Investigation into the remediation of the contaminated site at Mapua

Water quality technical annex

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Water quality

Water quality has been a secondary consideration in the remedial works at Mapua; the principal remedial action being treatment of the contaminated soil source. However water quality in the shallow unconfined aquifer underlying the Mapua site and nearby properties is likely to be a concern for current and future residents.

Taking up to 5 m^3/day of water for any purpose appears to be generally a permitted activity in Tasman District (with certain exceptions and restrictions; refer Chapter 31 of the Tasman Resource Management Plan). Several properties in the vicinity of the Mapua site already have wells that draw from the underlying shallow groundwater for irrigation and even drinking, although TDC advises that it has localised bacterial contamination and tastes unpleasant. So it is a local resource, albeit of limited potential. The area is now on reticulated water supply and there are also understood to be deeper confined aquifers present underlying the site.

According to the Assessment of Environmental Effects[1] (AEE) submitted as part of the resource consent application for the works, the objective of remediation is to reach standards acceptable for intended end uses with the minimum of restrictions (Section 5.2). Appendix I of the AEE, covering groundwater issues, indicates that a specific goal is to remediate the FCC West Area for future unrestricted residential land-use (I.1.2).

So it is reasonable to infer that the groundwater in the FCC West Area would be expected to be suitable for domestic use, potentially including for drinking, following remedial works.

This technical annex discusses:

- groundwater conceptual models for the Mapua site
- results of groundwater monitoring
- consent requirements
- actions taken in respect of groundwater
- stormwater issues.

[1] FCC Mapua site remediation: Assessment of environmental effects, reference 18777.004, Tonkin and Taylor Ltd for Thiess Services Pty Ltd, May 2003.

Hydrogeology of the Mapua site

The Woodward-Clyde conceptual model of 1996

Woodward-Clyde (1996)[2] presented a conceptual model for groundwater at the Mapua site, based on:

- July 1996 static water levels in 27 monitoring wells on site and two wells off site to the north on Iwa Street
- site lithology as shown by borehole logs and inferred from regional geology
- slug tests in monitoring wells at three locations along the northern boundary of the site
- regional rainfall
- distributions of sealed areas on site.

This conceptual model comprised an unconfined heterogeneous sand and gravel aquifer with spatially variable rainfall recharge and upward leakage through the underlying aquitard, the (clay-bound) Moutere Gravel. A computational MODFLOW two-dimensional finite difference groundwater flow model was also developed based on the conceptual model (for details see Appendix 8 of the Woodward-Clyde report).

The principal features of the model are:

- a groundwater divide obliquely crossing the FCC West Area from northwest to southeast
- groundwater flow, modelled at 120 m^3/day, entering the Mapua site from the northwest
- net average rainfall recharge of 20 m^3/day
- net upward leakage of 1 m^3/day.
- groundwater flow, modelled at 40 m^3/day, west from the divide across the Landfill Area toward the drainage ditch on the western boundary, which discharges into the Waimea Inlet
- a hydraulic gradient east to southeast from the divide across the FCC East Area into the Mapua Channel
- a hydraulic gradient south to southeast from FCC West toward residential properties along Tahi Street

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[2] Mapua site remediation: assessment of environmental effects, Woodward-Clyde (NZ) Ltd for Tasman District Council, October 1996.

The model estimates that groundwater flows to the east and south total 101 m^3/day.

Although not explicitly shown, poorly permeable clay bunds and fill material were present along both coastal frontages. This should have led to some pooling behind the bund walls and consequent flow around each end of each bund. However, some groundwater may instead be discharged underneath the bunds, as some seeps had been observed on the Waimea Inlet foreshore (refer Appendix I of the AEE). Conversely, the drainage ditch forming the northern boundary of the Landfill Area appears to provide a preferential flow pathway for groundwater, lowering the water table in that area. Tidal influences were expected to be limited to within 35 m of the boundary.

Actual hydraulic gradients will have been further complicated by site drainage, which is likely to have affected groundwater flow through discharges to ground and the formation of preferential pathways, especially when the FCC plant was operating. The Ministry for the Environment (MfE) monthly report for July 2007 observes that:

> "SG26 contains a large 'soak hole' which was a result of the solutions mixing building being in this area. Over the course of the project there have been considerable piping, sumps, wells and foundations removed from the site. The East was riddled with a complex system of piping which drained wastes out to the estuary or into groundwater. The West has been equally criss-crossed with a complex labyrinth of pipes and conduits which drained wastes to the sea from the established landfill or into groundwater. Results have indicated that wherever these wells, sumps or piping occurred high levels of contamination were also found."

The drainage 'system' would have included the "Lake Tas" waste disposal area in the middle of FCC East, which had been infilled by the time this model was developed, and TDC services running down Tahi Street. The latter are still present.

The AEE and Remedial Action Plans

Appendix I of the AEE presents an updated groundwater conceptual model based on the same static water level data as used by Woodward-Clyde in 1996.

The AEE cites (but does not appear to provide a reference for) repeated slug tests carried out by Soils & Foundations in 1997, which indicated that the shallow aquifer was likely to have substantially lower permeability than inferred by Woodward-Clyde (k in the range 2×10^{-6} to 8×10^{-5} m/s instead of 2×10^{-4} to 4×10^{-4}). Lower permeability means less inflow to the Mapua site from the northwest, so the AEE expected that the main source of groundwater would be rainfall infiltration. Lower permeability would also mean less discharge of groundwater and any entrained contaminants.

The AEE then used a Domenico 3-dimensional analytical solute transport model, and 95 percent confidence upper bounds to mean previously determined concentrations of contaminants, to predict concentrations of organochlorine pesticides and heavy metals during remedial works in:

- water at the 13 Tahi St bore, 20 m south of the site boundary, due to groundwater discharges from FCC East
- water in the Mapua Channel, 10 m from the site boundary, using a 100-fold dilution factor, due to groundwater discharges from FCC East
- water in the Waimea Inlet, 10 m from the site boundary, using a five-fold dilution factor, due to groundwater discharges from FCC Landfill.

Human exposure to contaminants in surface water, through ingestion of fish and dermal exposure to water while swimming, were also modelled.

The AEE concluded that:

- concentrations of all modelled contaminants at 13 Tahi St would probably exceed New Zealand drinking water standards (MoH, 2000) but not guidelines for irrigation (where provided by ANZECC, 2000[3])
- concentrations of all contaminants in both Mapua Channel and Waimea Inlet waters adjacent to the site would probably exceed ANZECC (2000) guidelines for the protection of marine ecosystems
- daily intakes of all contaminants through surface water exposure pathways were likely to be well below relevant health criteria.

The predicted DDX concentration at 13 Tahi St was 0.22 mg/L during remediation, approximately 100 times the drinking water MAV of 0.002 mg/L [note that actual concentrations were much lower, see later]. However, the AEE included two surveys of water use in houses along Tahi St, which found that no residents used water for potable purposes. It did find that up to 12 properties used well water for garden watering (nos. 13, 17, 21, 23A, 23B, 29, 30, 36, 37, 39, 39A, 40) but suitability of groundwater for irrigation with respect to DDX was not assessed, because ANZECC (2000) does not provide guideline values for pesticides in irrigation water. The site auditor did not propose any criteria for the purpose, although site-specific criteria for assessing risks posed by DDX through other pathways had been derived. It appears that, because there were no criteria and hence no exceedances, the AEE implicitly did not consider DDX in irrigation water to be a significant risk to nearby users.

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[3] Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australia and New Zealand Environment Conservation Council, June 2000

Because the soil source of DDX and ADL was to be treated by remedial works, any continuing discharge after remediation was expected to be temporary, so the proposed mitigation measures were to:

- maintain the low permeability clay cutoff wall on the eastern boundary
- implement a 35 m buffer zone on land (i.e. the limit of tidal influence) along each seaward boundary, in which soil had to meet the site-specific acceptance criteria for residential use
- monitor selected wells on the site boundaries
- pump groundwater out of affected areas and discharge into unprocessed soils, if the cutoff wall caused groundwater levels to rise during works to the point that contaminated soils currently above the groundwater table were inundated and concentrations of contaminants in groundwater increased.

These proposed measures are repeated in section 8 of the original Thiess Remedial Action Plan. They do not include any measures relating to groundwater users, other than monitoring. Also, presumably because the AEE model posits rainfall infiltration as the principal source of groundwater, the proposed mitigation measures do not include any diversion of clean groundwater entering the site from the northwest.

Groundwater investigation of May 2007

MfE commissioned CH2M Hill to prepare a report[4] on groundwater conditions following remediation. This included measurement of static water levels in 12 onsite monitoring wells on 22 May 2007, and five wells on properties to the south on 24 May 2007. Because groundwater levels were higher in the residential bores than on the southern boundary of the site, CH2M Hill concluded that there was no significant groundwater flow off site to the south, and so:

> "Groundwater impacts to residential properties… [are] expected to be largely confined to those nearest to the Site… there may be another source of nitrate… in the vicinity of No. 26 Tahi Street".

However it appears (section 7.2.1 of the CH2M Hill report) that there was a "significant" rainfall event at Mapua on 23 May 2007. It is possible that this elevated the groundwater table in the residential bores the following day. Their conclusion in regard to groundwater discharge to the south is therefore open to question.

The CH2M Hill report further concludes in the executive summary that:

> "Gross estimates of contaminant fluxes in groundwater discharges indicate that… discharges are likely contributing to the re-contamination of sediments…"

[4] Groundwater and sediment investigation report, former Fruitgrowers Chemical Company site, Mapua, reference 358982.01.07, CH2M Hill Australia Pty Ltd for Ministry for the Environment, August 2007

This conclusion is inconsistent with the detailed discussion within the report (sections 7.2.1, 7.7), where it is made clear that estimates of contaminant discharges to sediments via groundwater rely on upper values of hydraulic parameters for undisturbed site soils collected prior to works, single measurements of contaminant concentration, and no consideration of the effects of bund walls on groundwater flows. Additionally it does not appear that any allowance was made for attenuation of contaminants during transport in groundwater, as was done in the AEE. The conclusion should have followed the text in section 8.4.1:

> "Groundwater discharges are also considered to be a potential source of sediment contamination; however this impact is difficult to quantify with the limited investigation conducted…"

Groundwater issues report, December 2007

Tasman District Council subsequently commissioned Pattle Delamore Partners Ltd (PDP) to produce a further groundwater report[5] using a further survey of water levels on 30 November 2007. This report was written by the Peer Review Panel's groundwater expert, Peter Callender.

The conceptual model presented in PDP (2007) is similar to that of Woodward-Clyde and the AEE. It draws attention to the locations where the greatest masses of residual contaminants are present following remedial works (refer Soil Technical Annex):

- MCD-treated fine soils containing residual DDX and nitrogen compounds, backfilled into the Landfill area
- MCD-treated fine soils containing residual DDX and nitrogen compounds, backfilled into the FCC East area
- untreated soils thought to contain DDX at concentrations meeting commercial criteria, either remaining or backfilled into the FCC East area.

It provides a detailed discussion on the extent to which these soils are inundated by groundwater, and concludes that leachate potentially containing elevated concentrations of contaminants can migrate:

- from the Landfill Area to the Waimea Inlet
- from the FCC East Area to the Mapua Channel
- from the FCC East Area to residential properties close to the site on the east site of Tahi St (nos. 13, 15 and 17).

But while groundwater is also shown to migrate south down Tahi St from the southern boundary of FCC West, the groundwater issues report does not consider this to pose a

[5] Report on Groundwater Issues Arising at the Mapua FCC Site, at Completion of the MCD Soil Remediation Process, Pattle Delamore Partners Ltd for Tasman District Council, December 2007.

long-term hazard because residual contamination on the FCC West Area should be much lower after remediation.

The groundwater issues report acknowledges that "the hydraulic conductivity of the site materials is not well defined" and does not attempt to estimate groundwater flows. To improve the conceptual model in this respect, it recommends more monitoring wells be installed within and upgradient of treated fines and Commercial category soils, and quarterly monitoring of all wells.

In this regard, we note from groundwater monitoring reports by ChemSearch, University of Otago, for MfE, that recharge of site monitoring wells BH1 (on the eastern boundary) and BH4 (adjacent to the drainage ditch) is very slow, indicating that soils at screened depth in those wells have much lower permeability than in wells elsewhere on the site.

Technical points

- The site auditor should consider if there is any significant risk in using groundwater for domestic irrigation at residential properties on Tahi St (or on the Mapua site in future use).

- The conclusions of the CH2M Hill report in respect of groundwater flows should be rejected.

- Monitoring wells should be installed at and around the Mapua site, and regularly monitored, as advised in the groundwater issues report. This should particularly look to identify discharge pathways from site.

- Testing should also be carried out at several locations to better determine hydraulic parameters for site soils.

- An updated groundwater conceptual model, including a water balance accounting for all principal flows into and out of the Mapua site, should be produced when sufficient information is available. This model should be updated as part of any significant changes to the groundwater regime, for example if a substantial area of the site is sealed or if new bunds or trenches are installed.

Groundwater quality

Site threshold concentrations

Environmental threshold concentrations for discharges to groundwater were set under condition 28 of consent RM030524 for the remedial works. These are stated in the AEE and the conditions of consent to be the lower of:

- the New Zealand Drinking Water Standard (2000) Maximum Acceptable Value (NZDWS MAV); and
- 100 × the ANZECC (2000) freshwater aquatic ecosystem trigger values protective of 99% of species, where the factor of 100 is an allowance for dilution into surface waters of the Mapua Channel, as per the conceptual model (see above).

However this derivation protocol was not followed for copper. The site threshold concentration is 0.13 mg/L, which is 100 × the ANZECC (2000) criterion of 1.3 μg/L for protection of 95 percent of species in marine ecosystems (i.e. suitable for slightly to moderately disturbed systems; lower than the NZDWS appearance, taste and odour criterion of 2 mg/L). This also seems to have happened with mercury. The use of marine criteria does not appear unreasonable for the estuarine environment around Mapua, but should certainly have been accurately described in the AEE.

The dilution factor for the Mapua Channel was used because the most significant discharge is assumed to be from the commercial category soils on the FCC East Area, where contaminant concentrations would be expected to be higher. But, according to the conceptual model, some monitoring wells (BH3, BH4, BH5, BH9, 26 and 36 Tahi St) are on the western side of the groundwater divide, on which groundwater will discharge to the Waimea Estuary. The dilution factor suggested by the AEE for the western side is only five-fold not 100-fold, which would imply that the threshold concentration in these wells should be 20 × lower. There is precedent for this in consent conditions relating to stormwater, for example RM030524:35, where western discharges have lower targets than eastern discharges.

Before remedial works

Groundwater sampling and analysis from 32 monitoring wells around the Mapua site by Woodward-Clyde (1994)[6] found that cadmium, copper, mercury, iron, lead, selenium, zinc, DDX, ADL and chlorobenzene exceeded selected environmental guideline values at one or more locations.[7] Of these, the following would have exceeded the environmental threshold concentrations had they been set at the time:

- mercury, at two locations in the FCC West area, maximum 1 μg/L compared with a threshold of 0.04 μg/L

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[6] Soil and groundwater investigation, Mapua, Woodward-Clyde (NZ) Ltd for Bell Gully Buddle Weir, April 1994.

[7] ANZECC (1992) guidelines for the protection of aquatic ecosystems, now superseded.

- DDT and/or DDE at all locations except downgradient of the bund around the Landfill, maxima 1.5 µg/L and 0.2 µg/L respectively

- Dieldrin, at three locations, maximum 4.0 µg/L

- Lindane, at one location in FCC West and one in FCC East, maximum 5.2 µg/L.

The condition does not specify threshold concentrations for cadmium, iron, lead or chlorobenzene.

Monitoring wells were later installed in the following locations (see Figure 3-2 in the Woodward-Clyde report (1996)):

- at BH1 and BH2 in the east of the FCC East Area

- in the Landfill Area at BH3 and BH4 next to the stormwater drain on the western boundary, and BH5 on the Waimea Inlet foreshore (inside the clay bund)

- at BH9 in the south of the FCC West Area.

Baseline groundwater sampling[8] of these montoring wells and four residential wells, for a comprehensive suite of analytes, found the following exceedances of consent criteria for groundwater:

- at BH5, dieldrin, DDT, DDD and DDE. (The organonitrogen pesticide diazinon also exceeded a criterion used in the report.)

- at BH2, DDT (not highlighted in the report because an incorrect criterion is given, 0.4 µg/L instead of 0.04)

- at the bore at 13 Tahi St, zinc (cadmium and lead were also elevated but there were no criteria for comparison).

Mercury was not detected in any sample (detection limit 0.08 µg/L). Only traces of dieldrin (0.028 µg/L at 13 Tahi St) and DDE (13, 26 and 36 Tahi St, maximum 0.01 µg/L) were detected in offsite wells.

In sum, before remedial works started, groundwater quality was marginally unacceptable on site, with DDX and ADL often exceeding threshold concentrations, and two mercury exceedances were also noted. Water quality in residential wells met all threshold concentrations, except for zinc at 13 Tahi St.

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[8] Report on baseline soil and groundwater sampling, Mapua, Nelson, Tonkin & Taylor Ltd for the Ministry for the Environment, draft dated March 2005.

Monitoring associated with works

Conditions 23 through 27 of consent RM030524 provide for groundwater samples to be collected monthly at the six site monitoring wells, and quarterly at 13, 17A, 26 and 36 Tahi St, and analysed (at a minimum) for:

- organochlorine pesticides (filtered sample)
- metals suite (filtered sample)
- acidic herbicides (filtered sample)
- electrical conductivity, pH, alkalinity
- static groundwater level.

According to data for the period up to September 2007, this sampling was carried out beginning at a 'baseline' in October 2004, although works had already begun by this stage. In practice, organochlorine pesticides were analysed in centrifuged samples (site monitoring wells) or decanted samples (residential bores). This is conservative, because centrifuged samples may still contain very fine particles and entrained pesticide, so would be expected to give higher results than filtered samples; decanted samples should also contain some larger particles and give higher results again.

From June 2005, on the site auditor's advice, the sampling protocol called for:

- monthly sampling for
  - organochlorine pesticides including DDX and ADL, on a centrifuged sample in all cases
  - electrical conductivity, pH, total alkalinity
  - static groundwater level
- quarterly sampling for
  - total Kjeldahl nitrogen and nitrate. From October 2005, ammoniacal nitrogen was added, and the sampling frequency in the six site monitoring wells was increased to monthly.
  - phosphorus
  - copper (in practice analysed more frequently)
  - carbaryl
- annual sampling for
  - volatile organic compounds
  - acidic herbicides, organonitrogen and organophosphorus pesticides

– boron, chromium, lead, mercury, selenium and zinc (all also analysed in the November 2005 round) in 0.45 μm field filtered samples.

Conditions 25 and 27 of consent RM030524 were amended to match this proposed protocol. Based on data received, it appears that this protocol was generally adhered to.

TDC has stated that it has conducted further quarterly groundwater sampling rounds, however no groundwater data have been supplied to PCE following the close of works in July 2007.

For the principal contaminants of concern, there were multiple exceedances of consent threshold concentrations:

- **DDT** was generally well above threshold at the more southerly onsite monitoring wells, BH2, BH5 and BH9, throughout the works (see Figure 1). Results for BH1, BH3 and BH4 were generally around or about the threshold concentration. DDT was generally below threshold at residential wells, but as of July 2007 had exceeded twice at 26 Tahi St. The trends for **DDE** were similar. The concentrations of 0.22 mg/L DDX predicted in the AEE for 13 Tahi St have not eventuated.

- The highest concentrations of **DDD**, at BH1 and BH5, generally exceeded threshold concentrations. There was very little detectable DDD in residential wells.

- **Lindane** in BH5 has been above the 0.0007 mg/L threshold since June 2005, peaking in December 2005 at 0.0568 mg/L (see Figure 3). In BH9 it exceeded the threshold between February and December 2006, and in BH2 it exceeded the threshold between January and July 2007.

- **Dieldrin** was well above threshold concentration at BH5 in August and October 2005, but close to or below threshold at all other wells and times.

However, it is not clear whether threshold concentrations for pesticides would have been met if samples had been filtered, as discussed above.

Conversely, if the threshold concentrations for wells to the west of the groundwater divide were lowered by a factor of 20 to allow for the lower dilution factor on discharge to the Waimea Estuary, almost all samples from all those wells, especially BH5 and BH9, would exceed criteria for some of DDX and ADL.

Figures 1 and 3 show a distinct increase in DDT and lindane results from June 2005 onwards. This coincides with the change in sampling protocol, but monitoring reports from the sampling contractor, ChemSearch, show that samples for pesticide analysis were centrifuged both before and after June 2005. The CH2M Hill (2007) report states that their pesticide samples were decanted, which may account for the high DDT concentrations seen during their investigation, particularly in BH5. (The site auditor had recommended that CH2M Hill filter samples for pesticide analysis.)

Figure 1: DDT concentrations in site monitoring wells

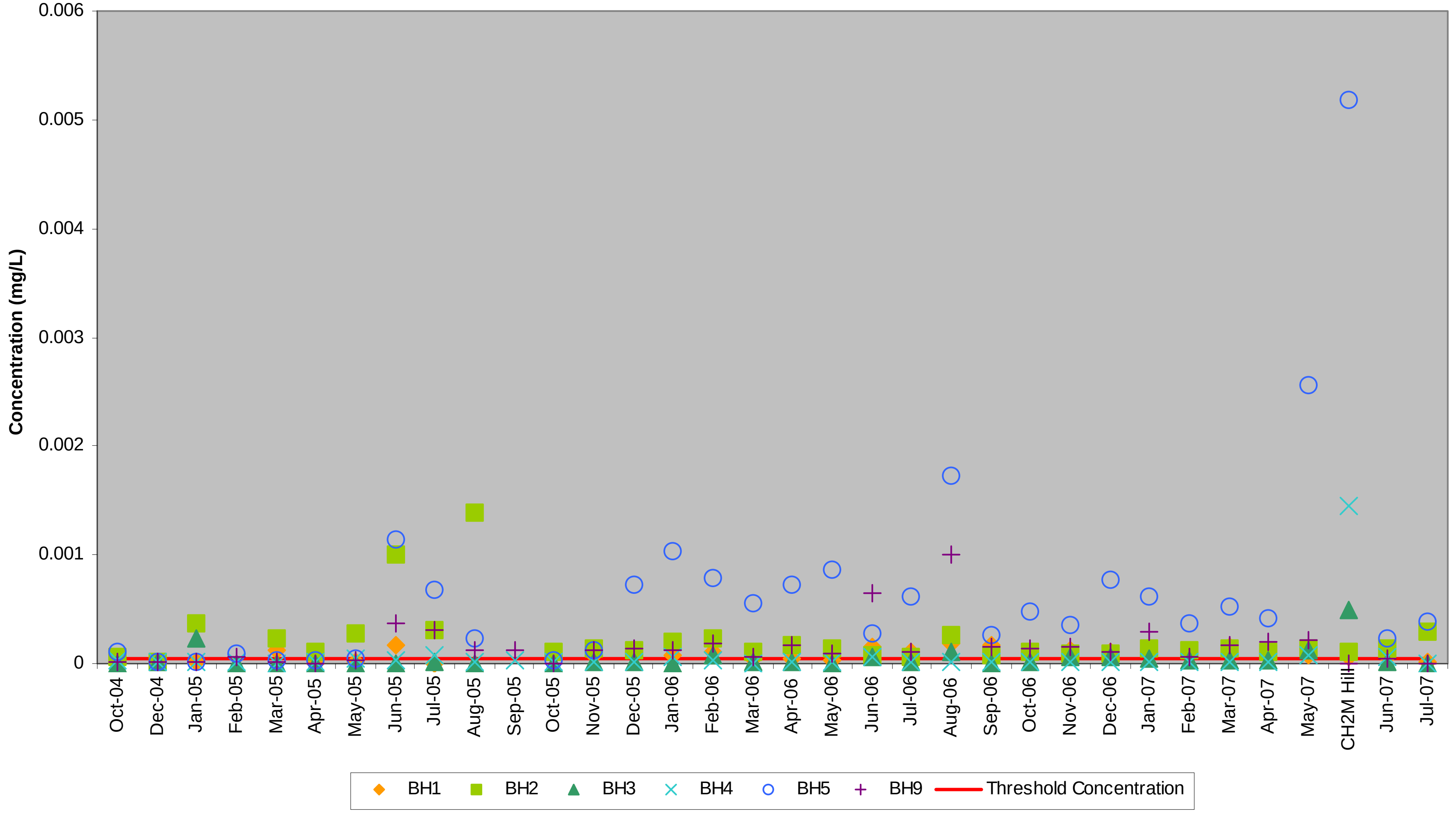


Figure 2: DDT concentrations in residential bores

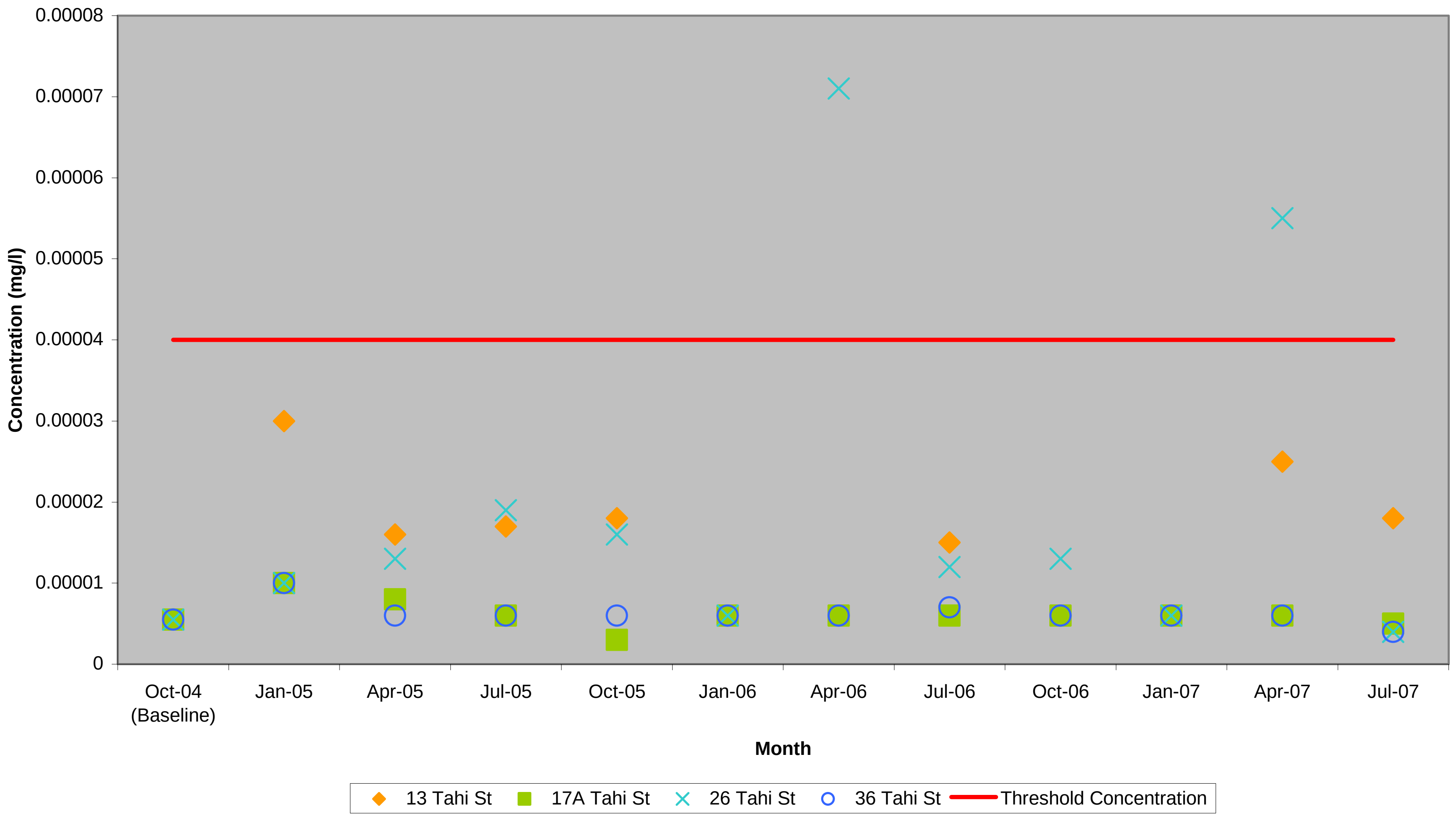
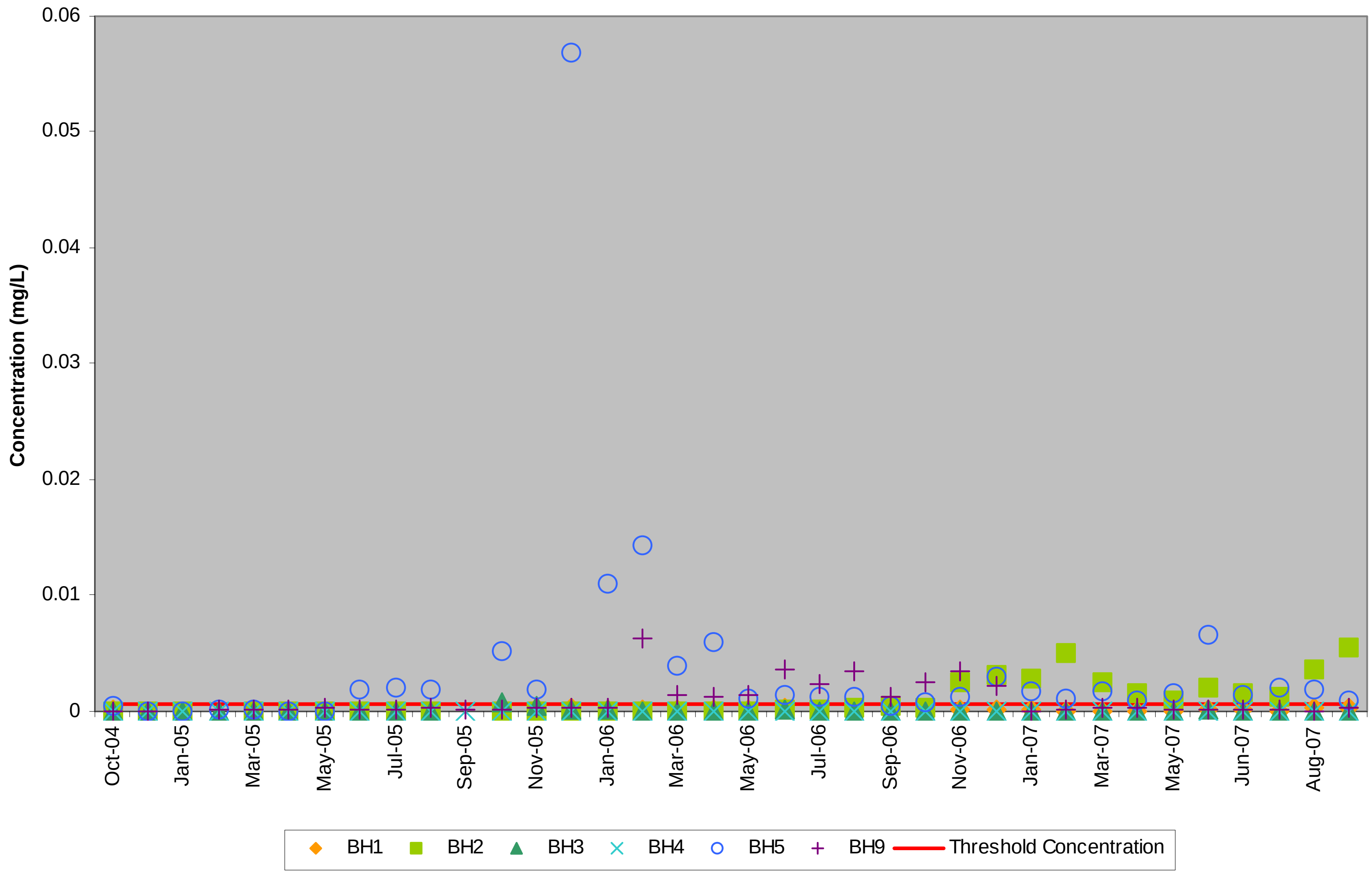


Figure 3: Lindane concentrations in site monitoring wells



Nutrients were not initially contaminants of concern. However, the nitrogen compounds diammonium phosphate (DAP) and urea were used as MCD process additives (refer discussion on copper sulphate use in the Soil Technical Annex). Data supplied by MfE show that DAP was added at up to 5.2% by dry weight of soil, to a total of more than 600 tonnes, and urea at up to 0.3%. It appears that ammoniacal nitrogen (NH_4-N) and its oxidation product, nitrate, were added to the analytical suite suggested by the site auditor in mid-2005 when the extent of nitrogen addition became evident. NZDWS of 11.3 mg/L for nitrogen as nitrate (NO_3-N), and 0.1 mg/L for NH_4-N have been informally used as threshold criteria on the site auditor's advice.

Figures 4 and 5 show that nitrate concentrations at the southern site monitoring wells BH2, BH5 and BH9, and the residential bore at 26 Tahi St, have generally been well above the threshold concentration. From early 2007, nitrate began to exceed criteria at BH1, BH3 and BH4, and then at 13 Tahi St as well.

Figures 6 and 7 show that ammonia concentrations at site monitoring wells BH2 and BH5, and to a lesser extent BH1 and BH9, have been greatly elevated, up to four orders of magnitude greater than the site threshold concentration. Concentrations at residential wells have been generally similar to or below the criterion.

The distribution of elevated nutrients is not quite as expected in the AEE or the PDP (2007) groundwater issues report. It was expected that nutrients would be detected principally in monitoring wells BH1 and BH2 on the FCC East area where the majority of nutrient-containing treated fines were deposited (refer the Soil Technical Annex). Figures 4 and 6 show that nitrate and NH_4-N are indeed elevated at BH1 and BH2, and also at BH4 and BH5 in the Landfill Area where some treated fines were placed. But nitrate is elevated at BH9 on the southern boundary of the FCC West Area, and further south of FCC West at 26 Tahi St, which cannot be explained by reference to backfilled treated fines.

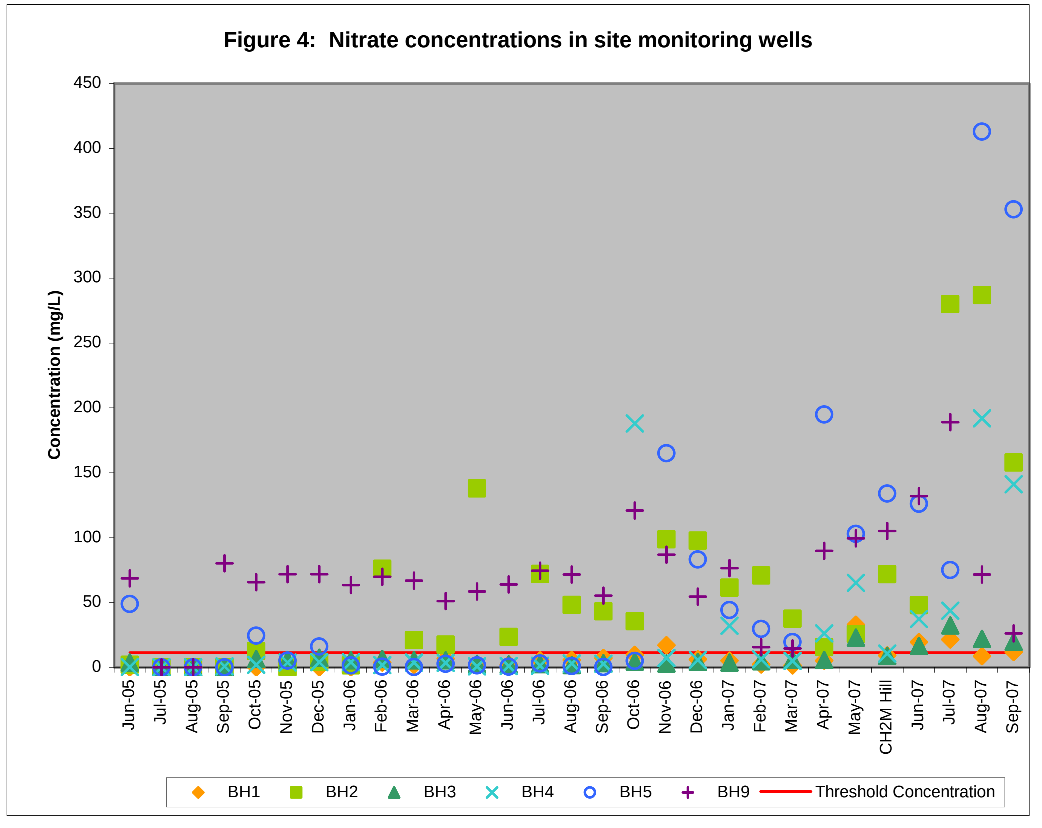


Figure 4: Nitrate concentrations in site monitoring wells
Concentration (mg/L)
BH1
BH2
BH3
BH4
BH5
BH9
Threshold Concentration

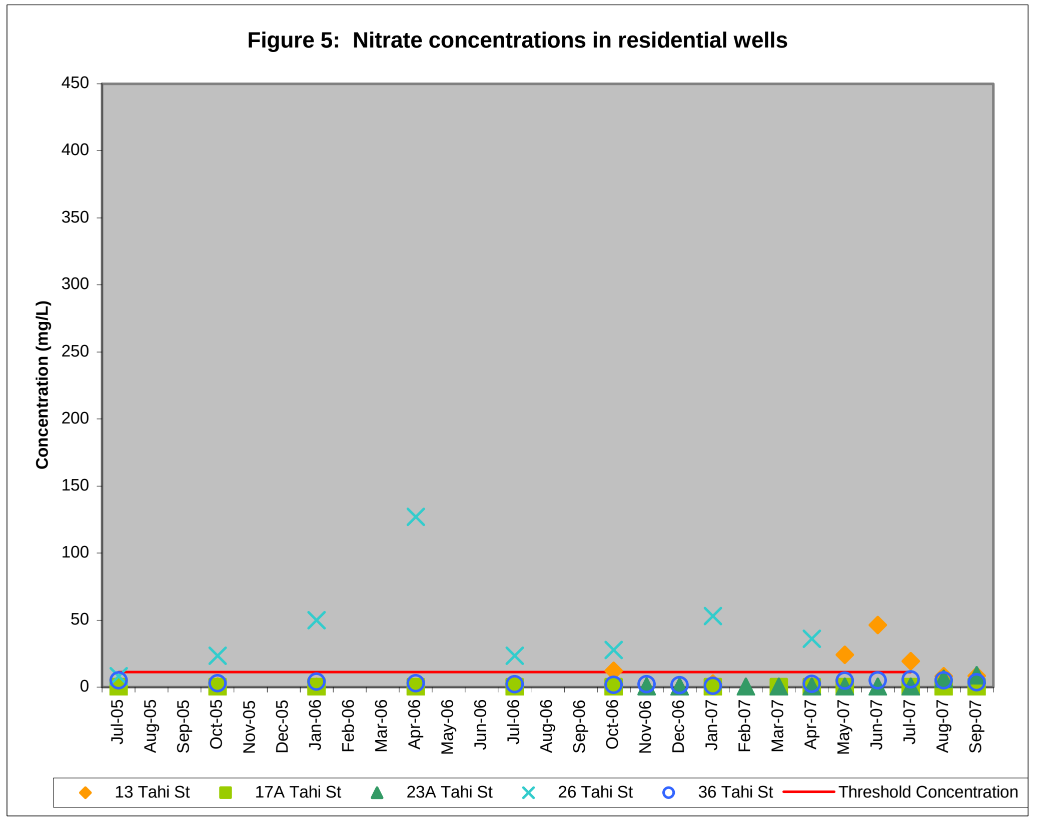


Figure 5: Nitrate concentrations in residential wells
Concentration (mg/L)
13 Tahi St
17A Tahi St
23A Tahi St
26 Tahi St
36 Tahi St
Threshold Concentration

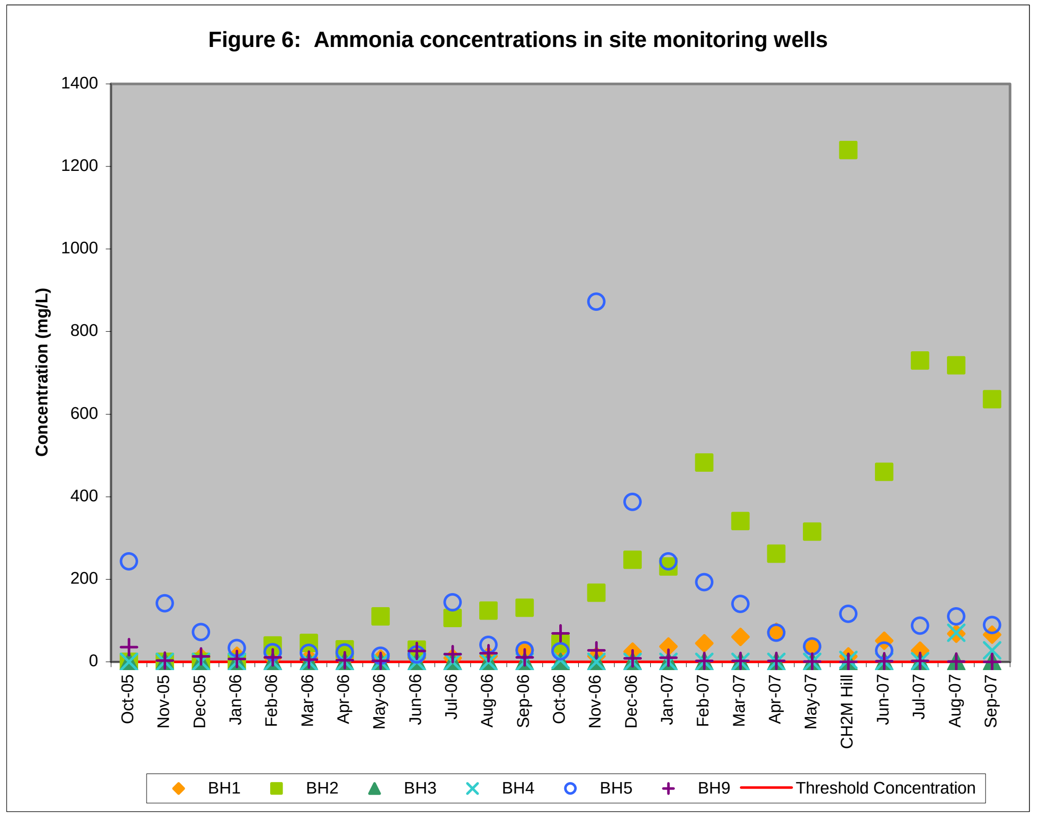


Figure 6: Ammonia concentrations in site monitoring wells
Concentration (mg/L)
BH1
BH2
BH3
BH4
BH5
BH9
Threshold Concentration

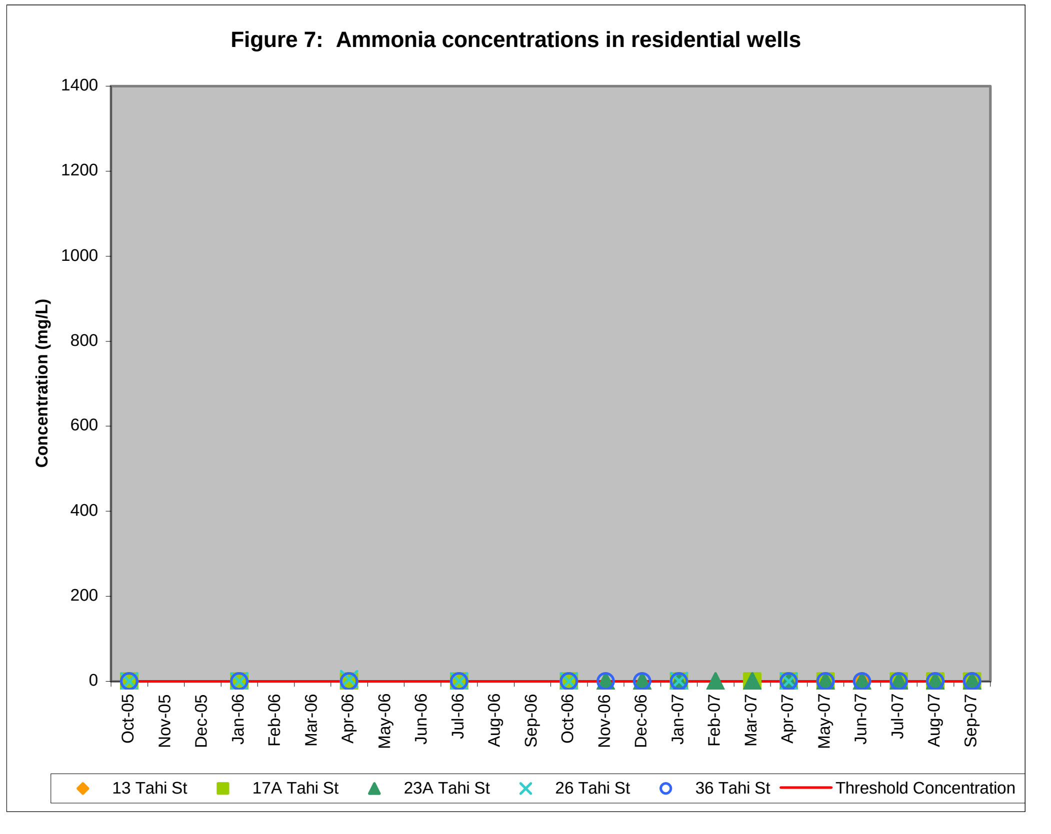


Figure 7: Ammonia concentrations in residential wells
Concentration (mg/L)
13 Tahi St
17A Tahi St
23A Tahi St
26 Tahi St
36 Tahi St
Threshold Concentration

Neither CH2M Hill (2007) nor PDP (2007) comment on metal concentrations in groundwater.

Groundwater sampling results indicate that boron, chromium, lead, and zinc have not exceeded New Zealand Drinking Water Standards or site threshold concentrations, either on- or off-site.

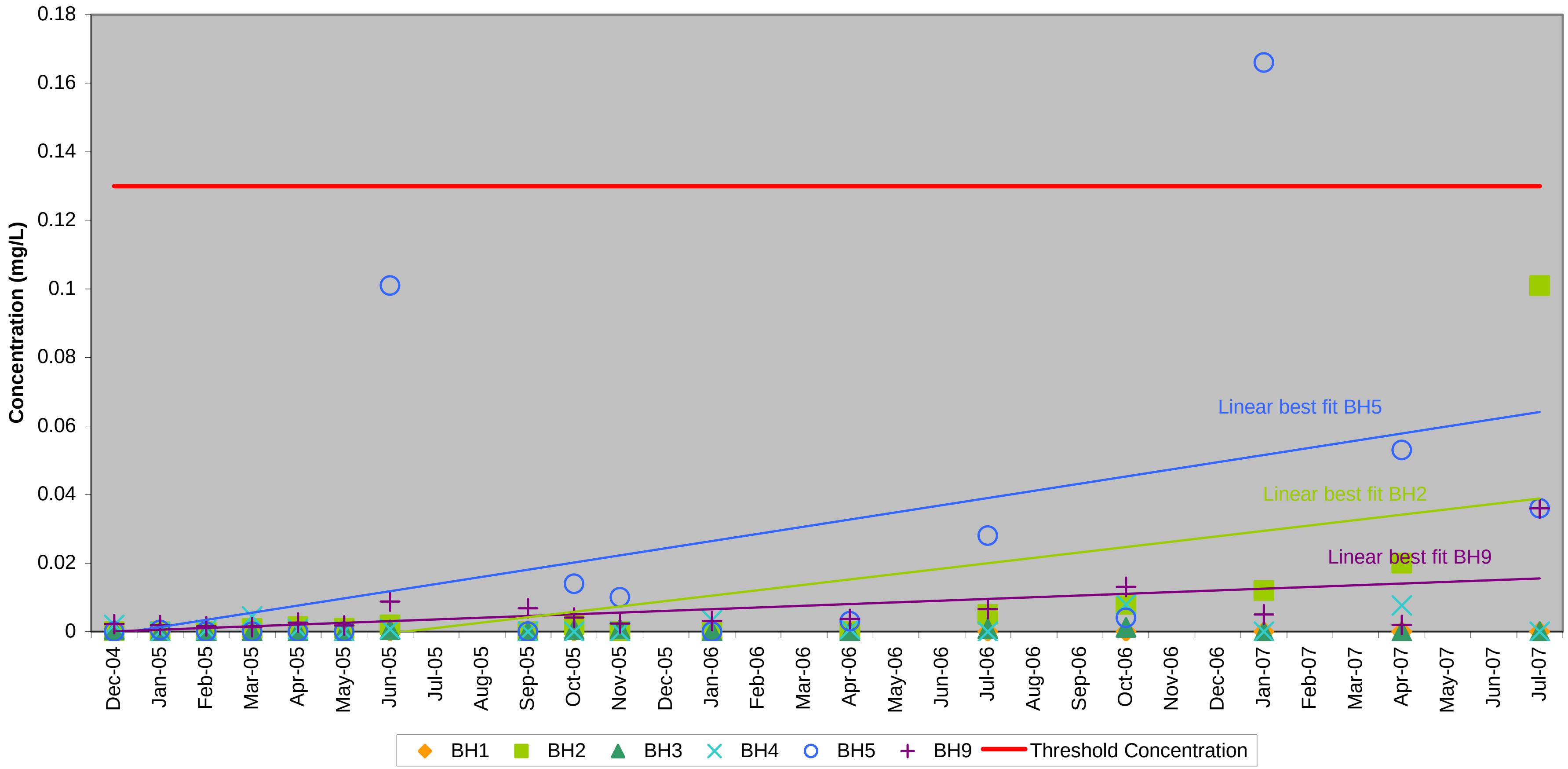
Copper, which appears to have been used extensively as an MCD process additive during works was initially only present at trace levels, with a maximum concentration in December 2004 of 0.0022 mg/L at BH9. However, as shown in Figure 8, copper concentrations in groundwater have increased erratically in BH2, BH5 and BH9 throughout the works. To date, just one result (0.166 mg/L in BH5 at the foreshore of the Landfill area in January 2007) exceeds the site threshold concentration of 0.13 mg/L set in the consent, however the apparent increasing trend suggests that further elevated results can be expected. Had the threshold concentration been derived using freshwater ecosystem trigger values (see above), it would have been 0.10 mg/L, which would have been marginally exceeded by two further elevated results, in BH5 in July 2005 and in BH2 in July 2007. If the threshold concentration for wells to the west of the groundwater divide was further adjusted for a 20-fold smaller dilution factor to the Waimea Estuary, to 5 µg/L, the majority of copper results from BH5, BH9 and 36 Tahi St would then be exceedances.

Mercury and selenium do not generally appear to have been detected. The detection limit employed for mercury, however, was greater than the site threshold concentration. The MfE monthly report for July 2005 comments: “Mercury was detected in BH 3 and 4 for the first time at levels above the drinking water standard. There is no apparent reason for this change and the area will be closely monitored during the next round of testing.” A similar comment is found in the Peer Review Panel meeting minutes of August 2005. The next analysis for mercury was in January 2006 and there does not appear to be any subsequent mention of mercury detection.

Note that groundwater samples were never analysed for arsenic or cadmium during works, and threshold criteria were not set for these contaminants in the resource consent. This is of concern, as arsenic was believed to have been stored on site, and cadmium was listed in Appendix I of the AEE as a contaminant of concern in groundwater. Stormwater discharge targets were set for both these metals.

Traces of numerous compounds other than DDX and ADL were detected in on- and off-site monitoring wells in the January 2007 sampling rounds. The triazine herbicides atrazine and simazine in BH5 and BH9 exceeded drinking water standards.

Figure 8: Copper concentrations in site monitoring wells



In summary, groundwater results have not met criteria set out in the resource consent throughout the remedial works. At monitoring wells BH5 and BH9, on the site's down-gradient boundaries with the Waimea Estuary and with adjacent residential properties, multiple contaminants exceed criteria, especially if threshold concentrations were adjusted to allow for a lower dilution factor into the Waimea Estuary. Some contaminants, particularly nitrate and on occasion DDT, are also elevated above threshold in nearby residential wells (13 and 26 Tahi St).

Concentrations of most contaminants of concern, including DDX, ADL and copper, appear to have increased from the October 2004 benchmark. Before the remedial works began, no samples were analysed for nitrate or ammonia, but high concentrations of both since late 2005 suggest that the extensive addition of DAP to Mapua site soils during remedial works may have impacted the groundwater.

Note that, although concentrations of contaminants at monitoring wells BH1 and BH4 rarely exceed thresholds, hydraulic testing results indicate that these boreholes appear to have been installed in fine grained soils with comparatively low permeability. Since low permeability and low concentration indicate low fluxes of contaminants at these locations, contaminant discharge from the Mapua site must be better represented by the comparatively high concentrations for BH2, BH5 and BH9 where permeability is also comparatively high.

There have been several explanations for groundwater contamination:

- The groundwater issues report hypothesises that stockpiling of MCD-treated fines on the southern boundary of the FCC West Area in early 2005, and consequent leaching, was the source.

- The TDC Compliance Officer's report for November 2005 Compliance officer report November 2005 states that:

  "The soak hole from EDLs pad is discharging contaminants into the groundwater, from the TFs, CMT spills and stack water scrubber discharge. The water in the hole has very high OCPs and BH9 has DDT at 10 × the threshold values in 524/28 since June to September. The September report, which is the last report received, includes analysis of the soak hole water." (The soak hole was replaced by a plastic-lined impoundment pond on 6 December 2005.)

- The site management meeting minutes for November 2005 include the response "The contamination could be due to a lot of contributing factors. For example the PoP stockpile, contaminated concrete, drum dump site…".

- From the same source, "…also a soil test next to [BH9] shows high contamination." The Peer Review Panel report for May 2006 refers to a "DG Shed sump" near BH9 as a possible source of contaminant in that area. The site management meeting minutes for September 2006 report that "a large solid waste pit of pesticides was also uncovered in the area of [BH9]".

- The compliance report for February 2006 advises that "The landfill rubbish is mostly going to be screened dry, but some washing is required and [the earthworks contractors] intend to discharge the settled water into the ground. This raises the question as to what the quality and quantity of wash water can be discharged into the ground and not significantly elevate the contaminants".

- The compliance report for November 2006 reports surface water entering BH3, BH5 and BH9; "it is very unlikely that water quality in BH9 represents the groundwater leaving the site".

- TDC has suggested that French drains under the road, that were removed late in the works, transported water affected by leaching from treated soils from the east to the west. This is consistent with the observed elevated concentrations at BH9, but not consistent with any of the groundwater models, all of which have the hydraulic gradient opposing such transport.

Any or all of these explanations for elevated concentrations of contaminants appear reasonable, but do not entirely explain why concentrations have consistently remained high, even after the sources have been removed.

If the analytical results for BH9 (and / or BH3 and BH5) actually represent surface runoff entering the well, as suggested by the November 2006 compliance report, then they may be representative of stormwater rather than representative of groundwater. These wells are close to site boundaries, so surface runoff quality at the wells is likely to be similar to that of any surface runoff being discharged from the site. Condition 35 of consent RM030524, and identical sections in consents RM030526 and RM030527, set preliminary stormwater discharge targets for DDX, ADL and metals to the west of the Mapua site. These targets incorporate a dilution factor of 5 for the Waimea Inlet and are the same as the adjusted groundwater threshold concentrations proposed above. For DDX, ADL and copper, these targets are exceeded (at least for DDT) in the majority of the samples from BH3, BH5, and BH9. So even if these samples do not represent groundwater, they may indicate potential consent compliance issues in relation to stormwater.

Actions taken

Consent requirements

Condition 29 of resource consent RM030524 specifies that:

> "In the event that contaminant concentrations in any groundwater sample…exceed the relevant threshold concentration, after confirmation by re-testing, a round of sampling of upgradient groundwater will be undertaken by the Consent Holder to determine the source of the contamination. The Consent Holder, in consultation with the Council Compliance Co-ordinator, shall implement interim corrective measures while the source of the contamination is determined and develop an appropriate long-term corrective response."

Condition 31 of the same consent adds:

> "…where remedial activities potentially alter the flow and quality [of groundwater]… the activities must be undertaken, or modified, in a manner that minimises the spreading of contaminated groundwater".

More generally, conditions in several consents (RM030524:30, RM030525:28, RM030527:25) provide that "the Consent Holder shall take all practical steps to limit the discharge and migration of contaminants in groundwater". And condition 24 of consent RM030527 goes further: "The best practicable option shall be adopted to ensure that activities are carried out in a manner that minimises any deviation of natural groundwater flow or deterioration in groundwater quality".

As shown in the previous section, in April 2005 consecutive results were available from BH2 showing DDT exceeding its threshold concentration. By July 2005 there were DDT exceedances at BH5 (also for lindane) and BH9. By the end of the year, it was clear that nitrogen compounds were exceeding threshold concentrations in groundwater. In all, contaminant concentrations have exceeded thresholds for around three years and more than thirty rounds of sampling. In the case of copper, the evidence even suggests that downgradient concentrations are steadily increasing, though rather erratically. In all that time, just one sample has been collected upgradient of an impacted monitoring well – from BHH in the FCC East area by CH2M Hill (2007). No effective corrective measures have been implemented.

TDC compliance reports first raise concerns in November 2005 in relation to discharging water into the soakhole by the EDL pad as "contrary to consent conditions". It requested by letter 17 November that all practical steps were taken to limit this discharge, and the soakhole was replaced 6 December.

In May 2006 the TDC compliance report commented that the site manager "is altering site practices to try and minimise the amount of time [contaminated soil] is exposed and able to leach contaminants into the groundwater, both on the East and West". If this was the case, it was a sensible action, but subsequent groundwater monitoring does not indicate that it had any significant success in reducing contaminant concentrations.

The site auditor raised concerns about groundwater monitoring by letter on 22 May 2006, making specific recommendations for soil, groundwater and estuary water quality monitoring. Groundwater quality was then discussed at the May 2006 Peer Review Panel meeting, and further recommendations were made, including further monitoring offsite, and that groundwater south of the site should not be used for drinking.

TDC wrote to MfE on 15 June 2006 to formally request additional groundwater monitoring according to the recommendations, referring to the resource consent conditions, and again to clarify on 8 August 2006. A further letter from TDC to MfE dated 23 March 2007 stated that no reply had been received to the 8 August letter and to reiterate its concerns, especially as groundwater concentrations of contaminants had not decreased in the interim. (MfE contests, by letter 9 July 2008, that it was informing TDC of progress via email.) TDC was not able to identify a remedy and advised "we consider it imperative that you commission consultants to better characterise the issue". CH2M Hill was promptly commissioned to produce its groundwater and sediment report of August 2007; but this report did not include any upgradient wells, and (as discussed above) did not advance the characterisation of groundwater issues.

It does not appear from the letter of 23 March 2007 that "a long-term corrective response" had been developed at the time, as required by the consent conditions, and we have found no evidence that one has been established since.

The AEE (sections 8 and 9) provided that, in the event that the groundwater mounded during works, such that groundwater came in contact with treated soils meeting commercial criteria and deposited above the original groundwater table, groundwater pumping would be undertaken. This proposal does not seem to be included in the amended MfE Remedial Action Plan. As set out in the groundwater issues report, groundwater does appear to be coming into contact with commercial category soils. Some groundwater pumping was undertaken during works to dewater excavations, but no pumping is currently happening nor does it appear that there is any plan to do so.

Proposed corrective responses

The site auditor advised MfE on 28 April 2005 by email that clean groundwater entering the Mapua site from upgradient to the north could readily be diverted and discharged to the estuary by means of French drains along the northern boundaries. This would reduce groundwater inflow to and through the site. It would also be expected to lower the groundwater table, breaking the contact between groundwater and soils with high residual contamination, and hence reducing leaching from those soils. Both these mechanisms should reduce contaminant discharges in groundwater; the extent of reduction would depend on the contribution from upgradient inflow. This solution was one of a number of options, and was never implemented, but could still be undertaken at any time.

The resource consents for the remedial works at Mapua expired on 21 November 2007. At the Peer Review Panel meeting of November 2006, TDC advised that:

> "…the RMA (sec 124,) will require a new groundwater discharge consent to be applied for, if the discharges are going to continue. The application should be made at least 6 months before the expiry date (ie by 21 May 2007) or, at the councils discretion 3 months before (21 August 2007)."

MfE did not apply for any such consent, so all consents relating to groundwater have now expired. MfE has advised PCE that monitoring by them ceased at the expiry of consents. MfE states (letter dated 9 July 2008) that TDC took back possession of the site in October 2007.

Stormwater

Conditions 19 through 25 of resource consent RM030526 provide "preliminary" targets for stormwater discharges to the east and west of the site. Stormwater quality was to be monitored at the point of discharge during six storm events per year from "stormwater retention ponds" proposed at the hearing. In the event, these stormwater ponds proved unnecessary.

MfE has advised that no stormwater monitoring was carried out. One reason for this appears to be that stormwater retention ponds were proposed at the hearing, but were never constructed, hence there was no obvious stormwater discharge. TDC's

Compliance Officer refers to the drainage ditch on the western boundary of the site as the "stormwater ditch".

In May 2007, surface water samples were collected from the drainage ditch before and after (but not during) a storm event, as part of the CH2M Hill (2007) investigation. These samples were only analysed for OCPs, nitrate and ammonia, and not for turbidity, the metals suite that was also required by the consent (comprising arsenic, cadmium, copper, lead, mercury, selenium and zinc). 'High-flow' water samples from after the storm event exceeded targets for all analytes, particularly DDX where the maximum concentration was 0.56 µg/L compared to a target of 0.002 µg/L. 'Low-flow' samples before the storm also exceeded criteria but to a lesser extent. However, because the ditch itself had been contaminated with buried FCC waste, it is not clear whether the contaminants found relate to the runoff into the ditch, or the incomplete remediation of the ditch itself.

The consents also provide that the Mapua site must "be managed to minimise the surface discharge of stormwater" and in addition "the Consent Holder shall as far as practicable avoid discharging stormwater…to areas of coastal sediment that have been remediated. The diversion and discharge of stormwater shall be under the supervision of a registered engineer experienced in stormwater disposal".

But the compliance officer's report for September 2007, near the end of the works, describes the following incident:

> "The wash water from the concrete pad, which contained contaminated soil from washing down EDLs equipment, was piped to a pit/pond about 20m away from the stormwater ditch on the West. On the morning of 16/8 during a site visit we noticed that they had dug a channel from this pond to the stormwater ditch and the sediment from the discharge was visible 3-4 m down the ditch. [EMS] got them (EDL and Taylors) to block up their temporary channel and remove the deposited sediment from the stream bed. Council has requested that the West beach and stream points used by CH2M Hill are resampled once the old landfill area is recontoured and covered with clean residential soil. This is because we suspect that if they could deliberately discharge contaminated sediments into the stormwater ditch they probably have done so before, and the May sampling by CH2M Hill is not the final picture of the West beach and stream bed contamination."

Although action was evidently taken immediately to cease this uncontrolled discharge, MfE did not carry out further sampling as requested by TDC. MfE did remove some of the sediment at the mouth of the ditch in October 2007. This incident did not result in formal enforcement action.

Glossary

2,4-D	An organochlorine pesticide
abatement notice	A formal order, issued by a regional council or local territorial authority, requiring compliance with resource consent conditions within the time specified in the notice
acidic	Being or containing an acid; a solution having an excess of hydrogen atoms (pH less than 7.0)
activated carbon	An amorphous form of carbon. Its chemical nature, high surface area and porosity make it an ideal medium for the removal of organic pollutants from liquid or gas streams.
ADL	A collective term for aldrin, dieldrin and lindane, three organochlorine pesticides
adsorbed	Gathering of gas, liquid or a dissolved substance on a surface in a condensed layer
AECS	Air Emissions Control System
AEE	Assessment of Environmental Effects: a report outlining the effects that a proposed activity might have on the environment, required under the RMA for resource consent applications
aerosol sampler	Device used to collect samples, which are analysed for specific liquid or solid particles in the air
AES Ltd.	Air quality and environmental consultants
aldrin	An organochlorine pesticide
alkalinity	The alkali concentration or quality of an alkaline substance (pH greater than 7.0)
ammoniacal nitrogen	Nitrogen combined with hydrogen
ANZECC	Australia and New Zealand Environment Conservation Council
aquifer	Any geological formation containing or conducting groundwater
arsenical compounds	Arsenic bonded with various other elements
atrazine	A herbicide
backfill (verb)	The restoration of excavated gravel or earth against a structure or back into a hole
backfill (noun)	The gravel or dirt that is replaced into a hole or against a structure
back pressure	The resistance to the flow of gas through the exhaust
ball mill	A grinder for reducing hard materials to powder, where the grinding is carried out by the pounding and rolling of ceramic or steel balls within a cylinder
baseline	A measurement, calculation, or location used as a basis for comparison
belt and braces	To have additional levels of protection
borehole	An excavation by a drilling rig, used for soil sampling and installing soil, gas and groundwater monitoring devices
breakdown products	Product resulting from a chemical breaking apart into smaller pieces

bund wall	A wall erected to prevent the escape of stored liquids into the surrounding environment
cadmium	A heavy metal
capping	Placement of a covering (cap) of one or more layers of sand, silt, rock or synthetic fabric over an established layer of contaminated earth. This cap is designed to prevent pollutants from migrating into surrounding waters by providing a physical and chemical seal.
carbaryl	A neurotoxic insecticide in the carbamate family, having a similar mechanism to organophosphate pesticides, but a shorter duration of action
carbon filter	A filter employing activated carbon to remove particles from the air
centrifugal samples	Samples where precipitate has been separated out using centrifugal force
Ceres Pacific	An historic owner of the Fruitgrowers Chemical Company (FCC)
ChemSearch	An environmental and analytical laboratory
chlorobenzene	A volatile organic compound
chlorophenoxyacetic acid herbicides	A class of pesticides that mimic plant hormones
CH2M Hill	Environmental and engineering consultants
clay bunding	Construction of a bund wall using clay
cleanup	Remediation of a contaminated site
Close-out Report	A report compiled at the end of a project, which determines if the expectations established as the project outcome were met
CMPS&F	Environmental consultants
containment	The process of keeping hazardous wastes confined to a particular location, to prevent their accidental release into the surrounding environment
contaminated land	Land identified as posing a significant possibility of significant harm to human health or the environment due to substances present in, or under, the ground
copper sulphate	A copper salt.
cut-off wall	A collar (metal, concrete etc.) placed around a culvert to prevent water flowing around the outside of the culvert
DAP	diammonium phosphate
DDD	A breakdown product of DDT
DDE	A breakdown product of DDT
DDT	An organochlorine pesticide
DDX	The sum of DDT and its primary breakdown products
decanted samples	Samples where precipitate has been separated out by carefully pouring liquid from a container
dehalogenation	The reduction or removal of halogens from a chemical compound. Halogens are various non-metallic elements that readily combine with metals. Halogenated compounds are more

	likely to be toxic.
de novo	Latin: to make anew
desorbed	To remove condensate from a surface upon which a gas, liquid or dissolved substance has been adsorbed
destruction efficiency target	The agreed percentage destruction of OCP contaminants in treated soil; also known as the Destruction / Removal Efficiency (DRE) target
diazinon	An organochlorine pesticide
dieldrin	An organochlorine pesticide
dioxin	Any of a group of toxic chlorinated compounds known chemically as dibenzo-p-dioxins. They are produced as a by-product of chemical production or combustion and are widespread pollutants in the environment.
discharge stack	A walled enclosure extending upward to direct exhaust air vertically away from fans
down-gradient	Areas in an aquifer with lower water levels
drier	A device used to heat and dry the contaminated soil
East Area	The eastern area of the Mapua contaminated site
ecosystem trigger values	Trigger values for ecosystem protection; if a set median water quality is exceeded, this 'triggers' a management response.
ecotoxic	Substances that may present immediate or delayed risks to one or more parts of the environment
EDL	Environmental Decontamination Limited
Egis Consulting	An environmental consultancy
electrical conductivity	Measure of the ability of material to conduct an electrical current
elemental sulphur	A chemical that is a very strong acidification agent
EMS	Effective Management Services Limited
enforcement order	An order issued by the Environment Court requiring a consent holder to comply with resource consent conditions within the time specified in the order
entrained	Carried along in a current
estuarine	Found in estuaries (the mouth of a river)
eutrophication	The process by which a body of water acquires a high concentration of plant nutrients, especially nitrates or phosphates, resulting in algae growth and depletion of dissolved oxygen in the water. This natural process can be greatly accelerated by human activities.
exposure pathways	Determination of exposure to contaminants, being a combination of: the source and mechanism of release, the means of retention and transport, the exposure route, and the point of human contact
FCC	Fruitgrowers Chemical Company
FCC East	Eastern part of the Mapua contaminated site
FCC West	Western part of the Mapua contaminated site

field filtered sample	Sample filtered in the field prior to laboratory analysis of nutrient content
fines	Fine fragments, as of crushed rock
fluxes	Fluid flows
French drains	A perforated pipe placed in a gravel-filled pit, where liquid is poured into the drain and then permeates through into gravel.
fugitive emissions	Emissions not caught by a capture system (due to factors such as equipment leaks, evaporative processes and/or wind)
g m^{-3}	Grams per cubic metre
groundwater	All water which is below the surface of the ground in a saturated zone and in direct contact with the subsoil
heavy metals	Metallic elements with high atomic weights or density, such as mercury, cadmium, arsenic and lead. Many heavy metals are toxic and, since they do not easily break down, tend to accumulate in the food chain.
herbicide	Any pesticide used to destroy or inhibit plant growth
hotspots	Localised areas where the concentration of contaminants is high relative to the surrounding area
hydraulic conductivity	A measure of the capacity for a rock or soil to transmit water; generally has the units of cm/sec
hydraulic gradient	Water level from a given point upstream to a given point downstream; or the height of the water surface above a subsurface point
hydrocarbons	Organic compounds that contain only carbon and hydrogen
hydrogeology	The interrelationships of geologic materials and processes with water, especially groundwater
impoundment pond	An area with bunding, designed to prevent the escape of stored liquids into the surrounding environment
in situ	Latin: present at the site, in place. Refers here to the treatment of hazardous waste on site, without removing them to another location.
Kjeldahl nitrogen	The protein nitrogen content of organic compounds
landfill	A site used for the disposal of solid waste
leachable	Able to be removed by the action of a percolating liquid
Lime and Marble	A mineral processing company, later known as Mintech
lindane	An organochlorine pesticide
lithology	The physical characteristics of rocks, such as type, size and mineral composition
low-lying areas	Areas of land lower than the surrounding area, into which water tends to accumulate
m/s	Metres per second
m^3/day	Cubic metres per day
Manco Environmental Ltd	Manufacturer, importer and distributor of waste collection equipment; associate company of EDL
MAV	Maximum Acceptable Value

MCD	Mechano-Chemical Dehalogenation
metabolites	A substance that is the product of biological (metabolic) changes to a chemical
MfE	Ministry for the Environment
mg/L	Milligrams per litre
μg/L	Micrograms per litre
μm	Micrometre
micron	1/1,000 of a millimetre or 1/1,000,000 of a metre
microniser	Device designed to reduce a substance to particles that are only a few microns in diameter.
Mintech	A mineral processing company, formerly known as Lime and Marble
MODFLOW	A groundwater flow model
MoH	Ministry of Health
MWH	Montgomery Watson Harza Limited
National Environmental Standard	Tool provided for by the RMA; used to set nationwide standards for the state of a national resource
Nelson Marlborough District Health Board (NMDHB)	An organisation established to protect, promote and improve the health and independence of the population in the Nelson-Marlborough District
nitrate	A salt or ester of nitric acid
nitrogen compounds	Nitrogen bonded with various other elements
NZDWS	New Zealand Drinking Water Standard
OCPs	organochlorine pesticides
organics	Natural organic materials of waste or non-waste origin, including petroleum products, pesticides, herbicides, solvents, and chemicals from decaying plants and animals
organochoride pesticides	Synthetic organic compounds containing chlorine; also known as chlorinated hydrocarbons. Includes pesticides such as DDT, aldrin, dieldrin and lindane. Found to be toxic to non-target species, persist in the environment, and have a propensity to accumulate in the food chain.
organomercury compounds	Mercury bonded with carbon; organic mercury compounds are also called organomercurials
organonitrogen pesticides	A group of organic compounds consisting of nitrogen bonded with carbon
organophosphate	A group of organic compounds consisting of phosphorus bonded with carbon. Organophosphate pesticides break down rapidly when exposed to sunlight, air and soil.
orphaned site	Contaminated site where either no party can be fixed with legal liability, or the liable party is unable to fully fund the remediation
out-turn cost	The final cost at the end of the project
paraquat	An organochlorine pesticide
particulates	Sum of all microscopic liquid and solid particles, of human and

	natural origin, that remain suspended in a medium such as air for some time. Particulate matter may be in the form of fog, fumes, dust, soot or fly ash.
PCBs	polychlorinated biphenyls
PCE	Parliamentary Commissioner for the Environment
PDP	Pattle Delamore Partners Ltd
pesticide	Chemicals used to kill, control, repel or mitigate any pest; includes herbicides (to control weeds and plants), insecticides (to control insects), fungicides (to control fungi), rodenticides (to control rodents) and germicides (to control bacteria)
pentachlorophenol	A chemical, also known as PCP, historically used as an anti-sapstain fungicide for short-term protection of sawn timber surfaces
pH	Potential of Hydrogen, providing a measure on a scale from 0 to 14 of the acidity or alkalinity of a substance
phenoxy herbicides	A group of herbicides derived from phenoxy-acetic acid
PM_{10}	Particulate matter classified as 'coarse and fine' based on the size of their aerodynamic particles
PMP	Project Management Plan
polychlorinated biphenyls	A class of chemical compounds containing benzene and chlorine atoms. Some are used for pesticides and fire-resistant coatings.
PUF	polyurethane foam sampler
pug mill	A device that mixes and grinds clay or other materials to a desired texture, using rotating paddles or blades
rainfall recharge	The process of adding water to an aquifer
reagent	A substance used to react with another substance
remediation	The cleanup or mitigation of risks from contaminants in soil.
resource consent	Permission granted by a consent authority for an activity that might affect the environment and is not permitted 'as of right' in a District or Regional Plan
RMA	Resource Management Act 1991
rotary-type drier	A mixing apparatus using rotation, as opposed to other options such as kneading, pulverising or stirring
run-off	That element of precipitation that finds its way into streams and rivers
slag	Waste product formed from the heating of ore in a furnace
slug test	A test to determine in situ hydraulic conductivity
soakhole	An excavated pit where holes have been driven into the rock and then covered over, without being filled, so that stormwater can drain into the ground
soil acceptance criteria	Soil guideline values defining the levels of contaminants that are not considered to pose an unacceptable risk to human health or the environment
soil drier	A device used to heat and dry the contaminated soil
Soils & Foundations	Consultants

spike tests	Identification of the amount of pesticides remaining on a sampler after extended use through the use of radioactively labelled samples
stack emissions	Emissions to the atmosphere from a chimney or stack
static water levels	The water surface elevation in a well when the water is at rest; the level to which water naturally rises in a well
stormwater	Precipitation that accumulates in natural and/or constructed storage and drainage systems during and immediately following a storm event
stormwater drains	Openings leading to underground pipes or open ditches for carrying surface run-off
sump	A tank or pit that receives drainage and stores it temporarily
TDC	Tasman District Council
Thiess Services	A specialist remediation contractor
THI	Total Hazard Index
threshold concentrations	The concentration of a substance below which no adverse effect is expected to occur
triazines	A group of herbicides typically used on field crops; they have a relatively high solubility and slower degradation time compared to other types of herbicide
TSPs	Total Suspended Particulates
unitary authority	A territorial authority carrying out the roles of both regional and district councils under the RMA
up-gradient	Areas in an aquifer with higher water levels
Validation Report	A site validation report; assesses the results of post-remediation testing against clean-up criteria for a contaminated site
venturi	A short tube with a constricted throat used to determine fluid pressures and velocities by measurement of differential pressures generated at the throat as a fluid traverses the tube
venturi scrubber	An air pollution control device in which the liquid injected at the throat is used to scrub particulate matter from the gas flowing through the tube
volatile organic compounds	Organic compounds that will evaporate into the air naturally from water
West Area	The western area of the Mapua contaminated site.
Woodward-Clyde (NZ) Ltd	Environmental consultants, now known as URS Corporation New Zealand