HISTORIC PESTICIDE RESIDUES IN HORTICULTURAL AND GRAZING SOILS IN THE TASMAN DISTRICT

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The survey discussed in this technical report was carried out as part of the author's PhD studies at The University of Waikato supervised by Professor A Wilkins, Dr G Palmer and Dr N Kim (Environment Waikato).

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A significant proportion (including agrichemical use in NZ and the selection of trigger levels) of this work was initially prepared for a report to Auckland Regional Council (Gaw 2002). Permission has been granted to reproduce this information here.

EXECUTIVE SUMMARY

The Tasman District has a long history of horticulture. A previous study in the Auckland region had shown that historical farming practice including the use of agrichemicals had resulted in elevated levels of organochlorine pesticides and trace elements on some properties (Gaw 2002). This study was undertaken to assess the incidence of historic agrichemical residue contamination (organochlorine pesticides and trace elements) in rural soils in the Tasman District.

Soil samples were collected from 25 sites comprising 5 landuse types (berryfruit, grazing, market gardens, orchards and tobacco) in September 2002. All of the horticultural properties sampled in this survey were developed prior to 1975.

The soil samples were analysed by an IANZ accredited laboratory for an organochlorine pesticide suite and 15 trace elements.

The contaminants most frequently detected at the highest concentrations in cropping areas sampled in this survey were ΣDDT (sum of the *o,p-* and *p,p´-* isomers of DDT, DDE and DDD), arsenic, and lead. The levels of these contaminants found in rural soils in the Tasman District are comparable to those reported for the Auckland region (Gaw 2002) and those found overseas for similar land uses.

The levels of ΣDDT, copper, arsenic, and lead in cropping areas on some properties exceeded conservative guidelines for the protection of human health and/or ecological protection. Overall 60% of properties (horticultural and grazing) sampled were equal to or exceeded at least one trigger level. Approximately 65% of samples from horticultural properties in this survey exceeded at least one trigger level (Table I).

Table I Number of horticultural properties with agrichemical residue levels in cropping area soils equal to or exceeding the selected trigger level. The overall figure is presented as a percentage.

	Orchards (n = 5)	**Berries (n = 5)**	**Tobacco (n = 5)**	**Market Gardens (n = 5)**	**% Properties (n = 20)**
	Number of properties equal to or exceeding the trigger level				
Arsenic	3	0	0	0	15
Copper	1	1	0	0	10
Lead	4	0	0	0	20
Zinc	0	0	0	0	0
∑DDT	5	2	4	1	60
Dieldrin	0	0	0	0	0

The results from this study indicate that historic farming practices including the use of agrichemicals on horticultural properties in the Tasman District have resulted in comparatively elevated levels of contaminants in soils above background concentrations. These elevated levels of contaminants have the potential to impact on the suitability of such land in its current state for residential development.

Tasman District Council should consider requiring site assessments on rural properties prior to granting landuse consent for residential subdivision. The potential for agrichemical contamination should be taken into consideration when considering any changes to regional and district plans.

CONTENTS

TABLES

ABBREVIATIONS

AGCARM	Agriculture Chemical and Animal Remedies Manufacturer's Association
ARC	Auckland Regional Council
ANZECC	Australia New Zealand Environment Conservation Council
a.i.	active ingredient
As	arsenic
B	boron
CCME	Canadian Council of Ministers for the Environment
Cd	cadmium
Co	cobalt
Cr	chromium
CRM	certified reference material
Cu	copper
DDE	1,1-dichloro-2,2-*bis*(*p*-chlorophenyl)ethylene, degradation product of DDT
DDD	1,1-dichloro-2,2-*bis*(*p*-chlorophenyl)ethane, degradation product of DDT
DDT	1,1,1-trichloro-2,2-*bis*(*p*-chlorophenyl)ethane
ΣDDT	sum of *o,p* + *p,p´*-DDT, *o,p* + *p,p´*-DDE and *o,p* + *p,p´*-DDD
DSIR	Department of Scientific and Industrial Research
EQG	environmental quality guideline
Fe	iron
GC-ECD	gas chromatography with electron capture detection
GC-MS	gas chromatography mass spectrometry
HCl	hydrochloric acid

Hg	mercury
HNO_3	nitric acid
IANZ	International Accreditation New Zealand
ICP-MS	inductively coupled plasma mass spectrometry
MAF	Ministry of Agriculture and Forestry
MfE	Ministry for the Environment
Mn	manganese
Mo	molybdenum
MoH	Ministry of Health
NEPC	National Environmental Protection Council
Ni	nickel
NSWEPA	New South Wales Environmental Protection Agency
QC	quality control
Sb	antimony
Sn	tin
SPE	solid phase extraction
TOC	total organic carbon
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
Zn	zinc

UNITS

%	percent
°C	degrees celsius
ha	hectare (10 000 m^2)
mg kg^{-1}	milligram per kilogram (or part per million)
mm	millimetre
mL	millilitre
µg kg^{-1}	microgram per kilogram (or part per billion)
µm	micrometre (10^{-6} metre)

1.0 INTRODUCTION

Horticultural properties have historically been located on the peri-urban fringe of cities. Throughout New Zealand there is increasing pressure on this land for so called "greenfields" development. In a recent study of horticultural soils in the Auckland region, ΣDDT (sum of DDT and its degradation products DDE and DDD), copper, dieldrin, arsenic and lead were the contaminants most frequently detected in the highest concentrations in the cropping areas sampled. Approximately 70% of the horticultural properties developed prior to 1975 exceeded conservative guidelines for the protection of human health and/or ecological receptors for at least one of these contaminants. Acidic herbicides were not detected and generally only low levels of organonitrogen and organochlorine pesticides were detected in cropping areas (Gaw 2002).

As a result of this initial study, the Ministry for the Environment sent an advisory letter to all Territorial Local Authorities in May 2002, suggesting that it would be prudent in future to consider the question of contamination on any former horticultural block for which a subdivision consent request had been received.

1.1 PURPOSE

The main purpose of this study was to determine the extent to which residual historic pesticide contamination was also likely to be a problem for horticultural soils in the Tasman District. There are differences between horticultural regions throughout New Zealand in terms of climate, type of production and soil types. There may also have been differences in plant diseases and pests, which may have resulted in different spray regimes. For example Fielding (1957) states the following for orchards in the Nelson region:

"In comparison with other South Island districts, the absolute humidity of this region is high and aids the incubation of insect pests and fungus diseases. October to February is most critical period and during this time orchards must be sprayed once every 10-14 days."

This is a technical report and as such is focussed on the methodology and results of the survey of rural soils in the Tasman District. Remediation options, off-site effects and ecotoxicology assessments are outside the scope of this report.

1.2 HISTORICAL OVERVIEW OF HORTICULTURE IN THE TASMAN DISTRICT

The information presented in this section has been gathered from a large number of sources. Different authors used varying methodologies when surveying landuse in the Tasman District and the over time the boundaries of councils have been altered making direct comparisons difficult. The units for land areas have not been converted to a common unit[1].

1.2.1 GENERAL COMMENTS

The Tasman District has a long history of horticultural activities. The first recorded attempts at orcharding in the Tasman District were undertaken by early missionaries who planted fruit trees on mission stations in Nelson and Motueka (Campbell 1936). Crops historically grown in the Tasman District included pipfruit, tobacco, vegetables, berries and hops. There were 10720 acres under cultivation in Waimea County in 1921 (Rigg 1962) (Table 1) and 10,331 acres in Nelson region in 1954 (Fielding 1957) (Table 2). There were 12-14,000 acres under cultivation in the Nelson region in 1971; tobacco, vegetables and tree fruits were the main crops (Table 3) (Department of Agriculture 1972). The total area in horticulture in the Nelson region (including Nelson City Council area) in 1981 was 4296 ha or approximately 11000 acres (Hadfield 1982) (Table 4).

[1] For comparison purposes one hectare is equal to 10 000 m^2 or 2.47 acres.

Table 1 Horticultural crops in the Waimea County 1921 to 1959. Units are acres. Data from Rigg (1962).

	1921/22	1941/42	1951/52	1959/60
Apples and pears	9270	3620	3390	3670
Stone fruits	220	400	380	215
Berry fruits	400	300	230	210
Hops (net acreage)	525	570	620	510
Tobacco	-	3000	3650	3750
Tomatoes	65	125	225	330
Vegetables	240	200	345	530
Total	10720	8125	8840	9215

Table 2 Horticultural statistics in Nelson 1954. Units are acres. Data from Fielding (1957).

Crop	Acreage
Pipfruit	3275
Stonefruit	400
Berryfruit	240
Tobacco	3080
Hops	645
Tomatoes (glasshouses)	31
Tomatoes (outdoor)	300
Peas and beans (processing)	2100
Other vegetables	260
Total	10331

Table 3 Horticultural statistics for the Nelson Province 1971. Data from the Department of Agriculture (1972).

Crop	Acres	No. of growers
Tobacco	4969	466
Hops	534	56
Tree fruits	4860	235
Small fruits (berries)	522	157
Glasshouse tomatoes	34.2	185
Vegetables	3188	238

Table 4 Area in the Nelson region under cropping in 1981.
Data from Hadfield (1982).

Crop	Hectares
Apples	1832
Pears	86
Stonefruit	110
Boysenberries	234
Raspberries	134
Other berryfruit	62
Kiwifruit	700
Tobacco	470
Hops	144
Vegetables	370
Others	154
Total	4296

1.2.2 BERRIES

Berryfruit produced in the Nelson Province in 1955 included raspberries, strawberries, gooseberries and blackcurrants (Department of Agriculture 1957). The area planted in berryfruit (predominantly raspberries) fluctuated between 150 and 250 acres between 1954 and 1963. Raspberries accounted for approximately 80% of production: currants, strawberries and boysenberries comprising the rest (Owens 1965). Raspberries were produced in the Tadmor-Tapawera-Motupiko districts with scattered holdings in the Wai-iti and Moutere Valleys (Owens 1965). Over half of the raspberry crop was grown in the Tadmor Valley (Hadfield 1982). The area planted in boysenberries increased from 29 ha in 1970 to 234 ha in 1981 (Hadfield 1982). The majority of berryfruit holdings were less than 5 to 6 acres in size and berries were produced in conjunction with other forms of agriculture including sheep farming, hops, tobacco and dairying (Owens 1965). Boysenberries, raspberries, strawberries were also grown on Moutere Hill soils. In 1952 there were 12 growers producing strawberries on 10 acres (Adamson 1952). The sale of berryfruit within the Tasman District was governed by the Nelson Raspberry Marketing Regulations 1940 which outlined who the berryfruit growers could sell to (Cook 1977).

1.2.3 MARKET GARDENS

Vegetables were mainly produced on the Waimea Plain around Hope, Appleby and Stoke, around Motueka and Riwaka and in scattered areas in the Moutere Valley. Produce from the frost-free Hope District could be marketed up to 3 weeks earlier than elsewhere in New Zealand. Beans, outdoor tomatoes, cauliflowers and cabbages were the main vegetables grown (Owens 1965). There were 2000 acres used for vegetable production in 1955 (Department of Agriculture 1957) and this had decreased to 370 ha (914 acres) by 1981 (Hadfield 1982).

1.2.4 ORCHARDS

Historically the Nelson District has been New Zealand largest pipfruit producer. In 1922 the Nelson district was described in a government pamphlet as being New Zealand's largest fruit growing region. The first european fruit tree was planted in the Riwaka Valley, Motueka. Planting in the lower Moutere began in 1895 and apples were first exported from the Tasman District to England in 1908 (Fielding 1957).

Tasman Fruit Lands Ltd and associated ventures by other developers led to the planting of more than 7000 acres of orchard on Moutere Hill soils. There was corresponding development in the Riwaka area. However WWI led to a shortage of labour and the planting boom ceased (Motueka Fruitgrowers Association 1977). Upwards of 7000 acres of fruit trees were planted in the Tasman District during the boom years of 1911 to 1916. Many of these early plantings were abandoned. In 1952 there was 2,500 acres of apples and pears on Moutere Hills (from Mariri on the Moutere Inlet to Appleby and back to the Moutere Valley), while another 1,200 acres orchards were located on the flats of Riwaka, Moutere, Stoke and the Waimeas (Adamson 1952). The acreage planted in apple trees in Waimea County declined between 1921/22 (9270 acres) to 1951/52 (3,390 acres) as unprofitable orchards throughout the district were abandoned, however by 1959/60 the area planted in pipfruit trees had increased (Rigg 1962). In 1955 there were 3800 acres of

commercial orchards in Nelson Province (Department of Agriculture 1957). In 1965 there were 4000 acres of pip fruit planted in the Waimea County.

Fielding (1957) described the location of fruit growing in the Nelson region as "*essentially a coastal strip, consisting of the plains of the Waimea and Motueka Rivers together with the seaward sections of the Moutere Hills which separate them.*"

Two-thirds of the orchards were located in the coastal belt of the Moutere Gravels from Mariri to Mapua. Smaller areas of production were located on the alluvial soils around Riwaka, Richmond, Brightwater and Wakefield (Owens 1965). The size of orchards units ranged considerably (Table 5) (Department of Agriculture 1972); the average holding size in 1956 was 13 acres (5 ha).

Table 5 Orchard unit size range in Nelson Province 1972.
Data from Department of Agriculture (1972).

Acres	Percentage of orchards
1-5	15
6-10	13
11-15	21
16-20	17
21-25	9
>25	25

Apple plantings increased in the late 1970s and early 1980s as a result of good market returns (Hadfield). Plantings in the Hau Plains in 1960s were only made possible by irrigation and this added 150 acres to districts orchards (Motueka Fruitgrowers Association 1977). By 1977 there were 722 ha (1783 acres) of orchards in the Motueka depot's district alone (Motueka Fruitgrowers Association 1977).

Apples and pears were the main fruit varieties grown in the Tasman District. Only small quantities of stone fruit were grown in the Nelson region, for example there were 215 acres planted in stonefruit compared to 3670 acres in pipfruit in the 1959/60 season (Rigg 1962). By 1981 the areas planted had increased to 110 ha (272 acres) for stonefruit and 1918 ha (4737 acres) for pipfruit (Hadfield 1982).

Continuous cultivation caused widespread and severe soil erosion and wetness problems in orchards situated on the Moutere Hills. Leighs (1977) states that:

"*It was common for the roots of fruit trees on spurs and upper slopes to be left standing on "pedestals" of earth, the soil between the trees having been washed down to build up as much as one metre around the lower trees forming a swamp on the flats. Completely buried fences have been found*."

Fifty tonne losses of soil per ha per year under cultivation were not uncommon. Recontouring and subsoiling was undertaken to increase infiltration and reduce surface runoff. Long slopes were broken up into a series of shorter ones with grassed diversion banks at suitable spacings and grassing down between the row of trees was encouraged. By 1977, 95 of the approximately 200 orchards on the Moutere Hills had undergone some conservation treatment (Leighs 1977).

1.2.5 TOBACCO

The Nelson region was the only region in New Zealand to produce tobacco and hops on a commercial scale (Hadfield 1982). Tobacco was first planted in the 1920s (Owen 1965). The main areas of tobacco production were the Motueka-Riwaka Plain and the flats bordering the Motueka and Wai-iti Rivers. Tobacco was also grown around Tapawera and Dovedale and in scattered valleys draining the Moutere Gravels (Owens 1965; Rigg 1943). Smaller areas of tobacco production were located on the alluvial soils around Riwaka, Richmond, Brightwater and Wakefield (Owens 1965). In 1955 there were 3100 acres planted in tobacco (Department of Agriculture 1957). In 1972 there was 4681 acres of tobacco (James 1975). The average acreage per grower in 1935-36 was estimated to be 3.9 acres and this had increased to 12.2 acres by 1972-1973. In 1963-64 there were 763 growers and 5816 acres of tobacco, approximately 7.7 acres per grower. In 1972 there was 4681 acres of tobacco (James 1975).

Tobacco is no longer grown in the Tasman District; current uses for tobacco land include grazing and kiwifruit. The tobacco industry was restructured during the 1980s. Tobacco growers were paid $7000 per ha to go out of growing tobacco and a large proportion of former tobacco land was planted in kiwifruit (Hadfield 1982).

1.2.6 HOPS

Hops were planted by early settlers in the 1840s. In 1955 there were 646 acres planted in hops (Department of Agriculture 1957). In 1965 there were 70 hop gardens ranging in size from 2 to 30 acres. There were 457 acres planted in hops in 1962. Production was concentrated on alluvial soils around Motueka and Riwaka and in the Moutere and Wai-iti Valleys (Owens 1965). By 1981 the area planted in hops had decreased to 161 ha (Hadfield 1982).

1.2.7 OTHER CROPS

Oats, wheat and barley were also grown in the Tasman District. The acreage planted in these crops declined as the use of horse drawn farm machinery decreased. Seed peas and stock fodder (rape, turnips, swede) were also widely grown (Rigg, 1943).

Grapes are a relatively recent crop in the Tasman District. In 1952 only 5 acres were planted in grapes on the Moutere Hills (Adamson 1952). There were only 1.4 hectares of grapes in the Nelson District in 1960 (Townsend 1976). Ten growers with 6 ha (15 acres) of grapes were recorded in the 1975 viticultural survey (MAF 1976). By 1981 the area planted in grapes in the Nelson region had increased to 40 ha (99 acres) (Hadfield 1982).

1.3 USE OF HORTICULTURAL CHEMICALS

The New Zealand Department of Agriculture was established in 1892. In 1893, two 'Pomologists' were appointed. One of their chief duties was to disseminate information with regard to the chemical treatment of disease in orchards. The three main compounds in use at this time were bordeaux (copper) mixture, lime-salt-sulfur

and paris green (copper and arsenic). By 1903 the majority of fruit tree growers were using chemical sprays. In 1903 the Orchard and Garden Pests Act was passed which made it an offence to allow certain specified diseases to be present in an orchard (Cunningham 1925). The passing of the Agricultural Chemicals Act 1959 made the use of pesticides subject to compulsory regulatory control and established the Agricultural Chemicals Board (Buckland *et al.* 1998).

Spray schedules were recommended by growers' advisory groups and marketing boards such as the Apple and Pear Board. The Ministry of Agriculture and Fisheries also had horticultural advisors. Spray schedules for insect pests and fungous diseases of fruit trees in 1925 are detailed in Cunningham (1925). The use of lime-sulfur, bordeaux mix, arsenate of lead, precipitated sulfur, self-boiled lime-sulfur, red-oil (fumigant containing paraffin) and black-leaf (nicotine sulfate) was advocated. The 1956 spray programmes from Atkinson *et al.* (1956) are summarised in Table 6. DDT (1,1,1-trichloro-2,2-*bis*(*p*-chlorophenyl)ethane) was applied to fruit trees, grapevines, berry fruit and vegetables. Copper containing fungicides were widely used in horticulture along with sulfur. Lead-arsenate was widely used as a pesticide (Atkinson *et al.* 1956). Fertilisers were also widely applied on horticultural properties. Fertilisers included animal manure, compost, leaf mould, blood and bone products, fish meal, nitrate of soda, sulphate of ammonia, superphosphate and sulphate of potash (Christie 1977).

Table 6 Use of selected horticultural chemicals in 1956, as indicated by spray schedules. Source of spray schedules: Atkinson *et al.* (1956).

Crop	Lime	Copper	Sulfur	Lead-arsenate	DDT	Captan
Pip fruit	✓	✓	✓	✓	✓	
Stone fruit		✓	✓			✓
Citrus		✓	✓	✓	✓	
Grapevines		✓	✓		✓	
Berryfruit		✓	✓	✓	✓	
Strawberries		✓				
Vegetables	✓	✓	✓	✓	✓	

Early spraying on orchards was done by hand using a pressurised spray system. A pressurised or stationary spray system consisted of a network of underground pipes reticulated from a central spray house, holding pump and spray tanks. Sprays were pumped under pressure from a tank to taps located throughout the orchard (one approximately every seven trees). A hose would be attached to one of the pipes and the cropping area in the radius of the tap and hose sprayed (Winn 1968). During the 1950s, stationary spray systems were replaced by blast sprayers. Campbell (1936) described the stationary spraying system as follows:

"This system consists of the establishment of a pumping system at a fixed point, and the leading of high pressure pipes therefore throughout the orchard. Stand pipes with high pressure taps arise from the piping system at fixed intervals throughout the orchard. The spray liquid is forced through the pipes from the pumping station at a pressure of 300 to 350 lbs. A hose ranging from 90 to 150 feet in length with a spray nozzle or gun attached is coupled up to the tap of one of the stand pipes, from which a block of some forty trees and upwards may be sprayed before moving on to the next stand. The size of the pipes usually used for the purpose in this country are 3/4 inch mains with ½ inch laterals."

Some soils in the Tasman District are low in magnesium, copper, cobalt, boron and molybdenum. These deficiencies were corrected by the addition of these elements to superphosphate fertilisers and for some elements through the use of stock licks on grazing properties (Chittenden 1966).

1.3.1 DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane)

DDT is the most well known organochlorine pesticide. It was approved for use in New Zealand following World War II and according to Boul (1996) was first used on pasture in 1947. The first recorded use of DDT in the Tasman District was in 1945 (Motueka Fruitgrowers Association 1977). Due to its persistence DDT acted as both an eradicant and a protective spray. DDT was used to control a wide variety of chewing insects including bronze beetle, gladioli and onion thrips, and citrus leaf roller (Atkinson *et al.* 1956 and Osborne 1976). A major use of DDT was to control

caterpillars of the diamond back moth and the cabbage white butterfly on brassicas and the potato tuber moth (Osborne 1976). DDT was applied in vineyards to control mealy bug and other insect pests (Moran 1958).

DDT was also widely used to control grass grub (*Costelytra zelandia)* and porina caterpillars (*Wiseana* sp.) in pasture. It was frequently mixed with fertiliser or lime and applied to agricultural pasture, market gardens and parkland (Buckland *et al.* 1998 and Orchard *et al.* 1991). DDT was applied to pasture at a rate of 2.24 kg of active ingredient per hectare and one treatment would control grass grub for up to three years (Boul *et al.* 1994).

DDT was mainly used for horticultural activities either as a wettable powder or as an emulsion. DDT was used as an aerosol in glasshouses to control tomato white fly. Combination dusting powders containing DDT and either lindane or BHC were available (Atkinson *et al.* 1956).

From 30 June 1970 onwards DDT was banned for use for the control of grass-grub in pasture due to concerns relating to residues in meat. However it could still be used under permit to control grass grub on playing fields and bowling greens and for certain horticultural uses. A permit had to be sought from the Ministry of Agriculture and Fisheries if the quantity to be used was in excess of 60 g (Osborne 1976). Permits were only issued for horticultural use where non-organochlorine compounds were ineffective. However there is no publicly available data on the number of permits issued. Organochlorine pesticides such as DDT were replaced by carbamates and organophosphorus compounds.

A 1976 textbook on New Zealand insect pests recommends using DDT to control raspberry bud moth on berry fruit, gladiolus thrips, household pests (*e.g.* ants, cockroaches and carpet beetles) and medically important pests (*e.g.* bed bugs and fleas) (Ferro 1976). DDT was still registered for use in New Zealand in 1983 (Pesticides Board 1983) to control a wide range of chewing and sucking insects on horticultural crops (Long 1983). A MAF advice publication from 1983 refers to using

DDT on capsicums in glasshouses. The last products containing DDT were deregistered by the Pesticides Board in December 1989 (Buckland *et al.* 1998).

1.3.2 DDD (1,1-dichloro-2,2-bis(p-chlorophenyl)ethane)

DDD is a persistent organochlorine pesticide. It is both a degradation product of DDT and a pesticide in its own right. DDD was available as a wettable powder, dust or emulsion and was widely used as an insecticide. Like DDT, DDD was used to control chewing insects. Higher concentrations of DDD compared to DDT were used to control codling moth (Atkinson *et al.* 1956). An article in the 1964 edition of *The Orchardist of New Zealand* lists withholding periods for DDD for pipfruit, stonefruit, berryfruits, leafy vegetables, root crops, tomatoes, citrus and sub-tropicals (Slade 1964). DDD was also used to control mealy bug on grapes (Moran 1958).

From 1964 onwards the use of DDD was controlled through the Agricultural Chemicals (Insecticides) Regulations. DDD could only be used by horticulturalists under permit (Slade 1964). DDD was not listed in the 1983 Pesticides Board register of registered pesticides. Persistent organochlorine pesticides including DDD were deregistered by the Pesticides Board in 1989 (Buckland *et al.* 1998). The use of DDD ceased earlier in the Tasman District than in some other horticultural regions of New Zealand as resistance to DDD had developed (The New Zealand Fruitgrowers Federation 1967).

1.3.3 DIELDRIN AND ALDRIN

Dieldrin is a persistent organochlorine pesticide. It is a breakdown product of the pesticide aldrin and it was also used as a pesticide in its own right. Aldrin and dieldrin were introduced as stock remedies in 1954. Aldrin was more widely used than dieldrin, and the Horticulture Division only recommended the use of dieldrin on strawberries and root crops (Slade 1964). Aldrin was used to control horticultural pests such as wireworm, soldier fly and blackvine weevil. Dieldrin was used to control carrot rust fly, crickets and army worm (Buckland *et al.* 1998). Dieldrin was also used to control thrips and grass grub (Atkinson *et al.* 1956). Dieldrin was used

under permit on strawberries to control black vine weevil and grass grub at a rate of 3.5 kg of active ingredient per hectare (Osborne 1976). Aldrin was applied to strawberry cropping areas as 10% prills (MAF 1978).

Dieldrin was banned for use in sheep dips as a veterinary insecticide in the 1960s (Osborne 1976). In 1975 the Agricultural Chemicals Board recommended that the issuing of permits for any use of dieldrin cease (Buckland *et al.* 1998). From 1964 onwards the use of dieldrin was controlled through the Agricultural Chemicals (Insecticides) Regulations. Dieldrin could only be used by horticulturalists under permit (Slade 1964). Dieldrin was still registered for use by authorised users in New Zealand in 1983 (Pesticides Board 1983) and it was finally deregistered for use in New Zealand in December 1989 (Buckland *et al.* 1998).

1.3.4 LEAD ARSENATE AND OTHER ARSENICALS

Lead arsenate was one of the first pesticides used. It acted as a stomach poison to control chewing insects on fruit, vegetables and ornamental crops. Examples of chewing insects include leaf roller and codling moth (apples), looper caterpillars, corn earworm and stem borer (tomatoes) and tuber moth (potatoes) (Atkinson *et al.* 1956). Lead arsenate was used on grapes to control insects such as mealy bug (Moran 1958). Acid lead arsenate contained 32% arsenic pentoxide and 64% lead oxide. Basic lead arsenate was less phytotoxic (poisonous to plants) and contained 23% arsenic pentoxide and 75% lead oxide (Atkinson *et al.* 1956).

Lead arsenate was still in use in New Zealand in the early 1970s. A 1972 New Zealand Journal of Agriculture article (Thompson 1972) contained witholding periods for its use on pipfruit. Lead arsenate was still being used in New Zealand in 1976 albeit on a small and diminishing scale (Osborne 1976). Lead-arsenate was used later in the Nelson region than in other fruit growing regions of New Zealand as some chewing insects developed resistance to DDD (The New Zealand Fruitgrowers Federation 1967).

Arsenic containing mixtures were used to control weeds, poison trees and to destroy the tops of potatoes. These mixtures usually contained sodium arsenite; ortho-arsenite (Na_3AsO_3) and meta-arsenite ($NaAsO_2$) (Matthews 1960). Due to their toxicity they were withdrawn from use in the 1970s (Matthews 1975).

1.3.5 COPPER

A range of products containing copper was historically and is currently used as fungicides. Bordeaux mixture was prepared by mixing a solution of copper sulfate with a suspension of hydrated lime (Atkinson *et al.* 1956 and Cunningham 1925). Burgundy mixture was prepared by mixing copper sulfate, sodium carbonate and water (Cunningham 1925). Copper oxychloride was used on vegetable crops including curcubits, silverbeet, brassicas, celery and potatoes (Atkinson 1956). Copper sulphate was also used as a herbicide (Smith 1982).

Copper hydroxide, copper oxide, copper oxychloride and copper sulfate containing products are still registered for use in New Zealand as fungicides and are listed in the 2001 New Zealand Agrichemical Manual (Fussell and Walton 2001). Holland and Rahman (1999) in a recent survey found that the use of copper based fungicides and bactericides in New Zealand was decreasing and that formulations of cupric hydroxide had mostly replaced Bordeaux mixture and copper oxychloride. However copper containing formulations are still being used to control mildew and *botrytis* in vineyards (Holland and Rahman 1999).

1.3.6 MERCURY

Mercury compounds have been used in horticultural formulations for their antifungal and antibacterial properties. Organomercury compounds were commonly used as seed treatments. Phenylmercuryl chloride and phenylmercuryl ammonium lactate were active ingredients in sprays used to control black spot in apples. Phenyl mercury salicylate was used to control leaf mould on glasshouse tomatoes. Mercuric chloride was used in market gardening to control potato scab, clubroot in brassicas and against some soil insects. Wettable powders containing copper oxychloride and

phenyl mercury chloride were used to control late blight on potatoes (Atkinson *et al.* 1956). Organomercury compounds were also used in vineyards (Barzi *et al.* 1996; Berrysmith 1973). Phenyl mercury chloride is listed for use as a fungicide in pipfruit orchards in the 1967/1968 New Zealand Fruitgrowers Federation Spray Diary.

1.3.7 OTHER METALS

Zinc is a constituent of some fungicides including zineb, a dithiocarbamate (MoH 1996). Manganese and iron dithiocarbamates were used as fungicides (Atkinson *et al.* 1956). Iron sulfide was also used on some properties (Cunningham 1925) and iron sulphate may have been used as an early herbicide (Smith 1982).

Increased soil cadmium and zinc levels have been associated with fertiliser use (Taylor and Percival 2001). Manganese, cobalt, copper, boron, molybdenum, nickel and zinc were also added to some fertilisers. As an example, these trace elements are all listed as ingredients/active agents in a 1969 New Zealand Commercial Grower advertisement for fish fertiliser (Ivon Watkins Dow Ltd. 1969). Heavy applications of fertilisers were also made to market gardens; a basic fertiliser was sown either with or before the crop (Beyda 1961).

Organic tin compounds were used as acaricides. Examples are fenbutatin-oxide and cyhexatin which was used to control mites and spiders on pip and stone fruit, citrus, berry fruit and ornamentals. Organic tin compounds were also registered for use as fungicides (Long 1983).

2.0 METHODS

In this section the sampling and analysis methodology for the survey of residual soil contaminants on horticultural and grazing properties in the Tasman District is described. The fieldwork for the survey took place in September 2002.

2.1 SAMPLE SITE SELECTION

In this survey, a range of horticultural sites from within the Tasman District were selected according to landuse. The landuse categories were berries, market gardens, orchards, tobacco and grazing sites (with no known history of horticulture). All of the horticultural properties sampled in this survey were developed prior to 1975. 1975 was selected as the cutoff point for inclusion in the survey as the main contaminants of interest (with the exception of copper) were no longer widely in use in New Zealand after this time. The properties included in this survey are representative of the types of horticultural activities occurred prior to 1975 in the Tasman District. Efforts were made to ensure that sites from across the Tasman District were included for each land use category, however this was not always possible. It is probable that some land use types were over-represented in the survey and that others (e.g hops) have not been included. Due to the relatively small sample size within each land use category the results can be seen as being indicative of the scale of the problem in the Tasman District, rather than definitive.

The following criteria were used to select suitable sampling sites:

- Consent had been given by the landowner (conditional on maintenance of anonymity).
- The property was developed prior to 1975.
- The site had not undergone significant earthworks (apart from what would be normal for the specified land use).
- The site had not been regularly flooded (with the exception of some tobacco land).
- The site had not been used as a landfill or a cleanfill.
- The site was located within Tasman District Council's boundaries.
- The horticultural activity is typical of horticultural activities occurring within the Tasman District.

Precise details of site locations are not provided in this report because an undertaking of confidentiality was made to the site owners. For the purposes of this survey, the

ability to obtain cooperative access to a full range of sites from across the landuse categories was seen as being of prime importance.

2.1.1 SUMMARY OF SAMPLES COLLECTED

Soil samples were collected from 25 sites comprising 5 landuse types (Table 7) in September 2002.

Table 7 Summary of samples collected.

Landuse	Number of Samples
Market Gardens	5
Orchards	5
Berryfruit	5
Tobacco	5
Grazing sites	5
Quality control samples	3
Total	**28**

2.2 COLLECTION OF SITE HISTORY INFORMATION

As part of the survey, owners were interviewed about the history of their properties. This occurred twice; once during the initial contact telephone call and subsequently while on site. The questions that site owners answered are listed in Table 8.

Table 8 List of questions that site owners were asked as part of this survey.

- Location of any spills or leaks?
- Where were chemicals stored in the past?
- Where are chemicals currently stored?
- How were chemicals applied?
- What sprays/chemicals have been used on this property?
- Spray diaries and spray regimes?
- Have there been any earthworks?
- What crops are currently grown?
- Previous crops and their location?
- What was the previous land use?
- When was the property developed?
- Neighbouring land uses?
- Were any one-off crops grown?
- How often were the trees or vines replanted?
- Has the property been plowed or cultivated and if so to what depth?
- Were any areas more intensively sprayed?

Several difficulties were encountered gathering information on the site history. Very little information had been recorded by property owners on activities including spray schedules, crops and replanting that had taken place on the property. Often owners were unable to provide much site history prior to the 1950s. Few of the current owners knew much about activities occurring under the previous owners. Due to the site confidentiality aspect of the project, land titles and land information memoranda (LIMs) were not searched.

2.3 SAMPLING PROTOCOL

The sampling strategy was designed to provide an average level of contaminants over a representative area of the growing or grazing area of the property (Figure 1). It is assumed that as the chemicals were applied over the entirety of the cropping area that the contaminants will be relatively evenly distributed in the cropping areas (NSWEPA 1995). The Ministry for the Environment and Ministry of Health's Health

and Environmental Guidelines for Selected Timber Treatment Chemicals (MfE 1997) states that:

"Where chronic human exposure to ground contamination is the primary concern, it is reasonable to compare average concentrations rather than the maximum measured concentration with the proposed acceptance criteria."

The sampling strategy was not designed to detect hotspots.

Soil cores were collected to a nominal depth of 7.5 cm using a stainless steel foot soil corer with a diameter of 2.5 cm. The sampling depth of 7.5 cm was chosen as this depth represents the immediate surface layer that a future user (e.g. a child) of the site would be exposed to as well as the material that could potentially enter an adjacent waterway (Nortcliff 2001). The Public Health Commission (Graham and Bates 1996) recommended that preliminary sampling on a site to determine soil contamination should be carried out to a nominal depth of 5 to 10 cm.

A "Z" sampling pattern, as shown in Figure 1, was used to collect one aggregate sample from one representative hectare from the cropping area. Each aggregate sample comprised 10 soil cores. This sampling pattern ensured that there was sufficient sample for analysis as well as ensuring that a representative sample had been collected from that area. The "Z" sampling pattern is appropriate for assessing widely-spread contamination in a representative manner, and is used on dairy farms in New Zealand to determine soil DDT levels. This type of sampling pattern was used by Boul *et al.* (1994) to collect soil samples from pasture that had been treated with DDT.

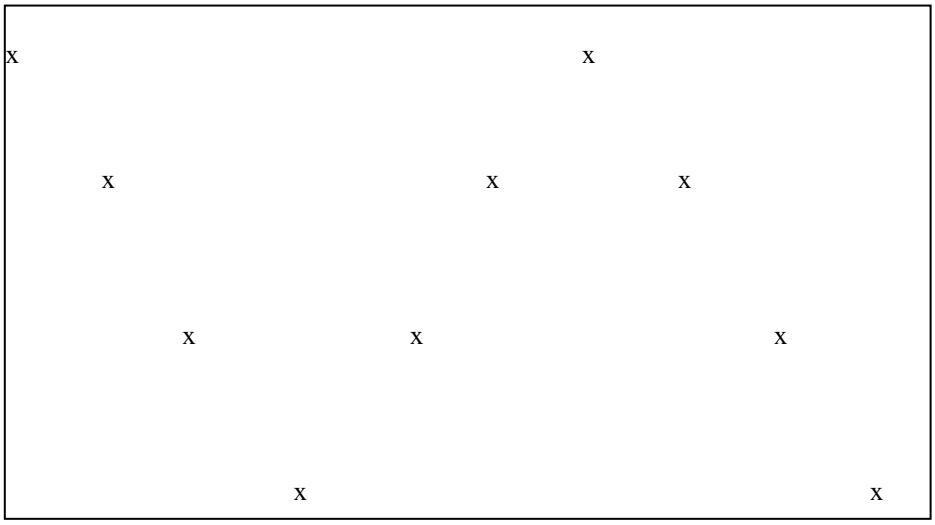

Figure 1 The sampling pattern used on cropping areas. Each aggregate sample contained 10 soil cores collected from a representative hectare of the cropping or grazing area.

All overlaying fresh (*e.g.* grass) and weakly decomposed organic matter was removed with a stainless steel trowel before sampling. Soil cores were collected into zip-locked plastic bags. Samples were double-bagged and transported on ice. The soil samples were stored at 5 °C.

Samples were given a unique code that identified both the property and the sample; bags were pre-labelled and labels were covered with waterproof tape. Any information collected while on the property was recorded on the sampling sheet for the property. This included neighbouring land use, cropping history and spray history (if available).

The following procedures were used to minimise contamination of the samples during sample collection and transport.

- disposable nitrile gloves were worn by the field staff and these were changed between cropping areas and hotspots on a property;
- during sampling care was taken to avoid contact of the soil cores with any item other than the soil corer. If required, a stainless steel bar was used to dislodge samples from the soil corer;

- samples were double-bagged once collected;
- direct contact with the soil cores was avoided once they had been collected;
- sampling in wet weather was avoided, in order to prevent the field staff from carrying material on their clothes between properties.

2.4 CLEANING OF FIELD SAMPLING EQUIPMENT

Sampling equipment was cleaned at the beginning of the day's sampling, between properties and prior to collecting any hotspot samples. If more than one cropping area was sampled on a property, the sampling equipment was cleaned in between. The soil corer and trowel were cleaned by scrubbing with a solution containing Decon 90™, a phosphate-free laboratory grade detergent, followed by rinsing with tap water followed by triple rinsing with distilled water. A three bucket system was used: the first bucket was used for detergent washing, the second for rinsing with tap water and the final for rinsing with distilled water. Once cleaned, the sampling equipment was placed in new plastic bags for transport. Before commencing sampling, the cleaned stainless steel soil corer was used to collect a minimum of six soil cores which were discarded. This acted as an extra cleaning step.

2.5 FIELDWORK HEALTH AND SAFETY

Property owners were asked to identify any hazards on their property during the initial telephone interview and these were recorded on the site sampling form. The most frequently identified hazard was large dogs. Other hazards included electric fences, blast sprayers and curious stock. Field staff wore nitrile gloves while sampling. No food or drink was consumed while on any property or before hands had been washed.

2.6 SAMPLE PREPARATION

Samples were initially transported on ice to a laboratory at the University of Waikato. The soil cores cores for each 1 hectare area were mechanically homogenised. A representative subsample of each sample was dried in an oven at 30 °C for 5 days and

sieved to <2 mm prior to being submitted to Hill Laboratories for trace element and organochlorine pesticide analyses. Sample analysis was undertaken on the <2 mm fraction.

2.7 SAMPLE ANALYSIS

Oven dried (30 °C) homogenised <2 mm soil samples were submitted to Hill Laboratories (Hamilton), an IANZ accredited laboratory, for analysis by routine commercial methods. The samples were analysed for trace elements and organochlorine pesticides as these were the contaminants most frequently detected in the Auckand region. The analysis suites are listed in Table 9. Two duplicate samples and one certified reference material sample (CW 7401 Soil, National Research Centre for CRMs (trace elements) were also submitted for analysis. All results are presented on a dry weight basis. Organic contaminant data has not been adjusted for recoveries. A brief overview of the extraction procedures and instrumental methods employed by Hill Laboratories for each analyte class is provided below.

Table 9 Analysis suites

Trace Elements	**Organochlorines**
Antimony	Aldrin
Arsenic	α-BHC
Boron	β-BHC
Cadmium	γ-BHC
Chromium	Chlordane
Cobalt	cis-Chlordane
Copper	trans-chlordane
Iron	ΣDDT
Lead	Dieldrin
Manganese	ΣEndosulfan
Mercury	Endrin
Molybdenum	Endrin Aldehyde
Nickel	Heptachlor
Tin	Heptachlor epoxide
Zinc	Methoxychlor

2.7.1. ORGANOCHLORINE PESTICIDES

Air dried and ground soil (<2 mm) was pre-wet with phosphoric acid followed by sonication extraction (Sonorex digital 10P Sonicator) using 1:1 hexane and acetone. Extracts underwent a florisil cleanup and were analysed by GC-ECD (Agilent 6890 plus with micro ECD detector) analysis with internal standard calibration. The GC parameters were as follows. Oven; initial temperature 120 °C, 60 °C/minute ramp to 220 °C, 5 °C/minute ramp to 250 °C, 30 °C/minute ramp to 300 °C, hold for one minute. Inlet: Pulsed splitless 1 μL injection, 250 °C, pulse time 0.5 minutes. Column type: SGE BPX50 GC column, 0.25 mm ID x 0.25 μm film thickness x 30 m column length.

A procedural blank was included with each batch of samples. Concentrations of target analytes in all procedural blanks were found to be less than their detection limits. An internal QC sample was analysed with each batch. This QC soil sample is comprised of a bulk homogenous field contaminated sample, which has been fully characterised both in house and by inter-laboratory comparison. Samples were spiked with 0.2 mg kg^{-1} equivalent pentabromobiphenyl as a system monitoring compound. Recoveries were in the range 75 to 122%. A sample duplicate was included in each batch and the percent difference for sample duplicates was ≤ 20%. One sample was spiked with 0.05 mg kg^{-1} of the full suite of organochlorine pesticides. Recoveries were within the range 66 to 104% with the exception of methoxychlor (191%) and endrin aldehyde (52%). Methoxychlor was not detected in any sample in this survey.

2.7.2 TRACE ELEMENTS IN SOIL

Trace elements were determined using US-EPA Method 200.2, Total Recoverable Metals in Soils/Sediments/Sludges. Air dried (<2 mm) samples were digested by a moderate HNO_3/HCl acid digestion at 85 °C for 45 minutes. The extracts were diluted and determined by ICP-MS (Elan 6000). A procedural blank was included with each batch of samples and concentrations of target trace elements in procedural

blanks were less than their detection limits. An internal QC sample was analysed with each batch of samples A duplicate sample was also analysed in each batch.

Two air-dried <2 mm blind duplicates and one certified reference material sample (CW 7401 Soil, National Research Centre for CRMs) were submitted to the laboratory for trace metal analysis. The recoveries for the certified reference material for arsenic, cadmium, copper, lead, mercury and zinc were in the range 86 to 107%. The trace element results for the 2 blind duplicates were within 20% except for trace element levels close to the detection limit (Appendix B).

3.0 RESULTS

3.1 OVERVIEW

Where the results were less than the limit of detection, a value of zero was used to enable statistical analysis. This is the conservative approach to the issue of how to deal with such data and ensures that pesticide and trace element residue levels in soil are not overestimated. All statistical calculations were performed using the software programme Minitab Release 12.22 (1999).

Data Reporting

- All concentrations are reported in mg kg^{-1} dry weight.
- The minimum value reported is the lowest concentration detected in a sample. Where these values are less than the detection limit they are reported as less than the specified laboratory value limit *e.g.* <0.01.
- The median value is the central value of the data. It is the middle numerical value.
- The mean value is the average value. It is obtained by dividing the sum of the individual values by the number of values.
- The data has been reported three ways; by landuse type and combined into two groups " horticulture" (all horticultural sites, n = 20) and "overall" (all sites included in the survey, n = 25).

3.2 SITE HISTORIES

There was a paucity of information available on the cropping and spraying activities for most of the properties. Owners have recorded very little information over time, and many of the sites had changed ownership. This lack of information suggests that site history alone cannot be relied upon when determining whether a former horticultural property is suitable for residential subdivision. A summary of the site history information is presented here.

Many of the properties had more than one type or age of cropping area on the property. On several of the older properties it was not uncommon to find two or more

distinct horticultural activities occurring concurrently. For example both tobacco and raspberries had been grown on some properties. Stock was also grazed on many of the horticultural properties sampled.

3.2.1 BERRIES

Raspberries and boysenberries are the main berry varieties grown in the Tasman District. It was common practice to cultivate to a depth of 10 to 15 cm between the rows on berry properties to control club root and improve irrigation. Lupins were occasionally grown between the rows and then used as mulch. No other cash crops were grown between the rows on berry properties. Several owners recalled using copper based fungicides, DDT emulsions and dieldrin. Pre-emergent herbicides are also used on berryfruit properties.

3.2.2 MARKET GARDENS

Current crops grown within the Tasman District include lettuce, cabbage, celery, onions, silver beet and potatoes. Tomatoes were previously grown on several properties. Market garden soils were ploughed between crops and on some properties, stones were manually removed. Generally soils were not continuously cropped; rather they were cropped for 4 to 5 years and then grassed down for a period of several years.

Owners recalled using DDT and lindane. Several of the growers are still using copper based fungicides. Soil amendments applied to market garden soils included animal manure and fertilisers, slag and blood and bone.

3.2.3 ORCHARDS

Prior to the late 1960s it was common practice to cultivate between the rows of fruit trees with discs. This practice was stopped to reduce erosion and replaced by grassing down between the rows. Herbicide strips around the base of the trees were visible on all of the properties sampled. Sheep were grazed over the winter on several

of the orchards sampled. Trees were generally replaced every 15 years. On some properties, new varieties were grafted onto old rootstocks.

Owners recalled using DDD, DDT, copper sprays and dithiocarbamate pesticides. Several orchardists recalled removing lead-arsenate from spraysheds. Lime, fertilisers and animal manures are also applied to orchard soils. Boron and zinc are added in some fertilisers as soils are deficient..

3.2.4 TOBACCO LAND

All of the tobacco land has now been converted to another landuse. Cover crops were grown between annual tobacco crops on some properties. Tobacco was planted in ridges. The rows were four feet apart with the plants spaced 15 to 21 inches (21-53 cm) apart in the row. The rows were cultivated to prevent the growth of weeds. Owners recalled using DDT emulsions to control chewing insects including cut grub and one owner recalled using an airplane to spray tobacco land with DDT. Fertilisers containing copper, boron and zinc were added to tobacco land.

3.2.5 GRAZING

Potash and lime had been added to some grazing soils. Several of the owners recalled using DDT to control grassgrub. Fertiliser had also been added to many grazing properties.

3.3 ORGANOCHLORINE PESTICIDES

3.3.1 ∑DDT

DDT and/or its degradation products (DDE and DDD) were detected in 24 out of the 25 samples collected. The values for both isomers of DDT (i.e. *o,p*- and *p,p´*-) and their breakdown products (DDE and DDD) have been combined and are reported as a single figure ΣDDT (Table 10). ΣDDT levels in horticultural soils ranged from 0.03 to 7.14 mg kg^{-1} with a median value of 0.99 mg kg^{-1} and in grazing soils from <0.03

to 1.30 mg kg^{-1} with a median value of 0.1 mg kg^{-1}. Orchard soils had the highest median ΣDDT level (3.09 mg kg^{-1}). Median ΣDDT levels follow in the order orchards>tobacco >berries >market gardens = grazing. The comparatively higher figure for orchards compared with market gardens is in agreement with the results of Wan *et al.* (1989) who found higher levels of ΣDDT in Australian orchard soils than in vegetable cropping soils. This trend was also observed in the Auckland region (Gaw 2002). The difference in ΣDDT levels between grazing and horticultural properties may be due to more frequent use on horticultural properties. DDT was applied once every three years on grazing properties (Roberts *et al.* 1996) whereas it was applied several times per year on horticultural properties (Atkinson *et al.* 1956).

Table 10 Summary statistics for ∑DDT residues in rural soils in the Tasman District. Units are mg kg^{-1} dry weight.

	No of samples	No. of positives	Min	Max	Median	Mean
Landuse						
Berries	5	5	0.03	5.46	0.32	1.34
Market gardens	5	5	0.06	1.16	0.10	0.31
Orchards	5	5	1.49	7.14	3.09	3.66
Tobacco	5	5	0.24	6.38	1.73	2.89
Grazing	5	4	<0.03	1.30	0.10	0.48
Summary						
Horticulture	20	20	0.03	7.14	0.99	2.05
Overall	25	24	<0.03	7.14	0.82	1.74

The median value of ΣDDT measured in Tasman rural soils (0.82 mg kg^{-1}) in this survey exceeds the maximum background levels of *p,p´*-DDT (0.034-2.70 µg kg^{-1}) and *p,p´*-DDE (0.048-2.69 µg kg^{-1}) measured by Buckland *et al.* (1998) in New Zealand indigenous forest soils.

The ΣDDT levels in Tasman horticultural soils are comparable to those measured in the Auckland region (<0.03 to 289 mg kg^{-1}). The median value for ΣDDT in Tasman soils was 3.09 mg kg^{-1} compared to 1.17 mg kg^{-1} for the Auckland region (Gaw 2002).

The ΣDDT levels measured in pasture sites in this survey are comparable with those reported for grazing properties elsewhere in New Zealand. Orchard *et al.* (1991) carried out experiments on the degradation of DDT in New Zealand soils using three agricultural soils with ΣDDT levels (top 5 cm) of 2.6, 1.3 and 0.004 mg kg^{-1}. The mean value for ΣDDT residues in paddocks on Canterbury farms was 0.27 mg kg^{-1} and only 7% of paddocks sampled had ΣDDT levels greater than 1.0 mg kg^{-1}.

The ΣDDT levels measured in cropping areas on horticultural properties are comparable with those reported in the international literature. Market garden and orchard soils from NSW had ΣDDT levels in the range from not detected[2] to 2.95 mg kg^{-1} (NSWEPA 1995a). Harris *et al.* (2000) measured ΣDDT in orchard soils in Canada 20 years after DDT had last been applied. They report mean ΣDDT levels of 1.9, 7.1 and 14.4 mg kg^{-1} for the top 10 cm of soil from orchards from three fruit growing regions. Szeto and Price (1991) report ΣDDT levels of 0.01 to 7.2 mg kg^{-1} for market garden soils in British Columbia. The market gardens sampled in the Tasman district had lower ΣDDT levels than those reported in the British Columbia study.

3.3.2 DIELDRIN

Dieldrin was detected on all tobacco properties (0.006 to 0.095 mg kg^{-1}) and on one grazing property (0.005 mg kg^{-1}) (Table 11). The dieldrin levels measured in cropping areas on tobacco properties are comparable with the maximum level of 0.042 mg kg^{-1} measured by Buckland *et al.* (1998) for background New Zealand soils. In comparison, dieldrin levels in Auckland cropping soils ranged from <0.005 to 0.56 mg kg^{-1}. The dieldrin levels measured in cropping areas on horticultural properties in the Tasman District are similar to those measured in comparable overseas studies. The NSWEPA (1995) reports dieldrin levels in range of not detected to 0.49 mg kg^{-1} in soil samples from 9 market garden properties. Dieldrin was not detected in a survey of soils used for vegetable and tropical fruit production in New South Wales (Wan *et al.* 1989). The maximum dieldrin level measured by Wang and Webber

(1995) in Canadian agricultural soils was 0.01 mg kg^{-1}. However Szeto and Price (1991) measured dieldrin levels of 0.1 to 1.3 mg kg^{-1} on 4 market garden properties in British Columbia. Martijn *et al.* (1993) measured a dieldrin level of 0.43 mg kg^{-1} in an experimental plot that had had dieldrin applied to it over a 15 year time period. At the time of sampling, dieldrin had not been applied for 29 years.

Table 11 Summary statistics for dieldrin residues in rural soils in the Tasman District. Units are mg kg^{-1} dry weight.

	No. of samples	No. of positives	Min	Max
Landuse				
Berries	5	0	<0.005	<0.005
Market gardens	5	0	<0.005	<0.005
Orchards	5	0	<0.005	<0.005
Tobacco	5	5	0.006	0.095
Grazing	5	1	<0.005	0.005
Summary				
Horticultural	20	5	0.006	0.095
Overall	25	6	<0.005	0.095

3.3.3 OTHER ORGANOCHLORINE PESTICIDES

∑Endosulfan was detected once on a berryfruit property (0.30 mg kg^{-1}) and chlordane residues (cis, trans and total isomers = 0.04 mg kg^{-1}) in one grazing sample. Endosulfan is an organochlorine pesticide that is still registered for use in New Zealand under the tradename Thiodan to control chewing and sucking insects (Fussell and Walton 2001). The endosulfan residues detected are most likely due to recent use.

3.4 TRACE ELEMENTS

3.4.1 OVERVIEW

Soil samples were analysed for the following suite of trace elements: antimony, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury,

molybdenum, nickel, tin and zinc. All of the trace elements except boron were detected in soil samples collected from cropping areas on horticultural properties in the Tasman District. This is not unexpected because all of the trace elements assayed occur naturally in soil, in contrast to the situation with synthetic organic compounds. The maximum, minimum and median values for all trace element levels in cropping and grazing soils are listed in Appendix B.

3.4.2 ARSENIC

Arsenic levels above the detection limit were measured in 16 out of 20 samples collected in horticultural soils and in 2 out of 5 samples collected from grazing sites. Arsenic levels in horticultural soils ranged from <2 to 48 mg kg^{-1} with a median value of 3 mg kg^{-1} (Table 12). In comparison arsenic levels in grazing soils ranged from <2 to 48 mg kg^{-1}. Orchards had the highest median arsenic value (33 mg kg^{-1}). The elevated arsenic levels in the orchard samples are most likely due to the use of lead arsenate as a pesticide to control chewing insects.

Table 12 Summary statistics for arsenic residues in rural soils in the Tasman District. Units are mg kg^{-1} dry weight.

	No. of samples	Min	Max	Median	Mean
Landuse					
Berries	5	<2	4	2	2
Market gardens	5	2	21	10	10
Orchards	5	3	48	33	30
Tobacco	5	<2	3	<2	<2
Grazing	5	<2	7	<2	2
Summary					
Horticulture	20	<2	48	3	11
Overall	25	<2	48	3	9

Higher levels of arsenic (median 33 mg kg^{-1}) were found on orchards in the Tasman District than in the Auckland region (median 11 mg kg^{-1}) (Gaw 2002); this may be a result of a longer period of use of lead-arsenate pesticides. Lead arsenate was still

being recommended for use on orchards in the Nelson area in 1967 as resistance to DDD had occurred (The New Zealand Fruitgrowers Federation 1967).

Arsenic levels in cropping areas measured in this study are within the range reported by Merwin *et al.* (1994) for old orchard soils in New York State (1.6 to 141 mg kg^{-1}). The USEPA reported arsenic levels of between 3.1 and 114 mg kg^{-1} in the cropping area of an old orchard that had been converted to a residential subdivision (USEPA 2001). Lower levels of arsenic (not detected to 9.0 mg kg^{-1}) were reported by the NSWEPA (1995) in a survey of orchard and market garden properties in NSW, Australia.

3.4.3 CADMIUM

Cadmium values ranged from 0.1 to 1.0 mg kg^{-1} in Tasman rural soils (Table 13). The median value for horticultural soils was 0.3 mg kg^{-1} and the median value for grazing soils was 0.2 mg kg^{-1}. Orchards had the highest median value (0.4 mg kg^{-1}) followed by tobacco (0.3 mg kg^{-1}).

Table 13 Summary statistics for cadmium residues in rural soils in the Tasman District. Units are mg kg^{-1} dry weight.

	No. of samples	Min	Max	Median	Mean
Landuse					
Berries	5	0.2	0.6	0.2	0.3
Market gardens	5	0.1	0.4	0.2	0.2
Orchards	5	0.3	1.0	0.4	0.5
Tobacco	5	0.2	0.7	0.3	0.3
Grazing	5	<0.1	0.9	0.2	0.4
Summary					
Horticulture	20	0.1	1.0	0.3	0.3
Overall	25	<0.1	1.0	0.3	0.3

The results for cadmium residues in horticultural soils in the Tasman District are in keeping with those reported for horticultural properties in the Auckland region (<0.1 to 1.1 mg kg^{-1}) (Gaw 2002). Roberts *et al.* (1994) measured cadmium levels on 312

pastoral properties and 86 non agricultural sites. They reported an average cadmium level of 0.44 mg kg^{-1} for pastoral sites and 0.20 mg kg^{-1} for non agricultural sites. The elevated cadmium levels in several of the samples collected from the Tasman District are most likely due to the use of fertilisers which have been associated with elevated cadmium levels elsewhere in New Zealand (Taylor and Percival 2001). Taylor (1997) compared acid-extractable Cd in archived soils from pastoral sites with present day soil samples from the same sites. He found that mean levels of acid extractable cadmium had increased from 0.39 to 0.58 mg kg^{-1} and that the source of the cadmium was phosphate fertiliser.

3.4.4 COPPER

Copper values in cropping areas ranged from 5 to 123 mg kg^{-1} with a median value of 35 mg kg^{-1} (Table 14). Of the horticultural properties, orchards had the greatest range of copper values followed by market gardens. Overall horticultural properties had higher levels of copper in soil than grazing properties and this is most likely due to the use of copper based fungicides on horticultural properties.

Table 14 Summary statistics for copper residues in rural soils in the Tasman District. Units are mg kg^{-1} dry weight.

	No. of samples	Min	Max	Median	Mean
Landuse					
Berries	5	15	111	20	41
Market gardens	5	6	67	37	40
Orchards	5	10	123	60	58
Tobacco	5	7	40	30	27
Grazing	5	5	55	8	19
Summary					
Horticulture	20	6	123	35	41
Overall	25	5	123	30	37

Overall lower levels of copper were detected in horticultural soils in the Tasman District (6-123 mg kg^{-1}) than in the Auckland region (7-490 mg kg^{-1}). This may be due to less intensive use of copper based fungicides. The copper levels reported here

for Tasman orchards are in agreement with Holland and Solomona (1999) who reported copper levels in the range 100 to 250 mg kg^{-1} for 4 Nelson orchards. Morgan and Bowden (1993) reported mean copper levels of 126 and 87 mg kg^{-1} in soils on two Central Otago apricot orchards.

Merry *et al.* (1983) measured copper levels in Tasmanian and South Australian orchards, these were in the range of 11 to 320 mg kg^{-1}. The highest copper level measured in a cropping area on an orchard as part of this survey was 123 mg kg^{-1}.

3.4.5 LEAD

Lead levels in horticultural soils ranged from 5 to 243 mg kg^{-1} with a median value of 12 mg kg^{-1} (Table 15). In comparison lead levels in grazing sites ranged from 6 to 11 mg kg^{-1}. Orchards had the highest median lead value (149 mg kg^{-1}). The elevated lead levels in the orchard samples are most likely due to the use of lead arsenate as a pesticide to control chewing insects.

Table 15 Summary statistics for lead residues in rural soils in the Tasman District. Units are mg kg^{-1} dry weight.

	No. of samples	Min	Max	Median	Mean
Landuse					
Berries	5	8	14	10	11
Market gardens	5	8	21	12	13
Orchards	5	15	243	165	149
Tobacco	5	5	16	8	10
Grazing	5	6	11	8	9
Summary					
Horticulture	20	5	243	12	46
Overall	25	5	243	11	38

Higher levels of lead (15-243 mg kg^{-1}) were found on orchards in the Tasman District than in the Auckland region (11-178 mg kg^{-1}) (Gaw 2002) and this may be a result of a longer period of use of lead-arsenate pesticides in the Nelson region. Lead arsenate

was still being recommended for use on orchards in the Nelson area in 1967 as resistance to DDD had occurred (The New Zealand Fruitgrowers Federation 1967).

The range of lead levels found in orchards sampled as part of this study is lower than that reported by Merwin *et al.* (1994) for old orchard soils in New York State . Merry *et al.* (1983) report mean lead levels of 170 mg kg^{-1} for orchard soils in Tasmania and South Australia. Lead levels in some Tasman horticultural soils, particularly orchards exceed those found in the Dutch province of Zeeland (<5 to 104 mg kg^{-1}) (van Gaans *et al.* 1995).

3.4.6 TIN

Tin was only detected in samples collected from orchard sites (1 to 4 mg kg^{-1}) (Table 16). Organotin compounds were registered in New Zealand for use as fungicides and acaricides (Long 1983). Higher levels of tin were detected in Tasman orchards (median 3 mg kg^{-1}) than were previously reported for Auckland orchards (median 1 mg kg^{-1}) (Gaw 2002).

Table 16 Summary statistics for tin residues in rural soils in the Tasman District. Units are mg kg^{-1} dry weight.

	No. of samples	Min	Max	Median	Mean
Landuse					
Berries	5	<1	<1	<1	<1
Market gardens	5	<1	<1	<1	<1
Orchards	5	1	4	3	3
Tobacco	5	<1	<1	<1	<1
Grazing	5	<1	<1	<1	<1
Summary					
Horticulture	20	<1	4	<1	<1
Overall	25	<1	4	<1	<1

3.4.7 ZINC

Zinc values in horticultural soils ranged from 11 to 138 mg kg^{-1} and in grazing soils from 24 to 133 mg kg^{-1} (Table 17). The moderately elevated zinc levels measured on some properties may have several possible sources: zinc was and still is a constituent of some fungicides such as Zineb (Long 1983), and elevated zinc levels in New Zealand soils have also been associated with fertiliser use (Taylor and Percival 2001).

Table 17 Summary statistics for zinc residues in rural soils in the Tasman District. Units are mg kg^{-1} dry weight.

	No. of samples	Min	Max	Median	Mean
Landuse					
Berries	5	11	77	45	46
Market gardens	5	32	138	84	90
Orchards	5	33	97	78	70
Tobacco	5	34	77	67	63
Grazing	5	24	133	38	59
Summary					
Horticulture	20	11	138	71	67
Overall	25	11	138	67	65

The zinc levels measured in cropping areas from horticultural properties in the Tasman District are comparable to those measured elsewhere. The median zinc level in Auckland cropping soils was 53 mg kg^{-1} (Gaw 2002). In a survey of rural soil quality in the Netherlands, van Gaans *et al.* (1995) measured zinc levels in the range 7 to 95 mg kg^{-1}. The NSWEPA (1995a) collated data from consultants' reports from 9 market garden properties in NSW, Australia; zinc values were in the range 25 to 260 mg kg^{-1}.

3.5 COMPARISON TO TRIGGER LEVELS

3.5.1 SELECTION OF APPROPRIATE TRIGGER LEVELS

Conservative and provisional trigger levels were selected to put the data from the Auckland survey into context (Gaw 2002). For consistency, these trigger levels have also been used for the data collected in the Tasman District. These trigger levels are envisaged as initial Tier I screening (*i.e.* "is there an issue that warrants further investigation?") and are generic rather than site specific. Exceedance of any one trigger level indicates that further data assessment should be undertaken, including if necessary further sampling and analysis, but it does not and must not be assumed to indicate that there is a risk to human health for people living and/or working at the site. Such an assessment can only be made on a site-specific basis upon consideration of all the exposure pathways operating at the site.

Conservative guidelines were selected to protect human health under the most sensitive landuse scenario, which is considered to be lifestyle blocks with 50% produce (fruit and vegetables) ingestion. Where available, New Zealand risk-based trigger levels were selected. This is in accordance with the hierarchy developed for the selection of reference documents reporting trigger levels for contaminated site assessment (MfE 2002). In the absence of appropriate New Zealand guidelines, trigger levels were selected from international soil acceptance criteria.

3.5.1.1 AVAILABLE NEW ZEALAND GUIDELINES

There are a number of soil contaminant guidelines that have been developed for contaminated site assessment in New Zealand, and which can be used for assessing the data presented in this report. The Ministry for the Environment and the Ministry of Health (1997) have published Health and Environmental Guidelines for Selected Timber Treatment Chemicals, which provide trigger levels for copper, arsenic, boron and pentachlorophenol. The guideline considers multiple exposure pathways for these contaminants, including produce ingestion, soil ingestion and dermal contact. In 1992 the Department of Health published maximum soil limits for the application

of sewage sludge to land (metals only). The 1992 Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites (ANZECC 1992) contain risk based health investigation levels for selected contaminants and threshold environmental investigation levels. These health investigation levels do not consider uptake into plants and subsequent ingestion as an exposure route. The available New Zealand guidelines are compared in Table 18. Currently there are no New Zealand risk-based guidelines for organochlorine pesticide levels in soil.

Table 18 Available New Zealand Guidelines. Units are mg kg^{-1} dry weight.

Contaminant	**MfE/MoH[a]**	**ANZECC[b]**	**ANZECC[c]**	**DoH[d]**
Arsenic	30	100	20	10
Cadmium		20	3	3
Copper	80[e] 130[f]	-	60	140
∑DDT	-	-	-	-
Dieldrin	-	-	0.2	-
Lead	-	300	300	300
Tin		-	50	-
Zinc	-	-	200	300

[a] Health and Environmental Guidelines for Selected Timber Treatment Chemicals (Ministry for the Environment and Ministry of Health, 1997)

[b] Proposed Health Investigation Level Guidelines (ANZECC, 1992)

[c] Environmental Investigation Level Guidelines (ANZECC, 1992)

[d] Limit values allowable in soil for application of sewage sludge to arable land (Department of Health, 1992)

[e] 10% produce ingestion

[f] 50% produce ingestion

3.5.1.2 AVAILABLE INTERNATIONAL GUIDELINES

There are a large number of guidelines available internationally for contaminated soil. Four of the international soil acceptance criteria most commonly used in New Zealand are listed in Table 19. These guidelines have been developed (or are updates

of earlier guidelines) over the last few years, and therefore it can be assumed they are based on the most up to date knowledge of the toxicity and risk posed by these contaminants.

Table 19 International guidelines for contaminated soil. Units are mg kg^{-1} dry weight.

	USEPA Region 9[a]	NEPM[b]	CCME[c]	Dutch[d]
Arsenic	22*	100	12	55
Cadmium	-	20	1.4	12
Copper	2900	1000	63	190
ΣDDT[e]	1.7	200	0.7	4
Dieldrin	0.03	10	-	4
Lead	400	300	70	530
Tin	47000 (inorganic)	-	5	900
Zinc	23000	7000	200	720

[a] Preliminary Remediation Goals for residential soil. United States Environmental Protection Agency Region 9 (USEPA 2002). *The cancer risk value for arsenic is 0.39 mg kg^{-1}.

[b] National Environmental Protection Measure (NEPM), Australian Health Investigation Levels for residential category, (NEPC, 1999)

[c] Environmental Quality Guidelines (EQGs) for agricultural landuse, Canadian Council of Ministers for the Environment (CCME, 1999).

[d] Soil intervention values (Ministry of Housing, Spatial Planning and the Environment 1999)

[e] The NEPM, CCME and Dutch guidelines quoted are for total DDT (*i.e.* the sum of DDT, DDE and DDD). The USEPA Region 9 guideline quoted is for DDT only.

However, one area where overseas regulatory authorities may differ from each other in deriving trigger levels for contaminants in soil is in the methodologies followed and the exposure pathways that are assumed to operate at a site. The exposure pathways used to derive New Zealand and international soil acceptance criteria are compared in Table 20. Contaminant uptake into plants was considered as an exposure route for the derivation of the Health and Environmental Guidelines for Selected Timber Treatment Chemicals (Ministry for the Environment and Ministry of Health 1997). UESPA Region 9 excluded ingestion via plant, meat or dairy products raised on the property as an exposure route when calculating their preliminary remediation

goals (USEPA 2001b). The supporting documentation for the Australian NEPM health investigation levels specifically states that a site-specific risk assessment should be undertaken for "*residential settings with substantial vegetable gardens"* (NEPC 1999).

Table 20 Exposure pathways used to derive New Zealand and international risk-based soil acceptance criteria.

Exposure Scenario	NZ MfE and MoH	USEPA Region 9	CCME	NEPM
Soil ingestion	✓	✓	✓	✓
Dermal absorption	✓	✓	✓	✓
Inhalation	✓	✓	✓	✓
Consumption of home grown produce (50%)	✓		✓	
Protection of plant life	✓		✓	

Regulatory authorities also differ in what excess cancer risk they will tolerate. The cancer risk can never be zero, and for this reason it is necessary to set a "tolerable" level for excess cancers. The term "excess cancer" is used to distinguish cancer which is specifically due to the exposure to particular level of a potential carcinogen from the background cancer rate. The tolerable excess cancer risk therefore represents the number of additional cancers which might occur due to exposure to the carcinogen (usually over a 30 year time period), that the regulatory authority will tolerate. The New Zealand Health and Environmental Guidelines for Selected Timber Treatment Chemicals assume a 1 in 100,000 tolerable excess cancer risk. For some contaminants, the potential cancer risk becomes the primary "human health driver" behind the soil guideline number that has been set. Literally interpreted, the guideline number derived represents the point at which 1 person in 100,000 might go on to develop cancer specifically as a result of the exposure, over a 30 year time period. In comparison, the Dutch guidelines assume a 1 in 10,000 risk and the USEPA Region 9 bases its guidelines on a 1 in 1,000,000 risk.

3.5.1.3 RATIONALE FOR SELECTED TRIGGER LEVELS

Conservative trigger levels were selected to protect human health under the most sensitive land use scenario, which is considered to be lifestyle blocks with 50% produce (vegetables) ingestion (Table 21). Where available, (New Zealand risk-based guidelines were chosen (arsenic and copper). In the absence of New Zealand risk-based guidelines (ΣDDT, dieldrin, cadmium, lead, tin and zinc) trigger levels have been selected from overseas according to the procedures outlined in the draft *Contaminated Sites Guidelines No. 2. Hierarchy and Application of Environmental Acceptance Criteria in New Zealand* (Ministry for the Environment, 2002).

These trigger levels (ΣDDT, lead and zinc) were taken from the Canadian Environmental Quality Guidelines (EQGs) (CCME 1999) in preference to the USEPA Region 9 preliminary remediation goals and the Australian NEPM health investigation levels for two reasons.

i. The EQGs consider uptake of contaminants into plants and animals as well as soil ingestion, which is consistent with the approach taken in deriving the guidelines for copper and arsenic (Ministry for the Environment and Ministry of Health 1997). The hierarchy of environmental acceptance criteria (MfE 2002) states that "*preference should be given to those guidelines that employ risk assessment or acceptance criteria derivation similar to those adopted in New Zealand.*"

ii. The hierarchy for environmental acceptance criteria (MfE 2002) states that *"where several acceptance criteria values are available, the most conservative acceptance criteria should be used on consideration of all current and likely future users of the environmental medium under evaluation."*

The Canadian EQGs are generic guidelines designed to protect human and key ecological receptors. Soil quality guidelines are developed for both human health and ecological receptors and the most protective guideline is chosen as the recommended soil quality guideline. The following exposure routes were considered when deriving the agricultural land use soil guideline; soil contact (crops/plants, invertebrates,

nutrient cycling processes, livestock/wildlife), soil and food ingestion (livestock/wildlife) and human health (multi media exposure, child) (CCME 1999). The Canadian EQGs for agriculture were chosen for the purposes of this report as the ingestion of produce, meat and milk produced on site are considered for this landuse.

For dieldrin, in the absence of a Canadian EQG, the USEPA Region 9 value has been adopted. The USEPA Region 9 has set a risk based value of 0.03 mg kg^{-1} for a one in a million cancer risk. This is equivalent to a trigger level of 0.3 mg kg^{-1} for a one in 100,000 cancer risk, the incremental cancer risk level adopted in New Zealand risk based guidelines (MfE 2002). As discussed previously the USEPA did not consider uptake into edible plants as an exposure route when deriving the preliminary remediation goals, this value is likely to underpredict the health risk for situations where home-grown produce consumption occurs. The adjusted trigger level of 0.3 mg kg^{-1} is comparable to the New Zealand threshold value of 0.2 mg kg^{-1} (ANZECC, 1992).

Table 21 Trigger levels for contaminants in soil. Units are mg kg^{-1} dry weight.

	Trigger level	Source
Arsenic	30	a
Cadmium	1.4	b
Copper	80	a
ΣDDT	0.7	b
Dieldrin	0.3	c
Lead	70	b
Tin	5	b
Zinc	200	b

a Health and Environmental Guidelines for Selected Timber Treatment Chemicals for residential setting with 50% produce ingestion (Ministry for the Environment and Ministry of Health, 1997)

b Environmental Quality Guidelines (EQGs) for agricultural land use, Canadian Council of Ministers for the Environment (CCME, 1999).

c USEPA Region 9 Preliminary Remediation Goals -Residential soils adjusted for a one in 100,000 cancer risk (USEPA 2002)

3.5.2 COMPARISON WITH TRIGGER LEVELS

The results for each aggregate sample from either a cropping or grazing area have been compared with the trigger levels. In taking this approach it has been assumed that chemicals were applied relatively evenly over the cropping or grazing area. The NSWEPA Manual for Accredited Officers (1995b) states the following for potentially contaminated agricultural land *"If hotspots are not anticipated, it is acceptable to compare the average contamination levels with the investigation threshold levels to determine whether a site or an area is contaminated."*

The number of properties equal to or exceeding the trigger levels for contaminants in horticultural soils is listed in Table 22. Samples collected from horticultural properties exceeded the trigger levels for one or more of ΣDDT, copper, lead and arsenic on at least one property. Two of the grazing properties exceeded the trigger level for ΣDDT. All of the orchard samples exceeded at least one trigger level. One orchard sample exceeded 4 of the trigger levels and 2 orchard samples exceeded 3 of the trigger levels (Figure 2).

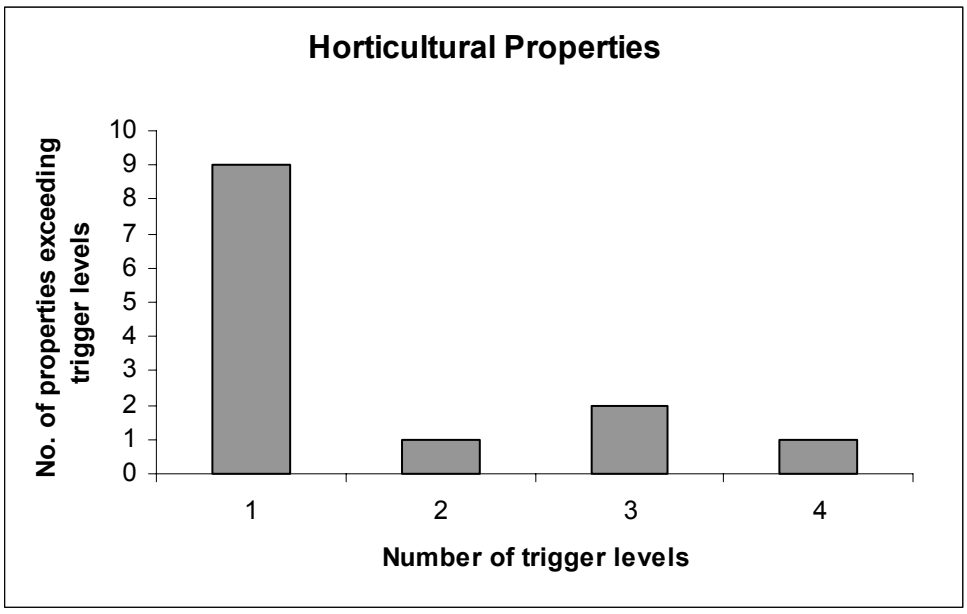

Figure 2 Number of horticultural properties equal to or exceeding selected trigger levels (Total number of horticultural properties sampled: 20).

Table 22 Number of horticultural properties with agrichemical residue levels in cropping area soils equal to or exceeding the selected trigger level. The overall figure is presented as a percentage.

	Orchards (n = 5)	Berries (n = 5)	Tobacco (n = 5)	Market Gardens (n = 5)	% Properties (n = 20)
	Number of properties equal to or exceeding the trigger level				
Arsenic	3	0	0	0	15
Copper	1	1	0	0	10
Lead	4	0	0	0	20
Zinc	0	0	0	0	0
∑DDT	5	2	4	1	60
Dieldrin	0	0	0	0	0

Overall 60% of properties (horticultural and grazing) sampled were equal to or exceeded at least one trigger level (including grazing sites in the data set). Approximately 65% of horticultural sites sampled were equal to or exceeded at least one trigger level (excluding grazing sites in the data set). These figures are comparable to those for the Auckland region where 70% of horticultural sites sampled were equal to or exceeded at least one trigger level (Gaw 2002).

3.5.2.1 ∑DDT

Approximately 60% of horticultural properties sampled were equal to or exceeded the Canadian environmental quality guideline for ∑DDT for agricultural landuse (0.7 mg kg^{-1}). All 5 orchard samples and 4 out of 5 tobacco samples contained ∑DDT levels equal to or exceeding the trigger level. Two of the samples collected from grazing paddocks with no known history of horticulture also contained ∑DDT levels equal to or exceeding the trigger level. In comparison 46% of the pre 1975 properties sampled in the Auckland region exceeded the trigger levels (Gaw 2002).

There are currently no New Zealand guidelines for DDT and its degradation products in soil. The risk based guideline for ∑DDT derived for the residential development of the former Fruitgrowers Federation factory at Mapua is 5 mg kg^{-1} (EGIS 2001); 4

samples collected from horticultural properties (2 tobacco, 1 berryfruit and 1 orchard property) contained ∑DDT levels equal to or exceeding this guideline.

Samples from 8 horticultural sites also exceed the USEPA Region 9's preliminary remediation goal for DDT (1.7 mg kg^{-1}) which is risk based for human health (at a 1 in 1,000,000 cancer risk). It should be noted that the USEPA Region 9 preliminary remediation goals are for soil ingestion only and do not consider situations where home-grown produce occurs. Lowe and Jamall (1994) calculated a "no significant risk level" (1 in 10^5 excess cancer risk) in soil for ∑DDT on former agricultural land in California of 7.9 mg kg^{-1}. Their exposure scenario included the following exposure pathways; soil ingestion, dermal contact with soil, inhalation, and ingestion of fruit and vegetable ingestion. None of the soil samples collected in the Tasman District exceeded this guideline.

3.5.2.2 DIELDRIN

Dieldrin was only detected in former tobacco soils. The dieldrin levels measured on former tobacco properties did not exceed the risk adjusted USEPA Region 9 level of 0.3 mg kg^{-1}. None of the properties sampled in the Tasman District have dieldrin levels equal to or exceeding the ANZECC 1992 environmental investigation level for dieldrin of 0.2 mg kg^{-1}. risk adjusted USEPA Region 9 preliminary remediation goal for dieldrin of 0.03 mg kg^{-1}.

3.5.2.3 ARSENIC

Orchards were the only landuse category with arsenic levels equal to or exceeding the New Zealand trigger level of 30 mg kg^{-1} (Ministry for the Environment and Ministry of Health 1997). Three out of five orchard samples contained elevated arsenic levels exceeding 30 mg kg^{-1}. Orchards were the only landuse category in the Auckland survey which exceeded the arsenic guideline value on at least one property (Gaw 2002).

3.5.2.4 CADMIUM

None of the cadmium levels measured in the Tasman District were equal to or exceeded the Canadian EQG for cadmium on agricultural sites (1.4 mg kg^{-1}). This trigger level was not exceeded on any of the properties sampled in the Auckland survey (Gaw 2002).

3.5.2.5 COPPER

Only 2 (10 %) horticultural properties sampled had soil copper levels equal to or exceeding the trigger level of 80 mg kg^{-1} and neither of these properties exceeded the Ministry for the Environment and Ministry of Health's soil guideline for copper on a property with 10% produce ingestion of 130 mg kg^{-1}. In comparison 43% of the pre-1975 horticultural properties sampled in the Auckland region had soil copper levels equal to or exceeding the trigger level of 80 mg kg^{-1}.

3.5.2.5 LEAD

Lead levels on 20% (4) of the horticultural properties sampled are equal to or exceed the Canadian EQG for lead on agricultural sites (70 mg kg^{-1}). All of these properties were orchards. None of the orchards sampled in the Tasman District exceeded the recommended soil replacement level for high contact areas of 400 mg kg^{-1} for soil contaminated by lead based paint (Ministry of Health 1998).

3.5.2.6 TIN

None of the properties sampled contained levels of tin equal to or exceeding the Canadian EQG for tin on agricultural sites (5 mg kg^{-1}). None of the samples collected in the Auckland survey exceeded the trigger level for tin (Gaw 2002).

3.5.2.7 ZINC

None of the soil samples collected contained zinc levels equal to or exceeding the Canadian EQG for zinc in soil on agricultural properties (200 mg kg^{-1}). Only 6% of the pre-1975 properties sampled in the Auckland region contained exceeded this value (Gaw 2002).

4.0 CONCLUSION

A survey of residual levels of organochlorine pesticides and trace elements in Tasman District Rural soils has been undertaken. Elevated levels of ΣDDT, lead, copper and arsenic were detected in this survey of horticultural and grazing soils in the Tasman District. The levels of contaminants found in cropping areas are comparable to those found in the Auckland region (Gaw 2002) and those found overseas for similar landuses. The levels of ΣDDT, lead, copper and arsenic in soil on some properties exceed conservative guidelines for the protection of human health and the environment. Approximately 65% of the horticultural soils sampled contained contaminant levels equal to, or exceeding, at least one of the trigger levels used in this report as generic Tier I screening levels.

The results from this study indicate that historic farming practices in the Tasman District including the use of agrichemicals have resulted in elevated levels of contaminants in rural soils. These elevated levels have the potential to impact on the suitability of rural land in its current state for residential development.

5.0 RECOMMENDATIONS

On the basis of the findings of this survey, the following recommendations can be made:

- That Tasman District Council consider requiring site assessments on rural properties prior to granting landuse consent for residential subdivision.

- That TDC take the potential for agrichemical contamination into consideration when considering any changes to regional and district plans.

- Future work in the area of rural contamination through agrichemical use could focus on:

i. Identification and sampling of potential hotspots (e.g. spray sheds, farm dumps, sheep dips (arsenic and dieldrin)) on rural properties. Hotspots are likely to contain similar chemicals to the cropping areas.

ii. Studies of the chemical behaviour of key contaminants e.g. depth profiles of contaminants.

iii. Sampling of other landuse types in the Waikato region e.g. maize.Identification of contaminants that are currently accumulating in soils, and measures that could be taken to reduce the likelihood of soil contamination.Identification of potential health hazards associated with modern spraying operations.Sampling of other landuse types in the Tasman District e.g. glasshouses and hop gardens.

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APPENDICES

APPENDIX A: Detection Limits

Table A1 Detection limits for trace elements and organochlorine pesticides. Units are mg kg^{-1} dry weight.

Trace Elements		**Organochlorines**	
Antimony	0.4	Aldrin	0.005
Arsenic	2	Alpha-BHC	0.005
Boron	20	Beta-BHC	0.005
Cadmium	0.1	Gamma-BHC	0.005
Chromium	2	Total Chlordane	0.02
Cobalt	0.4	cis-Chlordane	0.005
Copper	2	trans-chlordane	0.005
Iron	40	ΣDDT	0.03
Lead	0.4	Dieldrin	0.005
Manganese	1	ΣEndosulfan	0.015
Mercury	0.1	Endrin	0.005
Molybdenum	0.4	Endrin Aldehyde	0.005
Nickel	2	Heptachlor	0.005
Tin	1	Heptachlor epoxide	0.005
Zinc	4	Methoxychlor	0.005

APPENDIX B: Trace element summary statistics

Table B1 Summary statistics for all samples collected within a cropping area. Units are mg kg^{-1} dry weight. (Number of samples = 20)

Metal	Minimum	Maximum	Mean	Median
Antimony	<0.4	<0.4	<0.4	<0.4
Arsenic	<2	48	11	3
Boron	<20	<20	<20	<20
Cadmium	0.1	1.0	0.3	0.3
Chromium	3	188	48	17
Cobalt	0.6	35.1	11.3	7.4
Copper	6	123	41	35
Iron	2940	44200	20300	16000
Lead	5	243	46	12
Manganese	76	1250	460	336
Mercury	<0.1	0.5	<0.1	<0.1
Molybdenum	<0.4	1.5	<0.4	<0.4
Nickel	<2	320	54	14
Tin	<1	4	<1	<1
Zinc	11	138	67	71

Table B2 Summary statistics for all samples collected within a grazing area. Units are mg kg^{-1} dry weight. (Number of samples = 5)

Metal	Minimum	Maximum	Mean	Median
Antimony	<0.4	<0.4	<0.4	<0.4
Arsenic	<2	7	2	<2
Boron	<20	<20	<20	<20
Cadmium	<0.1	0.9	0.4	0.2
Chromium	6	130	57	11
Cobalt	1.9	30.7	12.1	4.3
Copper	5	55	19	8
Iron	6260	37400	20700	14300
Lead	5.7	11.1	8.5	8.3
Manganese	93	978	456	274
Mercury	<0.1	<0.1	<0.1	<0.1
Molybdenum	<0.4	0.4	<0.4	<0.4
Nickel	5	190	72	7
Tin	<1	<1	<1	<1
Zinc	24	133	59	38

Table B3 Median values for trace elements according to horticultural landuse**.** Units are mg kg^{-1} dry weight.

Landuse	Number of samples	Sb	As	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Hg	Mo	Ni	Sn	Zn
Berries	5	<0.4	2	<20	0.2	13	6.2	20	13900	10	299	<0.1	<0.4	12	<1	45
Market gardens	5	<0.4	10	<20	0.2	145	29.6	37	43200	12	1040	<0.1	0.5	138	<1	84
Orchards	5	<0.4	33	<20	0.4	8	1.3	60	8480	165	170	<0.1	<0.4	5	3	78
Tobacco	5	<0.4	<2	<20	0.3	15	7.6	30	19900	8	388	<0.1	<0.4	12	<1	67

APPENDIX C: Quality Control Data

Table C1 Comparative pesticide concentrations in primary and blind duplicate samples for detected pesticides. Organochlorine pesticide screen. Units are mg kg^{-1} dry weight.

Pesticide	Sample A		Sample B	
	Primary	Blind duplicate	Primary	Blind duplicate
∑DDT	0.99	0.64	4.21	4.97
Aldrin	< 0.005	< 0.005	< 0.005	< 0.005
Alpha-BHC	< 0.005	< 0.005	< 0.005	< 0.005
Beta-BHC	< 0.005	< 0.005	< 0.005	< 0.005
Delta-BHc	< 0.005	< 0.005	< 0.005	< 0.005
Gamma-BHC (Lindane)	< 0.005	< 0.005	< 0.005	< 0.005
Cis-chlordane	< 0.005	< 0.005	< 0.005	< 0.005
Trans-chlordane	< 0.005	< 0.005	< 0.005	< 0.005
Total chlordane	< 0.02	< 0.02	< 0.02	< 0.02
Dieldrin	0.005	< 0.005	< 0.005	< 0.005
∑Endosulphan	< 0.02	< 0.02	< 0.02	< 0.02
Endrin	< 0.005	< 0.005	< 0.005	< 0.005
Endrin aldehyde	< 0.005	< 0.005	< 0.005	< 0.005
Heptachlor	< 0.005	< 0.005	< 0.005	< 0.005
Heptachlor epoxide	< 0.005	< 0.005	< 0.005	< 0.005
Hexachlorobenzene	< 0.005	< 0.005	< 0.005	< 0.005
Methoxychlor	< 0.005	< 0.005	< 0.005	< 0.005

Table C2 Comparative trace element concentrations in primary and blind duplicate samples. Units are mg kg^{-1} dry weight.

Trace Element	Sample A		Sample B	
	Primary	Blind duplicate	Primary	Blind duplicate
Antimony	<0.4	<0.4	<0.4	<0.4
Arsenic	<2	<2	33	34
Boron	<20	<20	<20	<20
Cadmium	0.2	0.2	0.3	0.3
Chromium	10	11	9	8
Cobalt	4.9	4.9	1.6	1.7
Copper	5	5	67	72
Iron	9990	10400	7620	7720
Lead	7.5	7.7	165	170
Manganese	252	274	195	207
Mercury	<0.1	<0.1	<0.1	<0.1
Molybdenum	<0.4	<0.4	<0.4	<0.4
Nickel	8	9	8	6
Tin	<1	<1	1	1
Zinc	42	42	90	92