010	0.0026	0.0023	0.0012	<0.0010	<0.0010	0.0058	0.0038	<0.0010	0.045	0.36	0.25
4,4 DDE		<0.0011	0.183	0.096	0.027	0.0114	0.036	0.0048	0.04	0.0176	0.0103	0.0047	0.0131	0.047	0.023	<0.0010	0.27	1.57	1.05
2,4 DDT		<0.0011	0.0102	0.0064	0.0016	<0.0010	0.0019	<0.0010	<0.0010	0.014	0.0043	0.0033	0.0052	0.0122	0.0061	<0.0010	0.0068	0.044	0.025
4,4 DDT		<0.0011	0.047	0.038	0.0115	0.0026	0.0068	0.0014	0.0035	0.041	0.0196	0.066	0.045	0.067	0.031	<0.0010	0.037	0.37	0.178
ADL (aldrin, dieldrin, lindane) [1]	0.01	<0.0011	0.1711	0.0071	0.002	0	0.0049	0	0.0017	0.029	0.0024	0.0012	0.0014	0.0038	0.0058	<0.0010	0.025	0.2079	0.1629
Comparison 2010 to 2011		Decline	Increase	Increase	Decline	Decline	Increase	Decline	Decline	Increase	Decline	Decline	Decline	Decline	Decline	Decline	Decline	Increase	Decline
DDX [1]	0.01	<0.001	0.4812	0.2892	0.088	0.0274	0.0932	0.0089	0.0805	0.1161	0.0564	0.0828	0.0889	0.1946	0.0996	<0.0010	0.6338	4.604	3.093
Comparison 2010 to 2011		Decline	Decline	Increase	Decline	Decline	Decline	Decline	Decline	Decline	Decline	Decline	Decline	Decline	Decline	Decline	Decline	Decline	Decline

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. Deep sediment ADL and DDX levels and their component analytes sampled in 2009, 2010 and 2011 from FCC and control sites.

September 2009

DEEP (10 - 15 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 (10 - 15 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			

November 2011

DEEP (6 - 10 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		< 0.0010	< 0.0010	0.0012	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0016	0.0015	0.0029
Dieldrin		< 0.0010	0.0169	0.01	0.0022	0.001	< 0.0010	< 0.0010	0.0016	0.0058	0.0038	0.0057	0.0068	0.0012	0.0024	< 0.0010	0.055	0.058	0.0152
gamma-BHC (Lindane)		< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0021	0.0017	0.0022
2,4-DDD		< 0.0010	0.064	0.077	0.036	0.0034	0.0022	< 0.0010	0.0022	0.0107	0.0186	0.014	0.022	0.0028	0.0061	< 0.0010	0.2	0.31	0.169
4,4 DDD		< 0.0010	0.141	0.178	0.104	0.009	0.0134	< 0.0010	0.0055	0.025	0.044	0.039	0.038	0.006	0.0149	< 0.0010	0.5	0.92	0.46
2,4 DDE		< 0.0010	0.036	0.031	0.0129	0.0012	< 0.0010	< 0.0010	< 0.0010	0.0038	0.0058	0.0056	0.009	< 0.0010	0.0012	< 0.0010	0.11	0.128	0.057
4,4 DDE		< 0.0010	0.183	0.168	0.08	0.0137	0.009	0.0024	0.0092	0.023	0.047	0.025	0.077	0.0047	0.0103	< 0.0010	0.59	0.66	0.21
2,4 DDT		< 0.0010	0.0102	0.0095	0.028	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.0061	0.0122	0.0022	0.041	0.0033	0.0043	< 0.0010	0.0191	0.0117	0.0126
4,4 DDT		< 0.0010	0.047	0.064	0.32	0.0022	< 0.0010	< 0.0010	0.0014	0.031	0.067	0.029	0.25	0.066	0.0196	< 0.0010	0.086	0.31	0.41
ADL (aldrin, dieldrin, lindane) [1]	0.01	< 0.0010	0.0169	0.0112	0.0022	0.001	0	0	0.0016	0.0058	0.0038	0.0057	0.0068	0.0012	0.0024	< 0.0010	0.0587	2.4009	1.3389
Comparison 2010 to 2011		Decline	Increase	Increase	Decline	Decline	Decline	Decline	Decline	Decline	Decline	Decline	Decline	Decline	Decline	Decline	Increase	Increase	Increase
DDX [1]	0.01	< 0.0010	0.4812	0.5275	0.5809	0.0295	0.0246	0.0024	0.0183	0.0996	0.1946	0.1148	0.437	0.0828	0.0564	< 0.0010	1.5051	2.3397	1.3186
Comparison 2010 to 2011		Decline	Increase	Increase	Increase	Increase	Increase	Decline	Increase	Decline	Decline	Decline	Decline	Decline	Decline	Decline	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)

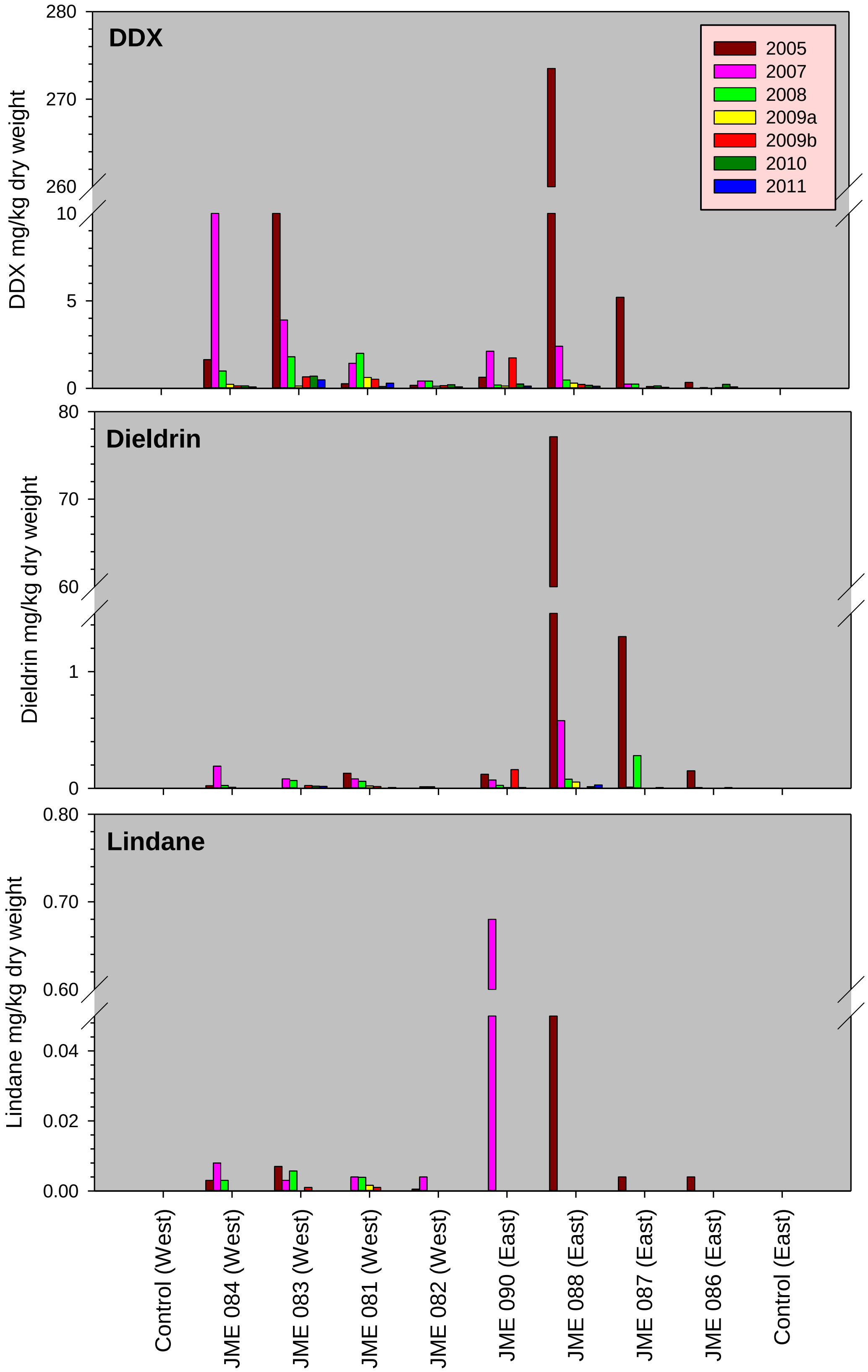

Figure 10. Levels of surface DDX (2,4DDT; 4,4DDT; 2,4DDD; 4,4DDD; 2,4DDE; 4,4DDE), dieldrin and lindane (mg/kg dry weight) recorded from the same control and impact sites in 2005, 2007, 2008, 2009a, 2009b, 2010 and 2011 (present study).

Table 7. Summary of DDX, dieldrin and lindane levels from surface samples collected between 2005 and November 2011 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, 2010 and 2011 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	2011	2005	2007	2008	2009a	2009b	2010a	2010b	2011	2005	2007	2008	2009a	2009b	2010b	2011
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	ND	ND	ND
JME 084(see note)	West FCC	1.64	16.6	0.987	0.23	0.1416	0.49	0.144	0.0815	0.022	0.19	0.025	0.009	0.0025	0.014	0.0049	0.0017	0.003	0.008	0.003	ND	ND	ND	ND
JME 083 (at concrete bridge)	West FCC	12	3.9	1.8	0.129	0.657		0.6931	0.4812	0.0018	0.08	0.067	0.005	0.023		0.0193	0.0169	0.007	0.003	0.0057	ND	0.001	ND	ND
JME 081 (40 m down ditch)	West FCC	0.26	1.43	2	0.62	0.518		0.1064	0.2892	0.129	0.08	0.06	0.02	0.015		0.003	0.0071	-	0.004	0.0039	0.0016	0.001	ND	ND
JME 082 (80 m down ditch)	West FCC	0.17	0.42	0.41	0.12	0.1565		0.2118	0.088	0.0035	0.013	0.013	0.004	0.0028		0.0027	0.0020	0.0005	0.004	ND	ND	ND	ND	ND
JME 090	East FCC	0.63	2.12	0.187	0.13	1.7395		0.2492	0.1244	0.12	0.071	0.026	0.006	0.16		0.0074	0.0045	-	0.68	ND	ND	ND	ND	ND
JME 088 (top of beach)	East FCC	273.5	2.4	0.477	0.3	0.2251		0.169	0.1161	77.13	0.58	0.078	0.054	0.0044		0.014	0.0290	0.36	ND	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	0.0564	1.3	0.0108	0.28	0.005	ND		0.006	0.0024	0.004	ND	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	0.0838	0.15	0.0057	0.004	ND	0.0013		0.0068	0.0012	0.004	ND	ND	ND	ND	ND	ND
Control	East (Hunter-Brown)	-	-	-	-	0.00148		0.0015	ND	-	-	-	-	ND		ND	ND	-	-	-	-	ND	ND	ND

Notes:	
JME 084	(West FCC snail sample site) 10m (2005, 2007), 40 m (2008), 45m (2009) from MHWS
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	Davidson et al., (2011) (Sample November 2010)
2011	Present report (sample November 2011)
	Values greater than Soil Acceptance Criteria (SAC)

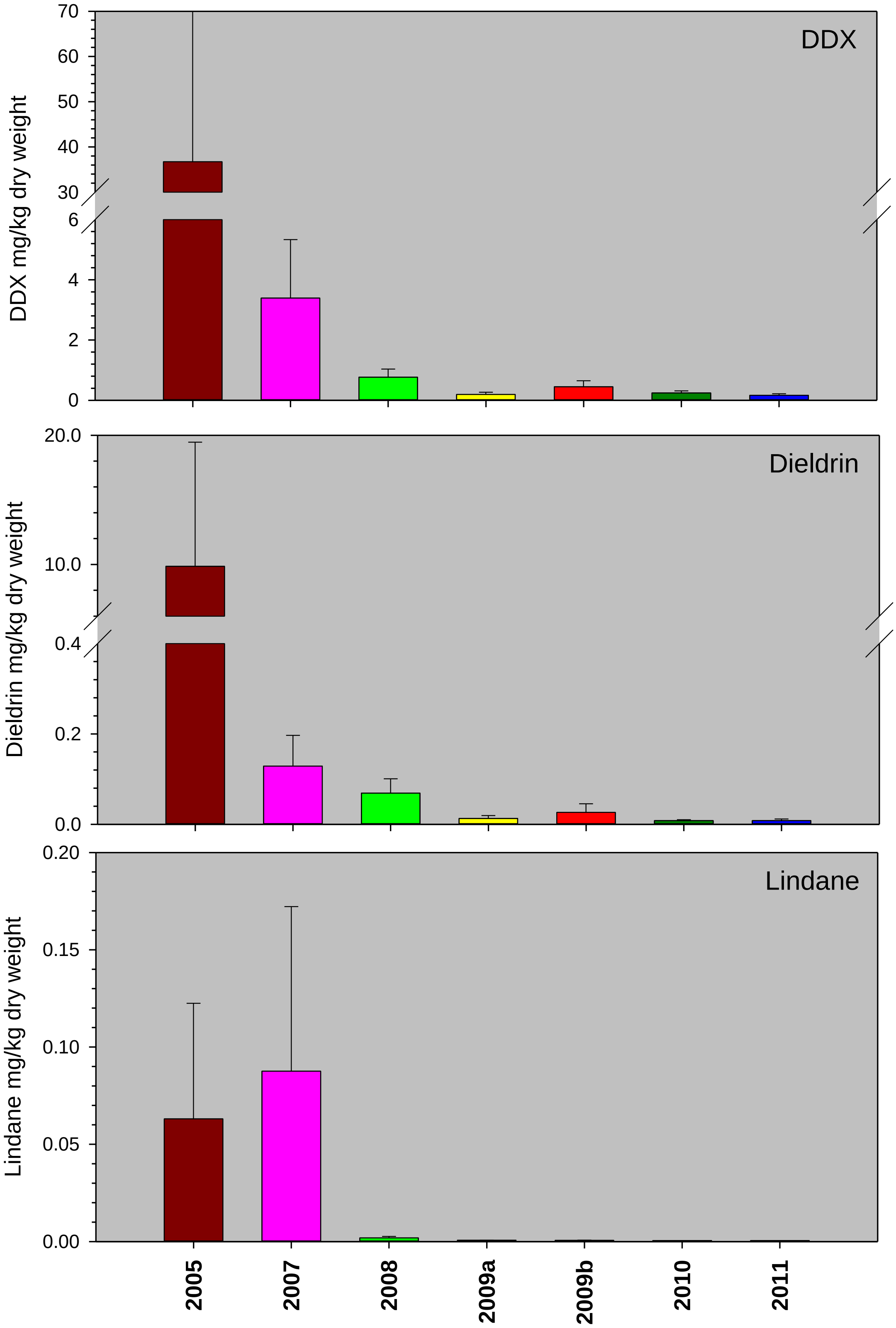

Figure 11. Mean DDX (2,4DDT; 4,4DDT; 2,4DDD; 4,4DDD; 2,4DDE; 4,4DDE), aldrin and lindane (mg/kg dry weight) pooled from the same impact sites where data was available for 2005, 2007, 2008, 2009a, 2009b, 2010 and 2011. Note: x axis values are variable between graphs. Error bars +/- 1 se.

6.1.2 Mollusc contaminants

In 2011, a variety of mollusc species were tested for pesticide contamination from four 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, 0.0026 mg/kg in 2010 and 0.0028 mg/kg in 2011). DDX levels for impact cockles (0.0087 mg/kg) were higher than levels recorded from control cockles (Table 8).

At the West FCC shore, mudflat snail ADL and DDX concentrations at site JME 084 were the highest values recorded in the present study. Values were lower than those recorded in 2009 but higher than those recorded for mudflat snails in 2010. 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) and double the present 2011 sample (Table 9). Dieldrin showed the same pattern in *Amphibola*. Lindane was not detectable in 2009, 2010 and 2011 samples. Samples of Amphibola collected by TDC from the West FCC site (January 2010) were comparable to present levels (Table 9).

East FCC mudflat snails (*Amphibola*) continued to decline with the lowest levels recorded from four sample occasions since 2005 (Table 9).

Topshells (*Diloma*) living on soft substrata were sampled during 2009, 2010 and the present study (Table 8). For the three events, highest values of DDX and Dieldrin were recorded from topshells living on soft substrata in 2011 (Tables 8 and 9).

Table 8. Pesticide concentrations in molluscs sampled from impact and control sites on 20 October 2009 (top), 16 November 2010 (middle) and 22 November 2011 (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

2011							
Location	West	West FCC	East FCC		East FCC	East FCC	East
Site	Control	JME 084	Composite		new2 (south)	JME 090	Control
Species	Amphibola	Amphibola	Amphibola		Diloma	Cockle	Cockle
Substrata	Soft	Soft	Soft		Soft	Soft	Soft
Pesticides (mg/kg)							
Aldrin	<0.0005	<0.0005	<0.0005		<0.0005	<0.0005	<0.0005
Dieldrin	0.0029	0.45	0.0126		0.77	0.0023	<0.0005
gamma-BHC (Lindane)	<0.0005	<0.0005	<0.0005		<0.0005	<0.0005	<0.0005
2,4-DDD	0.0043	0.81	0.0045		0.095	0.0009	<0.0005
4,4 DDD	0.024	2.7	0.032		0.61	0.0029	<0.0005
2,4 DDE	0.0009	0.046	0.0014		0.0064	<0.0005	<0.0005
4,4 DDE	0.078	6	0.027		0.81	0.003	<0.0005
2,4 DDT	<0.0005	0.037	<0.0005		0.0106	<0.0005	<0.0005
4,4 DDT	0.0192	1.59	0.0024		0.39	0.0014	<0.0005
ADL (aldrin, dieldrin, lindane) [1]	0.0034	0.4505	0.0131		0.7705	0.0028	ND
DDX [1]	0.12665	11.183	0.06755		1.922	0.0087	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	2010	2011	2005	2007	2008	2009a	2009b	2010	2010	2011	2005	2007	2008	2009a	2009b	2010	2011
Control	West	Amphibola	Soft	0.11	-	-	-	0.09575	-	0.0598	0.1267	0.007	-	-	-	0.002	-	0.0016	0.0029	-	-	-	-	ND	ND	ND
JME 084	West FCC	Amphibola	Soft	6.2	51.14	10.34	3.5	22.09	13 [2]	4.716	11.183	0.364	2.18	0.48	0.22	0.52	0.39 [2]	0.139	0.45	-	-	-	-	ND	ND	ND
Composite	East FCC	Amphibola	Soft	3.96	-	-	-	1.1399	-	1.1929	0.0676	1	-	-	-	0.23	-	0.141	0.0126	-	-	-	-	ND	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	ND
New2 (south)	East FCC	Diloma	Soft	-	-	-	-	0.1891	-	0.1218	1.922	-	-	-	-	0.0027	-	0.0121	0.77	-	-	-	-	ND	ND	ND
JME 090	East FCC	Cockle	Soft	-	-	-	-	0.01101	-	0.0149	0.0087	-	-	-	-	0.0028	-	0.0021	0.0023	-	-	-	-	ND	ND	ND
Control	East	Cockle	Soft	<0.01 [1]	-	-	-	0.00279	-	ND	ND	-	-	-	-	ND	-	ND	<0.0005	-	-	-	-	ND	ND	ND

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

6.2 Sediment descriptions at sediment sample sites

Most sample OCP sediment sample sites were characterised by a surface layer of silt covering deeper substrata dominated by granule, pebble, silt, fine sand and occasional cobbles (Table 10). Hard substratum (i.e. pebbles, granules and cobbles) were widespread at sites where estuary sediments had been remediated (i.e. silt and clay removed and replaced by fill). The eastern control site located at Hunter-Brown reserve was also characterised by this combination of substrata due to the alluvial origins of this site.

Sample sites located further from the West FCC estuarine edge, away from the remediated flats, were characterised by silt and clay substratum over the entire depth of the core sample (i.e. West FCC new2, new3, JME 082, JME 084, West control).

The three Stream sites were composed of remediated substrata with small cobble, pebble and granule size material being dominant.

Only one impact site had an anaerobic smell (JME 083). This site was located in the estuary immediately downstream of where the small stream entered the estuary proper. All other sites did not exhibit any anaerobic odour. Some sites did however, have variable levels of black colouration, usually observed close to the sediment surface (Table 10).

Table 10. Description of substrata at sediment sampling sites.

Area	Site	Deep sample depth	Substratum	Smell colour
Western embayment	Control	8-10 cm	Sand, fine sand	Orange colour below surface, no anaerobic smell
West FCC	JME 083	8-10 cm	Granules, pebbles, occasional small cobbles, fine sand, silt	Grey-black, anaerobic smell
West FCC	JME 081	8-10 cm	Granules, pebbles, occasional small cobbles, fine sand, silt	Grey, no anaerobic smell
West FCC	JME 082	8-10 cm	Silt and clay	Grey-black, no anaerobic smell
West FCC	new1 (west)	8-10 cm	Granules, pebbles, occasional small cobbles, fine sand, silt	Orange colour below surface, no anaerobic smell
West FCC	new2 (middle)	8-10 cm	Silt, clay, fine sand	Grey-black, no anaerobic smell
West FCC	new3 (east)	8-10 cm	Fine sand, sand (silty surface)	Mid grey with patches of orange, no anaerobic smell
West FCC	JME 084	8-10 cm	Fine sand, sand (silty surface)	Mid grey, old vegetation, no anaerobic smell
East FCC	JME 088	6-8 cm	Granules, pebbles, occasional small cobbles, fine sand, silt	Light grey, no anaerobic smell
East FCC	JME 087	6-8 cm	Granules, pebbles, occasional small cobbles, fine sand, silt	Light grey-brown (some black near surface), no anaerobic smell
East FCC	JME 086	8-10 cm	Granules, pebbles, occasional small cobbles, fine sand, silt	Light grey, no anaerobic smell
East FCC	new1 (north)	6-8 cm	Granules, pebbles, occasional small cobbles, fine sand, silt	Grey-dark brown, some black patches, no anaerobic smell
East FCC	new2 (south)	6-8 cm	Granules, pebbles, occasional small cobbles, fine sand, silt	Light grey (some black in top 4 cm), no anaerobic smell
East FCC	JME 090	8-10 cm	Granules, pebbles, occasional small cobbles, fine sand, silt	Grey-black, no anaerobic smell
Hunter Brown	Control	6-8 cm	Granules, pebbles, occasional small cobbles, fine sand, silt	Light grey-grey, patches of orange
West FCC	Stream1 (low)	8-10 cm	Granules, pebbles, occasional small cobbles, fine sand, silt	Grey-black, no anaerobic smell
West FCC	Stream2 (middle)	8-10 cm	Granules, pebbles, occasional small cobbles, fine sand, silt	Grey-black, black near surface, no anaerobic smell
West FCC	Stream3 (upper)	8-10 cm	Granules, pebbles, occasional small cobbles, fine sand, silt	Grey-black, black near surface, no anaerobic smell

6.3 Macroalgae cover

Photographs collected from comparable tidal heights at impact and control sites in October 2009, November 2010 and November 2011 have been displayed in photos 4-7.

Macroalgal cover was absent or recorded at low levels at both control sites in all sample years (photos 4 and 5). At the Hunter-Brown control site, areas of green macroalgae were observed near low water mark, however, little or no macroalgae was observed from the shore at higher tidal levels.

Photo 4. Macroalgae panoramic photos from West control. Top is October 2009, middle is November 2010, bottom is November 2011.

Photo 5. Macroalgae panoramic photos from East control (Hunter-Brown). Top is October 2009, middle is November 2010, bottom is November 2011.

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 and in Spring 2011, macroalgae was much reduced compared to Spring 2009. In 2010 and 2011, macroalgae was limited to a relatively narrow band directly adjacent and at the foot of the cobble bank.

At the East FCC shore, macroalgae was present but never common or abundant. Little difference in the level of macroalgae was observed between 2009 and 2010 (Photo 7). In Spring of 2011, the lowest levels of macroalage were recorded for the three years of sampling (Photo 7). Most notable was the decline in macroalgae from the middle and lower shore.

Photo 6. Macroalgae photos from West FCC (middle). Top is October 2009, middle is November 2010, bottom is November 2011.

Photo 7. Macroalgae panoramic photos from East FCC (south). Top is October 2009, middle is November 2010, bottom is November 2011.

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 also occurred between 2009 and 2010. In Spring 2011, little change to the vascular plant cover was observed compared to 2010.

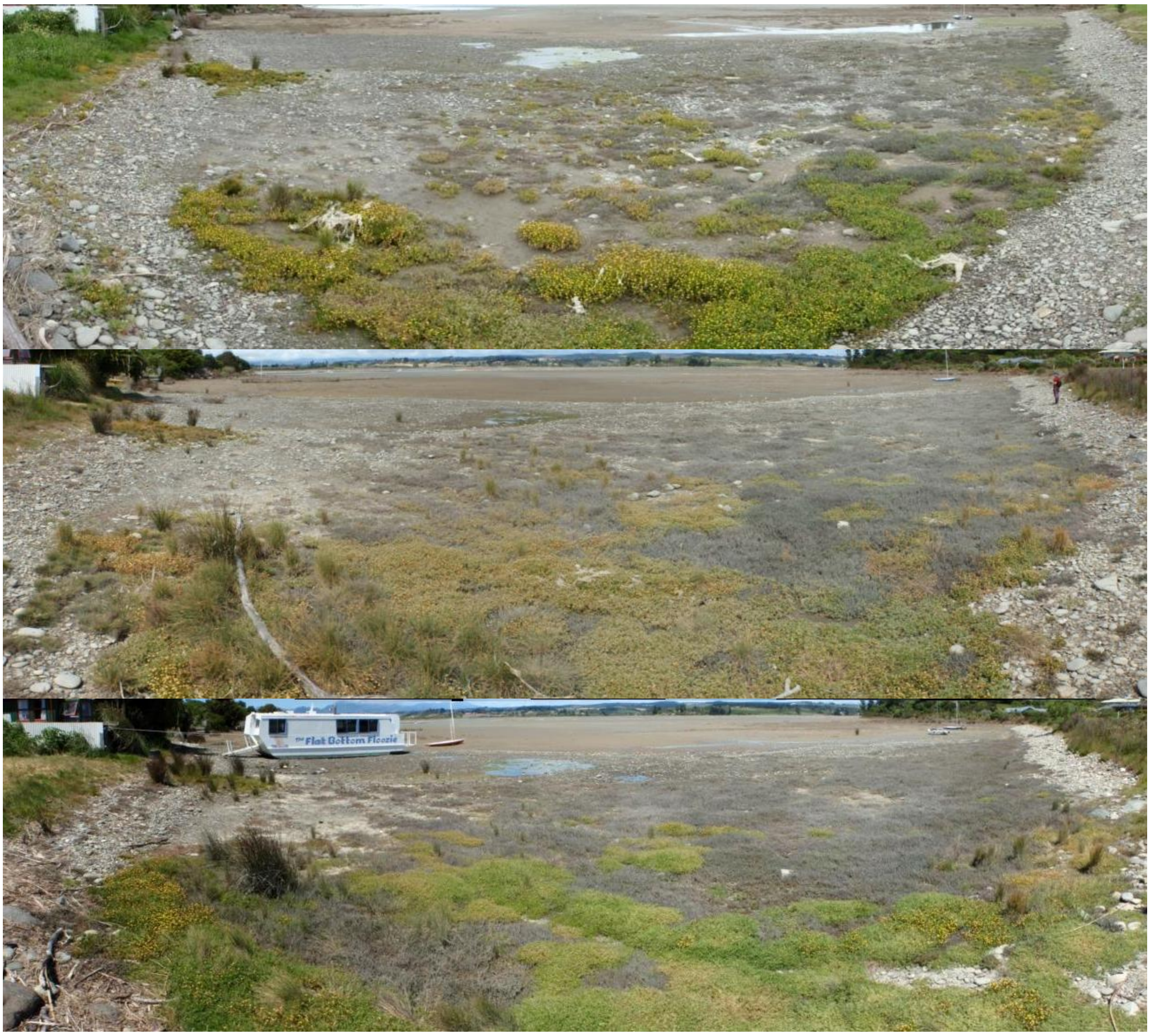

Photo 7. Vascular plants from West FCC (east). Top is October 2009, middle is November 2010, bottom is November 2011.

7.0 Discussion

7.1 Organism and sediment contaminant sampling

Surface sediment contaminant levels

In 2009, 2010 and 2011, DDX and ADL in surface sediments varied depending on location. In 2009, SAC levels for ADL were exceeded at three of the seven West estuarine FCC sites. In 2010 and 2011, the SAC ADL criterion was exceeded at only one of the seven West FCC sites sampled. The SAC criterion for DDX in both 2009 and 2010 was exceeded at all West FCC sites. In 2011, one of the West FCC site met the DDX SAC for the first time (West FCC new3). Three sites showed declines between 2009 and 2010, with DDX declines recorded at all but one site between 2010 and 2011. The one increase in DDX between 2010 and 2011 was recorded in the estuarine ditch draining the west stream.

For the West FCC tidal freshwater stream, all surface sediments sampled exceeded DDX and ADL SAC criteria in all years. The West FCC (stream1 low) site showed a decline for both contaminant groups since 2009. However, at the middle and upper stream sites, both ADL and DDX showed a relatively large increase since 2009. Of particular note was the concentrations of DDX at the middle and upper stream sites (4.604 and 3.093 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 from 2009, 2010 and the present study, it is probable that DDX in stream surface sediments are elevated due to seepage containing contaminants from adjacent terrestrial sediments. In the Auditor's report, a contaminant "hotspot" buried close to the stream edge was suspected (see Auditor's 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.

At the East FCC site, SAC criterion in surface sediments for ADL was exceeded at one of the six sites in 2009 and two in 2010 and one site in 2011. These exceeded levels were, however, relatively close to the SAC. For DDX, all East FCC surface samples exceeded the

SAC in the three sample occasions. All East FCC surface samples decreased below 2010 values.

Deep sediment contaminant levels

For deep sediments at West FCC sites, ADL levels remained relatively consistent with five small decreases and two small increases between 2010 and 2011. The increases were recorded in the estuarine ditch that drains the West FCC stream. Increases in deep DDX concentrations also occurred at estuarine sites along the ditch. It is probable that the elevated ADL and DDX concentrations found in the West FCC stream sites are responsible for the elevated levels found in the estuarine ditch that drains the stream. ADL and DDX levels in deep sediment samples at the West FCC stream increased from 2010 levels. Highest values were recorded from the middle stream site followed by the upper sample site. Lowest values were recorded from the bottom of the stream sample sites. This is consistent with shallow contaminant values suggesting that contamination continues to enter the middle and upper parts of the stream.

DDX levels at all deep East FCC sites showed a relatively large increase between 2009 and 2010. The present sampling event showed a decline back to levels comparable to 2009 (Davidson et al., 2010).

Davidson et al. (2011) suggested that water seepage channels arising from the foot of the East FCC rock wall could be carrying contaminated water from the adjacent FCC site onto the mudflats. The decline recorded in the present study suggests that this phenomenon has probably stopped and contaminants have returned to 2009 levels.

Overall patterns of contamination

Apart from sediments at the West FCC freshwater tidal stream, most sites showed some improvement, little change, or small increases for ADL and DDX between 2010 and 2011. Only one site in the eastern estuary had ADL levels above the SAC, while western estuary sites above the SAC were located in a ditch draining the West FCC stream.

In the 2009 auditor's 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. Only one sample (deep West FCC new3) met the DDX SAC, however, most sites showed lower levels than the 2010 sample event.

The only area of concern in the present study is the ADL and DDX levels in the West FCC stream. At these locations, sediment recontamination has occurred and has probably come from "hot spots" in the adjacent FCC site. Contaminants that have presumable come from the West freshwater stream appear in the estuarine ditch that drains the stream.

The reason or reasons for the increase in contamination between 2009 and 2010 for East FCC deep sediments in unknown. Based on the present sampling event, levels have returned to comparable values recorded in 2009. Further sampling of these sites will confirm if contamination of these deep sediments will remain at 2009 levels.

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, 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 2010 sample (Davidson et al., 2011), ADL and DDX declined well below the 2009 levels at all sites where cockles and topshells were sampled. In the present study, DDX in cockles returned to 2008 and 2010 levels.

For mudflat snails, ADL and DDX also declined in the present study relative to some previous years. At JME084 for example, DDX values have declined from 51.14 mg/kg in 2007 to 11.18mg/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 2010 and an increase in the present study are unknown. Clearly, DDX levels are highly variable with regard to mudflat snail samples, despite the relatively low and declining levels of DDX in the background sediments at the site where they live (JME084). Whether this is related to variable contaminant levels in the flesh or variation relating to cleansing of sediment in their gut, is unknown.

Further, the West FCC site where mudflat snails are sampled supports lower containment levels than the sediments where mudflat snails are collected at the East FCC site, despite the snails having lower DDX levels in the flesh at the East FCC. The reasons for this phenomenon are unknown and seem independent of background sediment contaminant concentrations.

DDX and Dieldrin levels from topshell living on soft sediment were the highest recorded for any sampling event since 2009 (1.92 mg/kg and 0.77 mg/kg respectively). This increase did not correspond to an increase in contaminant levels at this site and the reason for the increase remains unknown. Further, cockle contaminants at the East FCC site declined over the same period.

7.2 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 also noted by Davidson et al. (2011) in the spring of 2010, however, levels of macroalgae were reduced in the latter sample. Davidson et al. (2011) stated that the reduction also occurred at control sites and may have been due to the very dry and hot conditions. The macroalgae present in the West FCC shore was dominated by *Enteromorpha* sp., a species usually associated with freshwater flows into a marine environment. In the present study, little macraoalgae was observed at impact sites. The Spring of 2011 was very wet and should have been optimal for macroalgal growth. The decline of macroalgae recorded in the present study is therefore most likely due to a decline in nutrients.

7.3 Recommendations for future monitoring

Three sample events (Spring 2009, 2010 and 2011) have occurred in relation to the post-remediation 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 deep and shallow contaminant data has indicated annual fluctuations. One area of concern remains (west FCC stream). Contaminant levels have increased beyond levels that could be considered part of normal sampling variability at these sites and some evidence that contamination is entering the estuary along the ditch that drains the stream is apparent. The levels of contamination recorded in these areas suggest that recontamination is occurring in central and upper areas of the stream. It is therefore recommended that annual monitoring of contaminants from all FCC 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 the variability of sediment contaminants, the variability in contaminant levels in invertebrates and the continued contamination in estuarine and stream sediments, it is recommended that mudflat snail, cockle and sampling of soft sediment-dwelling *Diloma* (topshells) be continued.

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Appendix 1. Hill Laboratories results sheets for the November 2011 sample.

Hill Laboratories
BETTER TESTING BETTER RESULTS

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ANALYSIS REPORT

Client:	Davidson Environmental Ltd	**Lab No:**	955749 SPv1
Contact:	R Davidson	**Date Registered:**	24-Nov-2011
	C/- Davidson Environmental Ltd	**Date Reported:**	06-Jan-2012
	PO Box 958	**Quote No:**	42753
	NELSON 7040	**Order No:**	
		Client Reference:	Mapua samples
		Submitted By:	R Davidson

Sample Type: Sediment

Sample Name:		Stream Low Surface 22-Nov-2011	Stream Low Deep 22-Nov-2011	Stream Middle Surface 22-Nov-2011	Stream Middle Deep 22-Nov-2011	Stream Upper Surface 22-Nov-2011
Lab Number:		955749.7	955749.8	955749.9	955749.10	955749.11
Organochlorine Pesticides Trace in Soil						
Aldrin	mg/kg dry wt	< 0.0010	0.0016	0.0143	0.0015	0.0036
alpha-BHC	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
beta-BHC	mg/kg dry wt	< 0.0010	0.0051	< 0.0010	< 0.0010	< 0.0010
delta-BHC	mg/kg dry wt	< 0.0010	0.0055	< 0.0010	< 0.0010	< 0.0010
gamma-BHC (Lindane)	mg/kg dry wt	< 0.0010	0.0021	0.0036	0.0017	0.0023
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	0.085	0.20	0.66	0.31	0.50
4,4'-DDD	mg/kg dry wt	0.190	0.50	1.60	0.92	1.09
2,4'-DDE	mg/kg dry wt	0.045	0.110	0.36	0.128	0.25
4,4'-DDE	mg/kg dry wt	0.27	0.59	1.57	0.66	1.05
2,4'-DDT	mg/kg dry wt	0.0068	0.0191	0.044	0.0117	0.025
4,4'-DDT	mg/kg dry wt	0.037	0.086	0.37	0.31	0.178
Dieldrin	mg/kg dry wt	0.025	0.055	0.190	0.058	0.157
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:		Stream Upper Deep 22-Nov-2011	JME 083 Surface 22-Nov-2011	JEM 083 Deep 22-Nov-2011	JME 081 Surface 22-Nov-2011	JME 081 Deep 22-Nov-2011
Lab Number:		955749.12	955749.13	955749.14	955749.15	955749.16
Organochlorine Pesticides Trace in Soil						
Aldrin	mg/kg dry wt	0.0029	0.0021	< 0.0010	< 0.0010	0.0012
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	0.0022	< 0.0010	< 0.0010	< 0.0010	< 0.0010
cis-Chlordane	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010

Sample Type: Sediment						
Sample Name:		Stream Upper Deep 22-Nov-2011	JME 083 Surface 22-Nov-2011	JEM 083 Deep 22-Nov-2011	JME 081 Surface 22-Nov-2011	JME 081 Deep 22-Nov-2011
Lab Number:		955749.12	955749.13	955749.14	955749.15	955749.16
Organochlorine Pesticides Trace in Soil						
trans-Chlordane	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
2,4'-DDD	mg/kg dry wt	0.169	0.064	0.027	0.041	0.077
4,4'-DDD	mg/kg dry wt	0.46	0.141	0.066	0.092	0.178
2,4'-DDE	mg/kg dry wt	0.057	0.036	0.0115	0.0158	0.031
4,4'-DDE	mg/kg dry wt	0.21	0.183	0.059	0.096	0.168
2,4'-DDT	mg/kg dry wt	0.0126	0.0102	0.0014	0.0064	0.0095
4,4'-DDT	mg/kg dry wt	0.41	0.047	0.0108	0.038	0.064
Dieldrin	mg/kg dry wt	0.0152	0.0169	0.0099	0.0071	0.0100
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:		JME 082 Surface 22-Nov-2011	JME 082 Deep 22-Nov-2011	West FCC New 1 Surface 22-Nov-2011	West FCC New 1 Deep 22-Nov-2011	JME 084 Surface 22-Nov-2011
Lab Number:		955749.17	955749.18	955749.19	955749.20	955749.21
Organochlorine Pesticides Trace in Soil						
Aldrin	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 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	< 0.0010	< 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	0.0111	0.036	0.0032	0.0034	0.0094
4,4'-DDD	mg/kg dry wt	0.033	0.104	0.0091	0.0090	0.025
2,4'-DDE	mg/kg dry wt	0.0038	0.0129	0.0011	0.0012	0.0026
4,4'-DDE	mg/kg dry wt	0.027	0.080	0.0114	0.0137	0.040
2,4'-DDT	mg/kg dry wt	0.0016	0.028	< 0.0010	< 0.0010	< 0.0010
4,4'-DDT	mg/kg dry wt	0.0115	0.32	0.0026	0.0022	0.0035
Dieldrin	mg/kg dry wt	0.0020	0.0022	< 0.0010	0.0010	0.0017
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:		JME 084 Deep 22-Nov-2011	West FCC New 2 Surface 22-Nov-2011	West FCC New 2 Deep 22-Nov-2011	West FCC New 3 Surface 22-Nov-2011	West FCC New 3 Deep 22-Nov-2011
Lab Number:		955749.22	955749.23	955749.24	955749.25	955749.26

Sample Type: Sediment						
	Sample Name:	JME 084 Deep 22-Nov-2011	West FCC New 2 Surface 22-Nov-2011	West FCC New 2 Deep 22-Nov-2011	West FCC New 3 Surface 22-Nov-2011	West FCC New 3 Deep 22-Nov-2011
	Lab Number:	955749.22	955749.23	955749.24	955749.25	955749.26
Organochlorine Pesticides Trace in Soil						
Aldrin	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 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	< 0.0010	< 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	0.0022	0.0118	0.0022	< 0.0010	< 0.0010
4,4'-DDD	mg/kg dry wt	0.0055	0.031	0.0134	0.0027	< 0.0010
2,4'-DDE	mg/kg dry wt	< 0.0010	0.0057	< 0.0010	< 0.0010	< 0.0010
4,4'-DDE	mg/kg dry wt	0.0092	0.036	0.0090	0.0048	0.0024
2,4'-DDT	mg/kg dry wt	< 0.0010	0.0019	< 0.0010	< 0.0010	< 0.0010
4,4'-DDT	mg/kg dry wt	0.0014	0.0068	< 0.0010	0.0014	< 0.0010
Dieldrin	mg/kg dry wt	0.0016	0.0049	< 0.0010	< 0.0010	< 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:	JME 090 Surface 22-Nov-2011	JME 090 Deep 22-Nov-2011	East FCC New 2 Surface 22-Nov-2011	East FCC New 2 Deep 22-Nov-2011	JME 088 Surface 22-Nov-2011
	Lab Number:	955749.27	955749.28	955749.29	955749.30	955749.31
Organochlorine Pesticides Trace in Soil						
Aldrin	mg/kg dry wt	< 0.0010	0.0076	< 0.0010	0.0026	< 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	< 0.0010	< 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	0.0138	0.28	0.0189	0.159	0.0142
4,4'-DDD	mg/kg dry wt	0.036	1.05	0.045	0.43	0.027
2,4'-DDE	mg/kg dry wt	0.0020	0.025	0.0022	0.024	0.0023
4,4'-DDE	mg/kg dry wt	0.021	0.21	0.025	0.164	0.0176
2,4'-DDT	mg/kg dry wt	0.0116	0.066	0.0190	0.101	0.0140
4,4'-DDT	mg/kg dry wt	0.040	0.47	0.084	0.55	0.041
Dieldrin	mg/kg dry wt	0.0045	0.062	0.034	0.123	0.029
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	0.0014	< 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	0.0018	< 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

Sample Type: Sediment

Sample Name:		JME 090 Surface 22-Nov-2011	JME 090 Deep 22-Nov-2011	East FCC New 2 Surface 22-Nov-2011	East FCC New 2 Deep 22-Nov-2011	JME 088 Surface 22-Nov-2011
Lab Number:		955749.27	955749.28	955749.29	955749.30	955749.31
Organochlorine Pesticides Trace in Soil						
Total Chlordane [(cis+trans)* 100/42]	mg/kg dry wt	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002

Sample Name:		JME 088 Deep 22-Nov-2011	JME 087 Surface 22-Nov-2011	JME 087 Deep 22-Nov-2011	JME 086 Surface 22-Nov-2011	JME 086 Deep 22-Nov-2011
Lab Number:		955749.32	955749.33	955749.34	955749.35	955749.36
Organochlorine Pesticides Trace in Soil						
Aldrin	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 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	< 0.0010	< 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	0.0107	0.0061	0.0186	0.0028	0.0140
4,4'-DDD	mg/kg dry wt	0.025	0.0149	0.044	0.0060	0.039
2,4'-DDE	mg/kg dry wt	0.0038	0.0012	0.0058	< 0.0010	0.0056
4,4'-DDE	mg/kg dry wt	0.023	0.0103	0.047	0.0047	0.025
2,4'-DDT	mg/kg dry wt	0.0061	0.0043	0.0122	0.0033	0.0022
4,4'-DDT	mg/kg dry wt	0.031	0.0196	0.067	0.066	0.029
Dieldrin	mg/kg dry wt	0.0058	0.0024	0.0038	0.0012	0.0057
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:		East FCC New 1 Surface 22-Nov-2011	East FCC New 1 Deep 22-Nov-2011	East Control Surface 22-Nov-2011	East Control Deep 22-Nov-2011	West Control Surface 22-Nov-2011
Lab Number:		955749.37	955749.38	955749.39	955749.40	955749.41
Organochlorine Pesticides Trace in Soil						
Aldrin	mg/kg dry wt	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 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	< 0.0010	< 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	0.0076	0.022	< 0.0010	< 0.0010	< 0.0010
4,4'-DDD	mg/kg dry wt	0.0180	0.038	< 0.0010	< 0.0010	< 0.0010
2,4'-DDE	mg/kg dry wt	< 0.0010	0.0090	< 0.0010	< 0.0010	< 0.0010
4,4'-DDE	mg/kg dry wt	0.0131	0.077	< 0.0010	< 0.0010	< 0.0010
2,4'-DDT	mg/kg dry wt	0.0052	0.041	< 0.0010	< 0.0010	< 0.0010
4,4'-DDT	mg/kg dry wt	0.045	0.25	< 0.0010	< 0.0010	< 0.0010
Dieldrin	mg/kg dry wt	0.0014	0.0068	< 0.0010	< 0.0010	< 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

Lab No: 955749 v 1 Hill Laboratories Page 4 of 7

Sample Type: Sediment						
	Sample Name:	East FCC New 1 Surface 22-Nov-2011	East FCC New 1 Deep 22-Nov-2011	East Control Surface 22-Nov-2011	East Control Deep 22-Nov-2011	West Control Surface 22-Nov-2011
	Lab Number:	955749.37	955749.38	955749.39	955749.40	955749.41
Organochlorine Pesticides Trace in Soil						
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:	West Control Deep 22-Nov-2011				
	Lab Number:	955749.42				
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	< 0.0010	-	-	-	-
4,4'-DDD	mg/kg dry wt	< 0.0010	-	-	-	-
2,4'-DDE	mg/kg dry wt	< 0.0010	-	-	-	-
4,4'-DDE	mg/kg dry wt	< 0.0010	-	-	-	-
2,4'-DDT	mg/kg dry wt	< 0.0010	-	-	-	-
4,4'-DDT	mg/kg dry wt	< 0.0010	-	-	-	-
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 Control 22-Nov-2011	East FACC (Cockle) 22-Nov-2011			
	Lab Number:	955749.2	955749.4			
Individual Tests						
Dry Matter	g/100g as rcvd	15.7	25	-	-	-
Organochlorine Pesticides in Biomatter						
Aldrin*	mg/kg	< 0.0005	< 0.0005	-	-	-
alpha-BHC*	mg/kg	< 0.0005	< 0.0005	-	-	-
beta-BHC*	mg/kg	< 0.0005	< 0.0005	-	-	-
delta-BHC*	mg/kg	< 0.0005	< 0.0005	-	-	-
gamma-BHC (Lindane)*	mg/kg	< 0.0005	< 0.0005	-	-	-
cis-Chlordane*	mg/kg	< 0.0005	< 0.0005	-	-	-
trans-chlordane*	mg/kg	< 0.0005	< 0.0005	-	-	-
2,4'-DDD*	mg/kg	< 0.0005	0.0009	-	-	-

Lab No: 955749 v 1 Hill Laboratories Page 5 of 7

Sample Type: Shellfish						
Sample Name:		East Control 22-Nov-2011	East FACC (Cockle) 22-Nov-2011			
Lab Number:		955749.2	955749.4			
Organochlorine Pesticides in Biomatter						
4,4'-DDD*	mg/kg	< 0.0005	0.0029	-	-	-
2,4'-DDE*	mg/kg	< 0.0005	< 0.0005	-	-	-
4,4'-DDE*	mg/kg	< 0.0005	0.0030	-	-	-
2,4'-DDT*	mg/kg	< 0.0005	< 0.0005	-	-	-
4,4'-DDT*	mg/kg	< 0.0005	0.0014	-	-	-
Dieldrin*	mg/kg	< 0.0005	0.0023	-	-	-
Endosulfan I*	mg/kg	< 0.0005	< 0.0005	-	-	-
Endosulfan II*	mg/kg	< 0.0005	< 0.0005	-	-	-
Endosulfan sulfate*	mg/kg	< 0.0005	< 0.0005	-	-	-
Endrin*	mg/kg	< 0.0005	< 0.0005	-	-	-
Endrin Aldehyde*	mg/kg	< 0.0005	< 0.0005	-	-	-
Endrin ketone*	mg/kg	< 0.0005	< 0.0005	-	-	-
Heptachlor*	mg/kg	< 0.0005	< 0.0005	-	-	-
Heptachlor epoxide*	mg/kg	< 0.0005	< 0.0005	-	-	-
Hexachlorobenzene*	mg/kg	< 0.0005	< 0.0005	-	-	-
Methoxychlor*	mg/kg	< 0.0005	< 0.0005	-	-	-
Total Chlordane [(cis+trans)*100/42]*	mg/kg	< 0.002	< 0.002	-	-	-

Sample Type: Snails						
Sample Name:		West Control 22-Nov-2011	West FACC 22-Nov-2011	East FACC (Amphibola) 22-Nov-2011	East FACC (Diloma) 22-Nov-2011	
Lab Number:		955749.1	955749.3	955749.5	955749.6	
Individual Tests						
Dry Matter	g/100g as rcvd	26	30	47	25	-
Organochlorine Pesticides in Biomatter						
Aldrin*	mg/kg	< 0.0005	< 0.0005	< 0.0005	< 0.0005	-
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	0.0043	0.81	0.0045	0.095	-
4,4'-DDD*	mg/kg	0.024	2.7	0.032	0.61	-
2,4'-DDE*	mg/kg	0.0009	0.046	0.0014	0.0064	-
4,4'-DDE*	mg/kg	0.078	6.0	0.027	0.81	-
2,4'-DDT*	mg/kg	< 0.0005	0.037	< 0.0005	0.0106	-
4,4'-DDT*	mg/kg	0.0192	1.59	0.0024	0.39	-
Dieldrin*	mg/kg	0.0029	0.45	0.0126	0.77	-
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	0.0018	< 0.0005	0.0059	-
Endrin Aldehyde*	mg/kg	< 0.0005	< 0.0005	< 0.0005	< 0.0005	-
Endrin ketone*	mg/kg	< 0.0005	0.0025	< 0.0005	0.0035	-
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	-

Lab No: 955749 v 1 Hill Laboratories Page 6 of 7

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	-	7-42

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.	-	1-6
Shucking of Shellfish*	Removal of tissue from shell. Analysis performed at Hill Laboratories - Food & Bioanalytical Division, Waikato Innovation Park, Ruakura Lane, Hamilton.	-	1-6
Organochlorine Pesticides in Biomatter*	Sonication extraction, alumina cleanup, GPC cleanup, dual column GC-ECD analysis	-	1-6
Dry Matter (Env)	Dried at 103°C for 4-22hr (removes 3-5% more water than air dry) , gravimetry. US EPA 3550.	0.10 g/100g as rcvd	1-6

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.

Martin Cowell - BSc (Chem)
Client Services Manager - Environmental Division