

Identifying, Investigating and Managing Risks Associated with Former Sheep-dip Sites

A guide for local authorities

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Contents

Acknowledgements	iii
Executive Summary	viii
1 Introduction	1
1.1 Background	1
1.2 Purpose	2
1.3 Structure	3
2 Characteristics of Sheep-dip Contamination	4
2.1 Dipping practices	4
2.2 Likely pattern of contamination	5
2.3 Chemicals used for sheep dipping	7
2.4 Exposure pathways and risks	8
Exposure pathways	8
Health risks	9
Ecological concerns	12
Summary of most common concerns for local authorities	12
3 Planners' Guide	13
3.1 Resource consent applications	13
3.2 Information management	17
4 Identifying Former Sheep-dip Sites	18
4.1 Structural evidence	18
4.2 Anecdotal evidence	18
4.3 Old aerial photographs and public records	19
4.4 Soil and water sampling	20
4.5 Screening food products	20
4.6 Sniffer dogs	20
5 Site Investigation	21
5.1 Overview	21
5.2 Objectives of the investigation	22
5.3 Data review and conceptual model	22
5.4 Sampling design and strategy	23
5.5 Collection of samples	24
5.6 Data interpretation	24
Assessing the results	24
Applying soil guideline values	25
Guideline values for off-site receptors	27
Site-specific risk assessment	28
5.7 Report data	29

6	Risk Management	31
6.1	Overview	31
6.2	Requirement for resource consent	32
6.3	Remediation action plans	33
6.4	Soil remediation options	33
	Excavation and replacement (dig and dump)	34
	Soil screening and soil washing	35
	<i>In situ</i> biological treatment/bio-remediation	35
	Electro-osmosis	36
	<i>In situ</i> soil mixing	36
6.5	Management of discharges during earthworks	37
6.6	Site validation investigation	38
6.7	Site management options and strategies	39
	Fencing	39
	Capping	40
	Excavation and on-site disposal	40
	Alternative land use	41
6.8	Risk management plans	41
6.9	Contamination below existing barriers	42
6.10	Groundwater contamination	42
6.11	Monitoring	43
7	Best Practice Tips for Common Sheep-dip Scenarios	44
7.1	Scenario 1	44
7.2	Scenario 2	46
7.3	Scenario 3	48
7.4	Sampling tips from a professional contaminated land practitioner	50
7.5	Cost estimates for investigation, reporting and remediation	50
	Investigation costs	51
	Reporting costs (mapping, cross-sections, text)	51
	Remediation costs	51
	Appendices	53
	Appendix 1: Checklist for Landowners to Assess Sheep-dip Sites and Management Options	53
	Appendix 2: Draft District Plan Provisions for Disused Sheep Dips	57
	Appendix 3: Current Legislation and the Role of Local Authorities	59
	Role of city and district councils (territorial authorities)	59
	Role of regional councils	60
	Resource Management Act 1991 (RMA)	60
	Local Government Official Information and Meetings Act 1987 (LGOIMA)	63
	Hazardous Substances and New Organisms Act 1996 (HSNO)	63
	Building Regulations 1992	64
	Health Act 1956	64
	Health and Safety in Employment Act 1992 (HSEA)	65
	Appendix 4: The Historical and Legal Context for Sheep Dipping	66
	Appendix 5: Applied Chemicals and their Toxicity	68
	Arsenic	68
	Copper	68
	Derris	69
	Organochlorines	69
	Organophosphates	70

Synthetic pyrethroids	71
Insect growth regulators	71
Toxicity of chemicals	71
Appendix 6: Soil Guideline Values	73
Derivation of dip-site-specific soil guideline values to protect human health	73
Soil guideline values to protect on-site ecological receptors	76
Appendix 7: Case Studies	77
Detailed investigations of selected Waikato sites	77
Investigation of soil and groundwater on the Kaikoura plain	80
Coromandel residential case study	82
Dip Road – case study of a sheep dip in public ownership	82
Appendix 8: Comparing Different Sheep-dip Sampling Strategies	86
Judgemental sampling	86
Statistically designed systematic sampling	86
Sniffer dog sampling	87
On-site characterisation methods/technologies	88
Appendix 9: International Practices	90
Australia	90
USA	88
Appendix 10: Photographs of Sheep-dip Structures	91
Glossary	95
References	97
Bibliography	100

Tables

Table 1:	Summary of chemicals used in New Zealand for treating sheep ectoparasites	7
Table 2:	Overview of the potential risks to people from disused sheep-dip sites	11
Table 3:	Typical period of use of sheep-dip chemicals of concern in New Zealand	15
Table 4:	Soil guideline values for human health (mg/kg)	26
Table 5:	Guideline values for drinking water	27
Table 6:	Guideline values for surface water and sediment	28
Table 7:	Checklist of reporting requirements	29
Table A.1:	List of historical sheep-dipping chemicals and products (not exhaustive)	55
Table A.2:	Summary of toxicological effects of chemicals of primary concern	71
Table A.3:	Summary of the exposure parameters for each land-use scenario	74
Table A.4:	Contaminant-specific parameters used to derive soil guideline values	75
Table A.5:	Summary of soil guideline values (mg/kg) for individual pathways	75
Table A.6:	Soil guideline values protective of on-site ecological receptors (mg/kg)	76

Figures

Figure 1:	Target groups and the related key sections of the guideline	3
Figure 2:	Dipping in Levin on 2 March 1906	4
Figure 3:	Sketch of sheep-dip site with associated structures and buildings	6
Figure 4:	Exposure pathways from disused sheep-dip sites	9
Figure 5:	Flow chart for consent applications associated with pastoral land	14
Figure 6:	Recommended approach to a site investigation	21
Figure A.1:	Advertisement for derris-based dip in <i>New Zealand Journal of Agriculture</i> , 1945	69
Figure A.2:	Advertisement for aldrin-based dip in <i>New Zealand Journal of Agriculture</i> , 1956	70
Figure A.3:	A typical swim-through dip with full immersion of sheep using a crutch	91
Figure A.4:	The U or divided swim bath	92
Figure A.5:	Island or ring bath	92
Figure A.6:	Pot bath with curved race and covered sump	92
Figure A.7:	Stewart reciprocating sheep shower	92
Figure A.8:	Cattle grazing next to disused sheep dip trench	93
Figure A.9:	Redundant pot dip with partially collapsed yards	93
Figure A.10:	Former pot dip with large, partially collapsed, holding yards	93
Figure A.11:	Pre-1930s pot dip for manually dipping one sheep at a time	94
Figure A.12:	Concrete remains of filled-in dip structure, still accessible to livestock	94
Figure A.13:	1970s/1980s mobile spray dip	94

Executive Summary

This guideline was developed to raise awareness among council staff and landowners about the risks associated with former sheep-dip sites. Old¹ sheep-dip sites are typically contaminated due to the historical use of persistent and toxic chemicals such as arsenic, dieldrin, DDT and lindane. Exposure to these chemicals is likely to be hazardous to human health and the environment. Some of the toxicological effects may include effects on the central nervous system, liver and kidney damage, dermal lesions, suppression of the immune system and cancer.

The guideline aims to help local authorities address their statutory responsibilities in ensuring that land is suitable for its specified use, and to avoid an unacceptable risk to people and the environment. At high risk are children playing in or around old sheep-dip sites and ingesting contaminated soil, and site occupants who grow their own food on the contaminated area. Many areas in New Zealand previously used for pastoral farming are being developed into more intensive cropping, horticultural, dairying and residential land uses. As a result, local authorities now come across this kind of “hotspot” contamination more frequently, and having guidance available is very helpful.

The guideline provides best practice for local authorities to identify and oversee the investigation, management and remediation of contaminated sheep-dip sites. In particular, they provide guidance on how to:

- identify and locate former sheep-dip sites
- assess the risks to human and animal health, and to the environment
- evaluate remediation and long-term management options.

The different steps in the process of assessing a former sheep-dip site (identifying, investigating and remediating) are outlined. Guidance is also given to determine the acceptable level of contamination for various land uses.

Practical advice is provided in the form of a checklist that can be given to landowners to help identify dip sites on their property. There is also a flow chart that local authorities can incorporate into their “business-as-usual” contaminated land identification and management processes (ie, assessing applications for subdivision and other resource consents). The guideline recommends site management and remediation options, and give practical tips for the investigation and remediation of a site.

Like other existing industry-based guidelines, this guideline targets a specific contamination type – in this case, that associated with old practices of sheep farming – and should be used in conjunction with the Ministry for the Environment’s Contaminated Land Management Guidelines series.

¹ The terms “old”, “former”, “historical” and “disused” are used synonymously throughout the guidelines for pre-1980 sheep-dip sites.

1 Introduction

1.1 Background

Treating sheep with an external chemical insecticide for economic and welfare reasons has been universal farming practice in New Zealand since the 19th century, and was in fact a requirement under various Acts of Parliament. Approaches have evolved from dipping animals in a chemical bath (a “sheep dip”) through to the modern preferred pour-on methods. As a result, across New Zealand it is estimated that thousands of former sheep-dip sites exist on both public and private land. Their numbers and locations are largely unknown.

Old sheep-dip sites are defined for the purposes of this guideline as those in operation prior to 1980 and subsequently disused. They are typically contaminated due to the historical use of persistent and toxic chemicals, including arsenic, dieldrin, DDT,² aldrin and lindane.³ Exposure to these chemicals may cause harm to humans, animals and the ecosystem. Potential risks arise through contact with contaminated soils, groundwater or surface water; eating food grown in or on contaminated soil; or eating animals that have ingested contaminated soil. This guideline has been developed by the Ministry for the Environment to help local authorities address the potential risks to human health and the environment from exposure to contaminants associated with sheep dips.

Many areas in New Zealand previously used for pastoral farming are now being developed into more intensive cropping, horticultural, dairying and residential land uses. These changes in land use are due partly to an increased demand for high-value crops and horticulture, and partly to the continued growth and spread of urban centres. However, the change in land use of sites previously used for sheep-dipping activities raises the risk for contaminant exposure to people. Development activities can also increase the migration of any residual contaminants from a site.

Throughout New Zealand, and worldwide, management of the chemicals used to treat animals for external parasites has improved. Modern insecticides are hazardous at the time of use, but they usually degrade readily in the environment. The potential risk to consumers, handlers and the environment has decreased accordingly. This guideline therefore focuses on the problems resulting from the *historical use* of environmentally persistent dipping chemicals.

² 1,1,1-trichloro-2,2-bis (4-chlorophenyl) ethane.

³ Gammexane is the commercial name for formulations based on purified γ -hexachlorocyclohexane, also known as lindane. Note that BHC refers to a mix of different isomers of hexachlorocyclohexanes.

1.2 Purpose

Due to the likely presence of sheep dips in pastoral areas, it is important that local authorities⁴ and district health boards are aware of the risk these contamination “hot spots” may pose to human health and the environment. The guideline provides best practice advice on how to identify potentially contaminated sheep-dip sites, and how to determine the level of contamination that is acceptable for various land uses. They also provide recommended practical site management and remediation options.

The main purpose of the guideline is to provide local authorities with practical guidance on:

- locating former sheep-dip sites
- assessing risks to human health and to the environment
- evaluating remediation and long-term management options.

The guideline presents the entire process – from sheep-dip identification and investigation, to site remediation or management – in a logical flow. A number of case studies highlight the highly variable nature of sheep-dip sites, and different scenarios illustrate practical remediation and management options, depending on the proposed land use and the extent of contamination.

Recent amendments to the Resource Management Act 1991 (RMA) have specified the functions of local authorities for managing contaminated land. The New Zealand Waste Strategy (Ministry for the Environment, 2002) includes targets for contaminated sites that reflect the importance of improving contaminated sites management and reporting at the local level. This guideline is intended to be used both by territorial authorities for land-use planning and by regional councils for the management of contaminated sites and the protection of human health and the environment. These two functions combine to ensure that land is suitable for its specified use, and to avoid an unacceptable risk to people and the environment.

In addition to these functions, a council may have a direct interest in this guideline as an owner of public land on which sheep-dipping activity has taken place. Under section 17 of the RMA, every person has a duty to avoid, remedy or mitigate adverse effects on the environment. This means that landowners (public and private) may be responsible for identifying sheep dips on their properties. The guideline should therefore be useful for landowners in general and other interested parties, including property developers, surveyors and consultants. Good cooperation between landowners and their councils in the process of identifying, investigating and remediating sheep-dip sites is strongly advised.

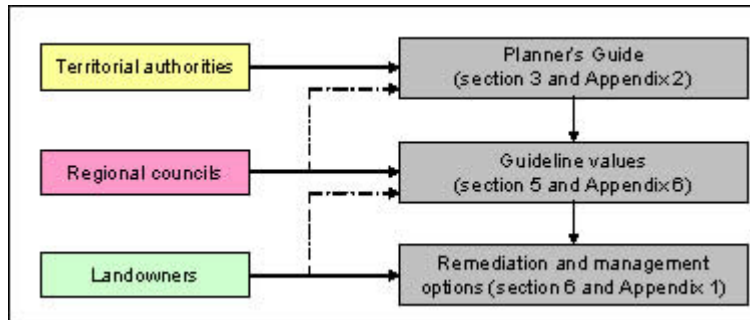
In addition to using this guideline, local authorities are encouraged to raise awareness among landowners. This could be done by a series of practical guidelines that address the potential risks to children who live on farms, occupational exposure of landowners/occupiers or remediators, livestock exposure, or contaminant residues in produce. A best practice approach for each landowner would be to record accurate information about the location of old dipping sites and any risk mitigation measures undertaken so that this information can be passed on to the next landowner.

⁴ For the purposes of this guideline, the term “local authorities” refers to the territorial authorities (ie, city and district councils), unitary authorities and regional councils.

1.3 Structure

The guideline addresses three target groups, as follows.

Figure 1: Target groups and the related key sections of the guideline



A local authority would ideally follow the proposed procedures in the Planner's Guide while taking into account the specific circumstances of a site. Not all sections in the guideline may be relevant to a particular situation, and sometimes simple management options can be applied.

Parts of the guideline particularly relevant to local authorities are:

- **section 3**, which describes a process that takes the user through a sequence of checking for the presence of sheep dips, assessing the risks of those identified, and ensuring the risks are adequately managed
- **Figure 5**, which contains a flow chart that local authorities may want to incorporate in their resource consent application process
- **Appendix 1**, which contains a checklist local authorities may want to supply to private landowners who are preparing their resource consent application and suspect that an old sheep dip might be on their property
- **Appendix 2**, which contains a draft district plan provision that can be used by territorial or unitary authorities as a template to incorporate into their district plans to provide for the management of sheep dips and the potential health risks arising from those sites.

In total, the guideline comprises seven sections, as follows.

1. **Introduction** – the purpose and structure of the guideline
2. **Characteristics of sheep-dip contamination** – sheep-dip practices, patterns of contamination, chemicals of concern, exposure pathways and risks
3. **Planners' guide** – a flow chart and checklist, plus guidance on information management for local authorities (especially relevant to resource consent applications)
4. **Identifying former sheep-dip sites** – practices and techniques to gather information on the presence of old sheep-dip sites
5. **Site investigation** – sampling and analysis, assessment of results and reporting
6. **Site remediation and risk management** – various options for managing the risks from, or remediating, former sheep-dip sites
7. **Best practice tips for common sheep-dip scenarios** – examples of possible approaches by local government to different situations.

2 Characteristics of Sheep-dip Contamination

2.1 Dipping practices

In New Zealand, historically most livestock farms had a sheep dip because sheep dipping was required by law. The current estimate is that there are around 50,000 sheep-dip sites across the country. This total is derived from stocking numbers and the number of sheep farm properties, and includes on-farm permanent structures, portable units, communal dip locations and spraying units. In addition, slab areas for applying powder and footbaths (containing, for example, arsenic, copper and zinc) to prevent footrot were often used on a sheep farm.

Sheep are affected by a number of external parasites that inhabit the fleece and feed on the wool, the skin and, in some cases, the flesh of the living animal itself. Sheep have no natural protection against these pests, which can cause considerable suffering, animal mortality and economic loss. Because sheep are protected by an oily fleece the treatment of pests is made more difficult. As a result, the chemicals used have to be potent and the dipping process thorough, in the past often involving complete immersion.

Initially, sheep in New Zealand were dipped to control scab, a small parasite living just under the skin that caused sheep to lose some of their condition. As a result of intensive sheep-dipping efforts, scab was eradicated in the late 19th century, with New Zealand declared free of the disease in 1894. The focus of sheep dipping then moved to controlling lice and keds, which are other parasites infecting sheep.

Figure 2: Dipping in Levin on 2 March 1906



Source: Adkin Collection, National Library.

In the early to mid-1800s the idea of using plunge-type dips was introduced as a dipping technique. These so-called “pot dips” were often shaped as a round bath, sometimes with the addition of an island in the centre. Pot dips were used with a variety of chemicals and were particularly popular for smaller flocks. Swim-through dips were also used from the outset of dipping, often on large stations. These dips always had a large amount of residual dip solution left over. Pot dips and swim-through dips were dug into the ground and lined with timber or concrete, creating a robust, semi-permanent structure.

Please see **Appendix 10** for photographs on typical sheep-dip structures.

The invention of the power-spray machine, which made its way to New Zealand by the mid-1940s, was a breakthrough for farmers, because this allowed a new and much faster method of dipping. Sheep did not have to be individually handled, as with previous dips. Instead, the sheep could be left in larger groups in the spray shower and saturation could still be easily achieved. Spray showers were constructed in above-ground structures, which included concrete enclosures, or steel piping and corrugated iron, and an underground sump for recycling dipping liquid. Contamination at these dip sites may not have been as severe compared to plunge or swim-through dips because very little dip was wasted and there was hardly any left-over dip to dispose of at the end.

Tip spraying was used for a relatively short time from the introduction of dieldrin and aldrin in 1955 to their withdrawal in 1961. Tip spraying worked by applying a high concentration of dip at high pressure onto the sheep, usually incorporating a mobile covered race with spray nozzles on either side and along the bottom to ensure that sheep were covered in dip as they ran through the race. The chemical would dissolve in the wool grease and then move towards the skin of the sheep where the parasites were located. Dusting also required the dissolving ability of the organochlorines and worked in a very similar way to tip spraying, except that the nozzles emitted dust and a blower carried the dust onto the sheep.

Jetting was, and is still, being used as additional protection against flystrike, and involves spraying the sheep through a handheld device with a highly concentrated insecticide. Recovery of “off-sheep” spent chemical is improbable. Since the 1980s the pour-on method has become popular to control flies, keds and lice. This method uses an applicator to place insecticide directly along the back of the sheep. The chemical then diffuses through the wool grease of the sheep. Both jetting and the pour-on method use chemicals such as synthetic pyrethroids or insect growth regulators that are of low toxicity for people and sheep, and hence are of lesser concern for the purpose of this guideline. They may, however, pose a risk to aquatic species if they get into waterways.

Antifungal footbaths were also used to prevent footrot, often in a separate location to the sheep-dip sites.

Finally, it should be noted that animal dips are not necessarily confined to sheep: a small number of cattle dips are confirmed in New Zealand.

2.2 Likely pattern of contamination

Due to the persistence of some of the main chemicals that were used historically in sheep dips and footbaths, these contaminants are likely to remain in the soil for years after dipping operations ceased. Some contaminants are highly likely to be present at concentrations that exceed the recommended human health or environmental criteria (see **section 5** and **Appendix 6**). This is usually the case for arsenic, often the case for dieldrin, and occasionally the case for lindane. It is common to find the highest levels of arsenic just below the surface layer due to its slow migration over time. However, generally speaking, on disused sheep-dip sites contamination does decrease with depth.

The migration of sheep-dip or footbath contaminants into aquatic environments may potentially cause adverse affects to humans, animals, aquatic animals and plants, and the wider ecosystem. On islands and properties located close to the foreshore, the dip contents were often discharged directly to the ocean. Humans living close to old sheep-dip sites may also inadvertently come into contact with these chemicals. The scale of historical use of individual dip sites may give an indication of the extent of contamination. For example, compare a communal dip processing 60,000 sheep per week from 1917 to about 1996, with a possibility of as many as 38,000,000 dip events, with a 400-sheep property used from about 1956 to 1960.

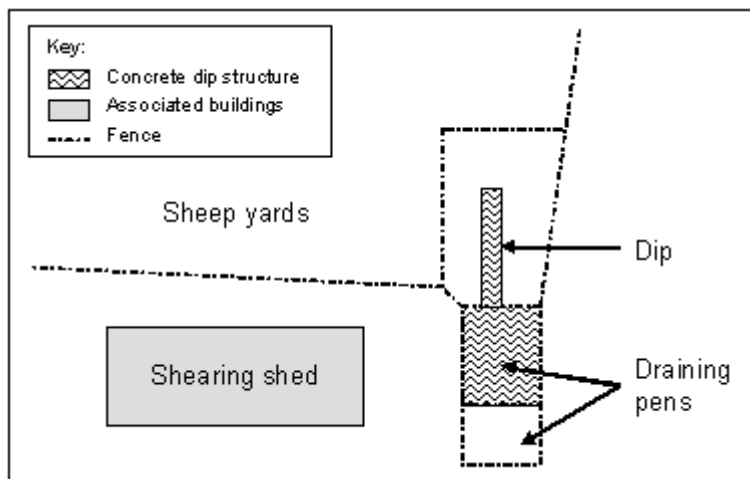
When investigating the risks from disused sheep dips, the focus is mainly on the actual site; that is, the location of the dip bath or structure, not the wider property. However, there are other potential areas of concern in the immediate surroundings. For example, the dip solution was often emptied into a burial pit close by, discharged by a pipe over a bank, or pumped out of the bath onto the adjoining yards and allowed to soak into the ground. The sludge from the bottom of the sump, potentially high in accumulated arsenic and organochlorines, was often shovelled out onto the ground alongside the dip (creating a so-called scooping mound).

Therefore, areas of concern include:

- beneath the dip bath and within the bath
- the area where the sheep-dip liquid was disposed of
- around the bath where dip chemicals may have splashed
- next to the dip bath where the sludge was disposed of
- the area where the sheep exited the sheep dip (the draining pen)
- the area where the sheep-dip chemicals were stored.

Depending on local topography and drainage, contamination may have spread some distance from the dip site itself. For example, surface-water run-off and/or groundwater movement may affect areas down-gradient of the former sheep-dip site (see **Figure 3**).

Figure 3: Sketch of sheep-dip site with associated structures and buildings



Although the focus of this guideline is on farmland, it needs to be stressed that dip sites may also have been located in stockyards, saleyards, railway yards and on other public land. See **Appendix 7** for some selected case studies of dip sites on public and private land.

2.3 Chemicals used for sheep dipping

Within New Zealand, a wide range of chemicals has been used historically to control sheep parasites (see **Table 1**). This guideline focuses primarily on the environmentally persistent chemicals that represent the greatest ongoing risk to human health, livestock and the environment: arsenic, and the organochlorines aldrin, dieldrin, DDT and lindane.

However, for the sake of completeness, brief reference is also made to derris (Rotenone), copper, organophosphate pesticides, synthetic pyrethroid insecticides and insect growth regulators. **Appendix 5** contains more detail on the historical application and toxic effects of these chemicals.

Other chemicals such as nicotine, zinc and phenols were used to a much lesser extent in New Zealand.

Table 1: Summary of chemicals used in New Zealand for treating sheep ectoparasites

Chemical*	Period of usage**
Arsenic	1840s–1980
Nicotine	1840s–mid-1900s
Carbolic acid and potash	1880s
Derris	1910–~1952
Lime sulphur	1849–1891
Zinc	1950s–present
Copper	1950s–present
Organochlorines:	
• DDT	1945–1961
• lindane	1947–1961
• dieldrin	1955–1961
• aldrin	1955–1961
Organophosphates	1960s–present
Synthetic pyrethroids	1970s–present
Insect growth regulators	Present

* Persistent chemicals of principal concern are highlighted.

** Years for organochlorines are based on Ministry for the Environment, 1998.

Of the chemicals listed in Table 1, the more recent (organophosphates, synthetic pyrethroids and insect growth regulators) usually readily break down, and so are not marked as persistent chemicals of principal concern. There are exceptions to this in cases where a high level of co-contamination (eg, from copper or arsenic) inhibits microbes that can be involved in chemical degradation.

In general, if there is a reasonable site history, which shows that the dip was used before 1961, it is recommended to test for arsenic and organochlorines (which include dieldrin, lindane, DDT and its primary degradation products DDE and DDD – often referred to as Σ DDT). When investigating a site with a former footrot bath, testing for arsenic, copper and zinc is recommended.

If the dip area is likely to have been used after 1960, it may also be advisable to test for residues of organophosphates and their breakdown intermediates (some may be more harmful to humans than the original compound). For dip sites in use after 1970, an additional test for synthetic pyrethroids may be advisable. However, these analytical suites can be quite expensive, and given the fairly low likelihood of detecting members of either class of compounds at significant levels after more than a few months, these tests might be justifiably carried out on only one or two representative samples collected from the area most likely to be contaminated. Further testing for organophosphates and synthetic pyrethroids would then proceed only if significant levels were detected in the test samples.

Appendix 7 presents a number of case studies that illustrate the behaviour of the chemicals in the environment and the concentrations that may be found in soil and other media.

2.4 Exposure pathways and risks

Exposure pathways

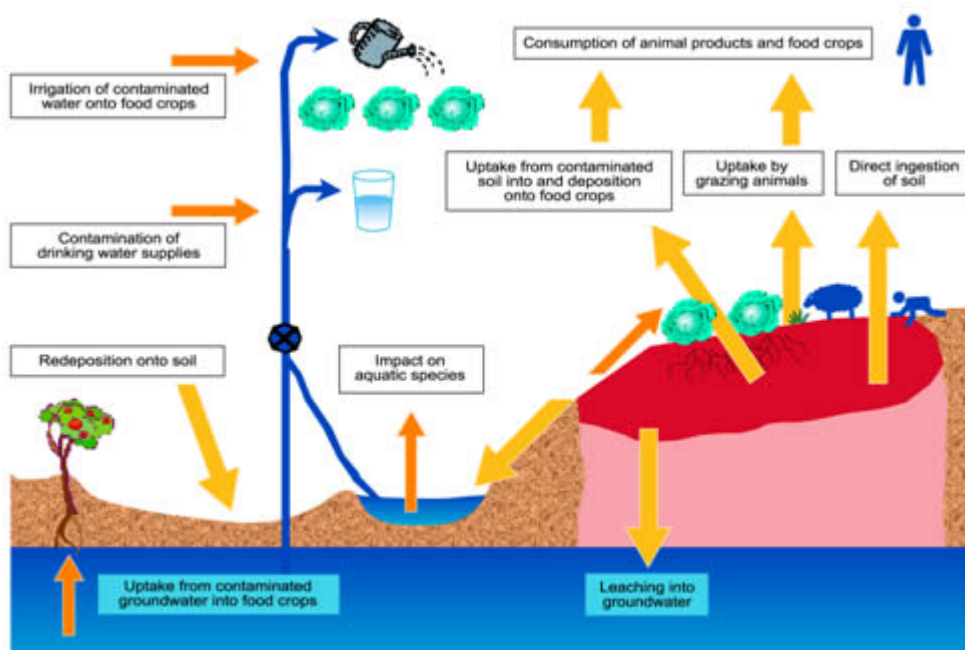
Disused contaminated sheep-dip sites present the following main potential exposure pathways.

- *Pathways for human exposure:* the primary pathway consists of ingestion of small amounts of soil or dust. Next most significant is the consumption of home produce if it is grown in contaminated soil, and consumption of drinking water if it has been contaminated. Whānau, hapū, iwi and others who regularly gather and consume aquatic and wild foods may be at risk from contamination of waterways, including sediments. Contamination of farm bore-water supplies near old sheep dips has been documented on several occasions (McBride et al 1998; Hadfield and Smith 2000; Environment Canterbury 2003; McBride 2004). Other minor exposure pathways include dust inhalation and absorption through the skin.
- *Pathways for livestock exposure:* the main pathway is ingestion of contaminated soil during grazing (eg, an adult cow may ingest up to 675 grams of soil each day, although variations occur depending on local conditions such as grazing height or the amount of dirt on the foliage), and the consumption of contaminated water.
- *Pathways for exposure of other organisms:* the main pathway here is the contamination of nearby stream waters and sediments. Where contaminant levels exceed guideline values (for either water or sediment), there may be some adverse effects on the abundance and nature of freshwater and marine invertebrates that form the base of aquatic food webs.

Figure 4 illustrates the main potential exposure pathways for contaminants present in old sheep-dip sites, and shows how some of the pathways described above are interrelated. The specific pathways and their importance depend on the actual land use at an affected site and should be assessed on a site-specific basis.

Note that disused sheep dips only present a risk to human health and well-being if a complete pathway exists for the uptake of contaminants by the human body.

Figure 4: Exposure pathways from disused sheep-dip sites



Health risks

One of the main concerns with contaminated sheep-dip sites is that the chemicals used may pose a risk to people. Risks can be divided into short-term (acute or immediate) risks and long-term, low-level (chronic) risks. The following section is based on health and environmental risk assessments undertaken on a sample range of dip sites in New Zealand (Stage 6b Preliminary Report by Kim 2003). The main acute hazard found was the high arsenic levels at these sites. A typical concentration was 1000–3000 mg/kg, and at some sites the sampled concentrations reached 11,000 mg/kg, compared with the natural soil arsenic content of about 5 mg/kg for that locality. Immediate risks were identified for children and young livestock.

Human health risks

Young children may be at *immediate* risk from exposure to contaminants in soil when playing in and around an old sheep-dip site, for four main reasons.

- Concentrations of arsenic at old sheep-dip sites can occasionally exceed 11,000 mg/kg (background concentrations of arsenic in New Zealand soils typically range from 2 to 30 mg/kg).
- Children ingest more soil and dust than adults due to frequent hand-to-mouth activity.
- Some children exhibit pica⁵ behaviour, which involves the routine ingestion of significant quantities of non-food items.

⁵ The word “pica” comes from the Latin word for magpie, a bird known for its large and indiscriminate appetite. Around 25 to 30 percent of children have an eating disorder called pica, which is characterised by persistent and compulsive cravings to eat non-food items.

- Children have a lower body weight than adults, meaning that an adult can tolerate ingesting more arsenic in total before being affected.

Disused sheep dips may also pose a *physical risk* for children if not fenced off. Accidental drowning from falling into dip vats containing liquid have been recorded in New Zealand. For these reasons, the risks posed by an old sheep-dip site to children need to be managed.

When a rural property containing an unrecognised (or unmanaged) sheep dip is subdivided, the *relative risk* of significant exposure to a small number of children increases even more. This is because one of the house lots will necessarily contain the former sheep dip, and adjacent lots may also contain some soil contamination. For a child living on such a property, the potential frequency and duration of exposure to the contamination is greater than on a farm, where a child is confined to a smaller wandering area. The risk of acute poisoning therefore increases substantially. For this reason, it is particularly important that territorial authorities properly manage old sheep-dip sites on properties that are being subdivided for residential and rural-residential use.

Chronic risk refers to long-term risks (eg, over 30 years) from lower exposure. As noted above, exposure to contaminants from disused sheep-dip sites can occur by several intake routes, which in order of importance are:

- ingestion of soil
- ingestion of home produce from around the old dip
- consumption of contaminated groundwater, surface water, or aquatic and wild foods
- inhalation (of either soil and dust, or volatilised contaminants)
- absorption through the skin (dermal absorption).

Usually, inhalation and dermal absorption are insignificant pathways compared with direct soil ingestion. An average child ingests approximately 100 mg of soil and dust per day through normal hand-to-mouth activity. Children with pica condition are particularly vulnerable because they are predisposed to eat soil, with a typical figure being approximately 5000 mg of soil per day. However, it should be noted that due to the potential for bioaccumulation, consuming eggs from chickens raised on-site may pose a greater risk to a child than soil ingestion.

Home-grown produce grown on contaminated soil can be contaminated through direct uptake into the plant from the soil, as well as adhesion of soil particles to the plant. The uptake depends on many factors such as soil pH, the extent of binding of the chemical to soil, or whether the chemical is similar to a nutrient for which the plant has an active transport mechanism. For example, zucchinis, pumpkins and carrots can accumulate organochlorines. In some cases, phytotoxicity may occur with high levels of arsenic contamination. In terms of human exposure at a specific site, ingestion of home vegetables can be a significant intake route. The extent of actual exposure, however, depends on someone eating vegetables or fruit from the contaminated area.

Guideline values for residential soils are designed to provide a good level of protection to ensure that long-term risks are tolerably low. A number of conservative assumptions (eg, taking into account all potential exposure pathways) and a typical exposure period of at least 30 years mean that these guideline values are also sufficient to protect against short-term risk.

Leaching of contaminants into the groundwater can become relevant to residents if their water-supply bores are located on the same or an adjacent property and the water is contaminated to levels above drinking-water standards.

Table 2 gives an overview of the potential human health risks from disused sheep-dip sites in relative terms (high, medium, low). Potential risks to exposed livestock, soil biota, terrestrial plants and aquatic fauna and flora are more difficult to determine on a general basis and have been excluded from the table.

Table 2: Overview of the potential risks to people from disused sheep-dip sites

Land-user group (likely land-use categories)	Main exposure route	Risk
Children (rural, residential)	Eating contaminated soil; touching and breathing in soil and dust when playing in or around old sheep dips	High (immediate risk)
Life-style block occupants (rural, rural-residential)	Eating vegetables grown on a contaminated area; consuming animal products (eg, meat, eggs and milk) from animals kept on a contaminated area; drinking contaminated bore water	High to medium (longer-term risk)
Residential occupants (residential)	Touching and breathing in contaminated soil or dust when gardening; eating vegetables grown on a contaminated area (depending on the residential character; eg, a significant number of home gardens)	Medium (longer-term)
Local iwi and hapū (rural, parkland, residential)	Eating mahinga kai (aquatic and wild food; eg, freshwater mussels, crayfish, eels, watercress, land-based ferns)	Medium to low (longer-term)
Farmers and workers (rural, rural-residential)	Touching and breathing in contaminated soil or dust when working on the farm	Medium to low (longer-term)
Neighbours of subdivision development (residential)	Breathing in wind-blown contaminated soil particles and dust from site redevelopment for housing	Low

Livestock health risks

Young stock are susceptible to acute poisoning from ingestion of high-to-moderate levels of environmental contaminants. In 1993, two heifers died in the Waikato region from acute arsenic poisoning as a result of ingesting arsenic-contaminated soil within an old sheep dip, and others were chronically poisoned.⁶ In the Kaikoura area, stock deaths have been reported from arsenic poisoning due to grazing near old sheep dips or footbaths (Environment Canterbury, 2003). The probability of livestock becoming poisoned depends mainly on whether:

- the soil associated with the old dip is high in arsenic (in particular), and the animal ingests a significant fraction of its daily soil from the area immediately around the old sheep-dip site
- the bore water for livestock is contaminated, or contaminated groundwater flows into surface water used by stock, both from on the property with the dip site and from off the property.

⁶ MAF Ruakura Animal Health Laboratory Report (*Case no. 9335861, dated 14/10/93*), a Post Mortem Report to Northern Waikato Veterinary Services. Note the comment in the report: “Arsenic levels in liver greater than 4 mg/kg are considered significant – animal had 15 mg/kg”.

Ecological concerns

Both arsenic and DDT bind strongly to soil, and so leaching into the groundwater is expected to be limited at old disused sheep-dip sites. In some places, however, contaminants in the soil are still progressively increasing in the groundwater after 40 years (see **Appendix 7**). This demonstrates that gradual leaching through the soil profile depends on the soil type at the site and the leachability of the contaminant, which means this pathway needs to be assessed on a site-specific basis. There may also be instances where surface activities – including remediation – enhance contaminant leaching. For example, arsenic can be mobilised by the addition of phosphate to soil, and organochlorines can be mobilised by organic colloids (eg, if an organic-rich soil amendment is added to the topsoil). It is fairly rare, however, for this low-level discharge to have a significant adverse effect on the wider environment.

Where significant discharge of contaminants to nearby freshwaters or marine water occurs, it poses a risk to aquatic biota. Usually contaminants are adsorbed to the sediment and gradually accumulate as the discharge continues. Surface run-off can also transport contaminated sediment to water in the vicinity of the site, resulting in aquatic flora and fauna being exposed to contaminated sediment.

Terrestrial plants in soils with high arsenic content may show inhibition of growth, photosynthesis and reproduction. Phytotoxic responses typically occur at lower concentrations than toxic effects on soil organisms. Organochlorine insecticides act on the central nervous system of animals and are (not surprisingly) acutely toxic to insects, while higher concentrations are required for acute poisoning of other invertebrates and vertebrates. Environmental concerns about organochlorine insecticide residues arise from their accumulation through the food chain.

Summary of most common concerns for local authorities

In summary, the most common concerns for *local authorities* relating to the risks of former sheep dips are as follows.

Territorial authorities: ensuring land is suitable for its intended purpose at the time of subdivision or new land-use activities. This essentially means making sure the site has been properly investigated and, if necessary, remediated as part of resource consent approval. Residual concentrations of contaminants at such a site should be equal to, or below, recommended guideline values for the proposed land use.

Regional councils: ensuring that all risks associated with sheep-dip sites are appropriately managed, including discharges to the environment. These may include discharges to groundwater or surface water, or discharges to air or soil associated with the removal or contouring of potentially contaminated soil during redevelopment.

Medical officers of health and health protection officers at district health boards: these usually work closely with local government on contamination issues that cause a nuisance or need to be notified to protect the public. Poisoning due to chemical contamination of the environment is required to be notified on reasonable suspicion (Health Act, Schedule 2).

3 Planners' Guide

Local authorities receive information of variable quantity and quality with new resource consent applications. This section of the guideline is aimed mainly at territorial authorities that evaluate information provided by applicants in the resource consent process with respect to identifying and assessing former sheep-dip sites. Regional councils may offer expertise and advice in the identification stage and often get involved at the investigation or remediation stage. Some overall guidance on information management is given in the last subsection.

Appendix 2 provides an example of a district plan containing policies and methods to avoid or minimise human health risks associated with contaminated land, specifically from former sheep-dip sites.

3.1 Resource consent applications

Most territorial authorities routinely check subdivision and other land-use applications for potential land contamination. Building consents can also be checked against potential land contamination. The checking process for disused sheep-dip sites is intended to be one of a number of assessments carried out on a resource consent application when it is received by a council. Even if the district plan does not have specific rules governing contaminated land, the checking routine should form standard practice in reviewing resource consent applications where potential contamination from historical land use exists.

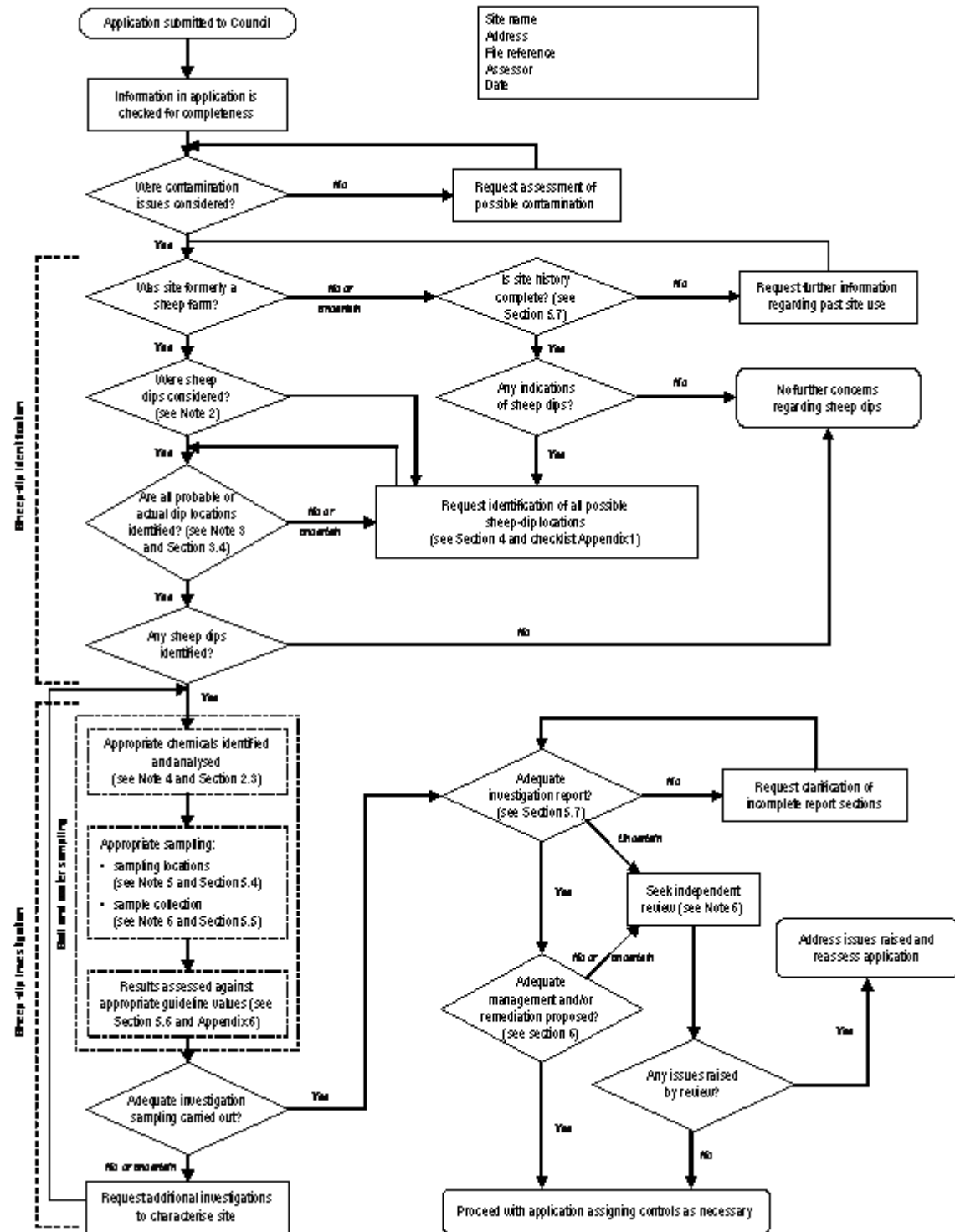
Aside from old sheep dips and footbaths, there could also be other contaminant types present on the property, such as fuel from fuel storage, rubbish dumps, and asbestos (which was often used in buildings and sometimes on farm tracks). It is possible to exacerbate the exposure to contamination when building activities take place, and risks may also arise when changing from existing pastoral land use (eg, a sheep farm) to horticulture or cropping. While local authorities are not usually notified of changes to the cropping regime on rural land, they could give advice of this potential risk in leaflets about rural land. Changes in the status of rural land should also include assessment for potential land contamination.

The flow chart in **Figure 5** sets out a systematic process for checking the adequacy of the information provided on potential former sheep-dip sites. The flow chart is designed as a series of prompts, to ensure that a processing officer can establish that all steps have been taken to determine whether a property is likely to have disused sheep dips, and that all probable sheep-dip locations have been identified and properly investigated.

The assumption is that the user is familiar with contaminated sites, and so the flow chart acts more as a prompt to ensure items are not overlooked than a “how to” guide for contaminated site investigations. Training should be given where this is not the case. The primary objective of the flow chart is to ensure that the right questions are asked and sufficient information is presented to allow the council officer to make a proper assessment.

Figure 5 pictorially summarises the information in the relevant sections in the guideline. It is intended for use in conjunction with this guideline, which should be read and understood *prior to* using the flow chart. Appropriate references are given to the guideline for clarification or prompting for the particular steps in the process. The accompanying notes provide some information on the use of the flow chart, including checklists and a table summarising the sheep-dip chemicals used in New Zealand.

Figure 5: Flow chart for consent applications associated with pastoral land



Flowchart notes

- Place a tick in the boxes as each section is completed.
- It can be assumed that most sheep farms will have had one or more dip sites. Only very small farms would not have had their own dips. Those sites that have been subdivided off larger properties need to provide sufficient evidence that the subdivided property would not have had the dip located on it. A steep site is unlikely to bear a dip site and would usually be exempt from further investigation unless there is evidence that chemicals were poured down the hillside. Note the practice of directly spraying the flock with chemicals while held in the stock yards, which means that chemicals in soil from this source may not be at a recognised dip site.
- Permanent dips are often associated with woolsheds and yards. A convenient water supply (eg, bore) could also be an indicator. The common discovery methods are:
 - existing structures or parts thereof
 - anecdotal information
 - historical aerial photographs
 - suspicious ground depressions
 - analytical confirmation, such as water and soil sampling.

Note that as many methods as feasible should be employed, so that *all* current and former locations are identified. For instance, a dip structure may be found, but one of the other discovery methods may identify another former location.
- Laboratory analysis is only required for the persistent chemicals most likely to be present. This will depend on the operating period of the dip and the concentration of chemicals that may inhibit bacterial breakdown. Therefore, the period(s) of use should be determined to justify the selection of analytes according to the table below.

Table 3: Typical period of use of sheep-dip chemicals of concern in New Zealand

Chemicals	Used at this site? Yes <input type="checkbox"/> No <input type="checkbox"/>	Typical period of use																
		1840	1850	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000
Arsenic	Yes <input type="checkbox"/> No <input type="checkbox"/>	1840–1980																
Copper	Yes <input type="checkbox"/> No <input type="checkbox"/>	1950s–present																
Organochlorines:																		
• DDT	Yes <input type="checkbox"/> No <input type="checkbox"/>																	
• lindane	Yes <input type="checkbox"/> No <input type="checkbox"/>																	
• dieldrin	Yes <input type="checkbox"/> No <input type="checkbox"/>																	
• aldrin	Yes <input type="checkbox"/> No <input type="checkbox"/>																	
Organophosphates:																		
• diazinon	Yes <input type="checkbox"/> No <input type="checkbox"/>																	
• nankor	Yes <input type="checkbox"/> No <input type="checkbox"/>																	
• others	Yes <input type="checkbox"/> No <input type="checkbox"/>																	
Synthetic pyrethroids	Yes <input type="checkbox"/> No <input type="checkbox"/>																	
Insect growth regulators	Yes <input type="checkbox"/> No <input type="checkbox"/>																	
Decades																		

5. Sampling methodology should be adequate to characterise soils surrounding a dip site, and, if appropriate, groundwater and surface water within the vicinity of the dip(s), which may be pathways for run-off/flow from the dip and drip areas. Sample site locations should be recorded on a site plan. Identifiable sampling locations may include:
 - soil beneath a dip bath and within the bath
 - soil in the splash zone and scooping mound around a dip
 - soil in any disposal/run-off areas where sludge/spent dipping fluid may have been disposed of and drained
 - soil from yards where freshly dipped sheep were collected before further transport
 - soil in the storage areas for chemicals, and beneath the woolshed
 - water from one or more areas of the identified dip area
 - water from one or more groundwater wells within approximately 200 m of the dip
 - water and sediment from one or more areas of a seepage zone, a stream or foreshore.
6. The ground investigation should be appropriate for the site. The collection, storage and transport of samples should follow the recommendations in the Ministry for the Environment's *Contaminated Land Management Guidelines No. 5* (2004a).

In the event that a report appears to be generally satisfactory but has some uncertainties of sufficient concern, independent advice should be sought from the regional council or a contaminated site consultant.

There will probably be times where an applicant has not provided sufficient information to satisfy council criteria. In such cases, it is assumed a council would request more information from the applicant or refer to council records. Local authorities may want to present the checklist contained in **Appendix 1** to landowners with a suspected dip site on their property to help them prepare a resource consent application for a potential subdivision, or a change in land use.

Discharge consents may also be required by regional councils during redevelopment and for remediation measures (compare **section 6.2**).

Note that the consent process is only one way to manage risks from old sheep-dip sites, which relies on councils establishing if any disused sheep dips are present. The risks are then managed through a resource consent or building consent application. Another way would be for local authorities, in consultation with landowner groups, to identify critical geographic areas for attention; for example, where significant land-use changes are occurring, such as on urban fringes. Where a property does not trigger a resource consent process, it is the current landowner's responsibility to make sure the site does not pose any risk to people or the environment and to manage or remediate the site with expert assistance, if appropriate.

3.2 Information management

Territorial authorities and unitary authorities have duties under the Local Government Official Information and Meetings Act (section 44A) to provide information on the likely presence of hazardous contaminants on land in Land Information Memoranda (LIMs), and also to include information on the presence of hazardous contaminants on land in Project Information Memoranda (PIMs) under the Building Act 2004.

For subdivision, building or land-use consent applications it is important that the territorial authority has up-to-date information about the site history and any contamination. When territorial authorities assess proposed changes in land use, they must have regard to the effects of the land-use change on the environment (including people), and may seek advice from regional councils. Territorial authorities also monitor, report and often keep (or have access to) records relating to hazardous substances or contaminants within their district or city area. This may entail compiling a register of known sheep-dip sites and other contaminated sites within their area as this information becomes available, although it may be better to take a proactive approach (see box below).

The investigation of land for the purposes of identifying and monitoring contamination is a function of regional councils. This allows regional councils to investigate land where contamination is suspected, even if there is no actual discharge occurring, to see if the land meets the definition of contaminated land in the RMA (see **Appendix 3**). Most regional councils maintain databases of sites where hazardous substances have been stored or used, or where historical land uses could have caused contamination of the soil. Information about the sites, including whether contamination has been confirmed or not, is recorded on the database. Some city or district councils maintain their own databases, or the regional council may have agreements with them about access to the information on the database. It is recommended that records of sheep-dip sites be maintained on one master database to avoid inconsistencies between regional and territorial authorities.

Landowners have no duty to report on the contamination status of their land, or on the remediation measures they may have undertaken, if there are no off-site effects. However, if they are asked by a potential purchaser about any contamination issues on their land they have a duty to disclose any knowledge they have, and the purchaser may have the right to withdraw from the purchase agreement if the former owner failed to disclose that information.

Councils may choose to employ an active programme of locating the old sheep-dip sites in each district before knowledge of their whereabouts is progressively lost. This approach would effectively address both the acute toxicity risk to children on farms or lifestyle blocks and the need to identify old dip sites by the time a property is subdivided. It is much harder to address contamination issues after the subdivision has taken place. The identification and site investigation may be carried out as a joint initiative between the regional council and the territorial authority.

Detailed protocols for classifying contaminated sites and managing information can be found in *Contaminated Land Management Guidelines No. 4: Classification and Information Management Protocols* (Ministry for the Environment 2006). Council staff are advised to refer to these for further guidance.

4 Identifying Former Sheep-dip Sites

Disused sheep-dip sites can be identified in a number of ways. For example, the landowner may locate the sheep-dip site in an effort to protect his or her family and livestock from harmful effects. Once the landowner has identified the sheep dip, the location should be recorded for future reference. Preferably the council should be made aware of the sheep dip's location, so it can be properly managed and added to its register.

In the course of a subdivision application, territorial authorities will check contamination issues. If the site history indicates a sheep farm, then any evidence of its existence needs to be followed up. The regional council may also detect adverse environmental effects in the groundwater or nearby surface water that can be traced back to an old dip site. Councils may also decide on a proactive programme to identify old sheep-sip sites on their property or in rural areas where land-use changes are occurring.

Appendix 1 provides a practical checklist that councils can hand to current landowners to help them identify and characterise former sheep-dip sites and the activities that occurred at the site. It lists relevant questions to address in that context and provides some management options.

4.1 Structural evidence

When determining if a sheep-dip site was previously located on a property there are a number of potential indicators to consider. Dip sites are often located near sheep yards, woolsheds or bore-water supplies, but their exact location may not be obvious. When investigating the location of a former sheep-dip site, consider where dip chemicals were stored and disposed of. Structures associated with disused sites include old plunge dips, which were often concrete structures, or shower booths. However, these structures may be covered over or may have even been removed, sometimes leaving suspicious ground depressions.

4.2 Anecdotal evidence

The most common and successful method for identifying previous sheep dips is through anecdotal information from current or previous landowners, especially when they used the land for agricultural purposes. Anecdotal information is particularly useful when the sheep-dip structures have been removed from the site and there is no visual evidence of the dip. For example, in a trial survey comparing anecdotal site identification versus aerial survey maps in the North Raglan area in 2003, it was found that two-thirds of old dip sites were no longer accompanied by obvious above-ground structures, with many having been buried or removed. This means that anecdotal information from people living at the time a dip was in use may be the only means of identifying the general area of a former sheep-dip site, short of extensive soil sampling.

Apart from landowners, sometimes stock sales agents and veterinarians in the area know a great deal about former sheep farms and may have records. Another option is to ask old-time shearers to locate the former shearing sheds in the area. The use of local historians or other researchers may prove valuable when assessing building permits or valuation records to help identify sheep yards, associated farm buildings and dip-like structures.

Although gathering anecdotal information is the best way to identify former sheep-dip sites, it relies on goodwill. Due to the liability associated with contaminated sites, information is often provided unofficially and landowners may be concerned about passing on information that may decrease the value of their property. However, the experience in survey work has been that landowner responses have generally been very supportive. It is important to keep in mind, though, that anecdotal information may be incorrect, either through mistake (especially after a long passage of time or via second-hand account) or deliberate intent.

Local knowledge is progressively being lost as generations pass and farms change hands. It is probable that this information resource will largely disappear as a means of identifying old dip structures within the next decade. Even now, it is often necessary to locate members of the most long-established surviving farming families in a district to gain the best insight into the number and location of old sheep dips in a given area. This means that if useful information on the location of dips is to be recorded for future reference, some urgency is required on the part of the current owner.

4.3 Old aerial photographs and public records

Old aerial photographs can be used to identify structures often associated with sheep-dip sites, including woolsheds and yards. However, the scale of historical aerial photographs across most of New Zealand usually only allows stockyard areas to be identified and not sheep-dip structures themselves. However, from survey work in North Raglan it would appear that only about half of identified stockyard areas had associated dips, with the other half being some distance from the stockyard.

When making use of aerial photographs in this way it is important to remember that dip structures and stockyards come and go, depending on the favoured parasite control method at the time. In some cases, the photograph may have been taken before a dip was constructed. As a result, aerial photographs are recommended only as a useful initial method to identify potential sites, if the photo quality allows.

Regional and city/district councils and public libraries may also hold some historical information or maps about the site in their archives, which could help to localise sheep dips and associated buildings. Also, reports from previous investigations into contamination issues that could be relevant may have been stored on council records. For councils, a review of existing information on their databases is probably a good starting point. Landowners, or consultants acting on their behalf, could enquire about publicly held information from councils via an official information request.

4.4 Soil and water sampling

Water and soil sampling is another method for identifying contaminated sheep-dip sites (see **section 5** for further information). Limited soil assessments are sometimes undertaken as part of a due diligence investigation, and may identify chemicals previously used in sheep dipping. Routine surface-water and groundwater monitoring may also be undertaken as part of regional council water-quality monitoring programmes and may lead to identifying the source of a contaminant discharge. Extensive sampling, however, is usually not done for the original identification, but serves as a confirmation in combination with other evidence that a sheep dip may have existed at the site.

4.5 Screening food products

Food products are being screened in Australia to identify chemical residues that indicate historical sheep-dip sites. This method identifies farms that produce contaminated meat, milk or crops. For this concept to be applied in New Zealand, additional monitoring of primary agricultural products would be required. Surveys of this type are provided for when evidence for the need is demonstrated. When a non-compliant level of a contaminant is found in an animal product, measures are applied to the livestock or the farm (or both) under the Animal Products Act Regulated Control Scheme 2004 to achieve compliance. The legislative power for sampling primary products more or less directly from farms currently lies with central government, however, and so this method of residue screening is not easily available to local government. Similarly most – although not all – testing and interpretation are done by central government (see under New Zealand Food Safety Authority at www.nzfsa.govt.nz).

4.6 Sniffer dogs

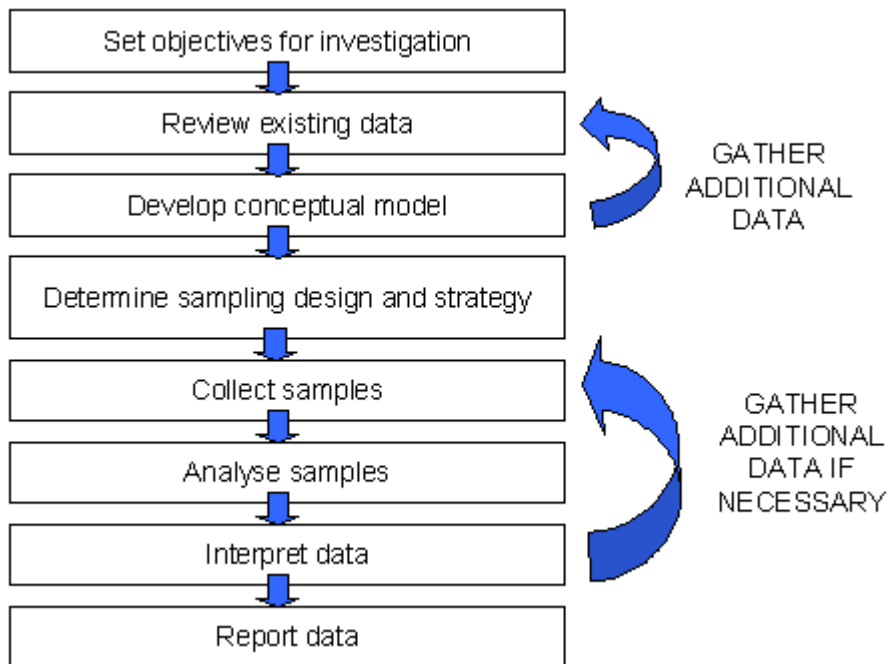
In Australia, sniffer dogs are used effectively to identify a range of organochlorine-contaminated sites. However, using these dogs in a trial conducted in New Zealand in 2004 did not deliver satisfactory results on all occasions. Therefore, this method is currently not considered viable in New Zealand, although it might become feasible in the future if the dogs are trained under New Zealand conditions and deliver reliable results similar to those in Australia. This method would likely be more acceptable to landowners, as it is a non-threatening approach. (See **Appendix 8** for more information on this as a sampling strategy.)

5 Site Investigation

5.1 Overview

This section looks at the best practice procedures to be followed in carrying out a detailed site investigation. All sampling programmes for contaminated sites should be undertaken in accordance with the *Contaminated Land Management Guidelines No. 1: Reporting on Contaminated Sites in New Zealand* (Ministry for the Environment 2003a), and *Contaminated Land Management Guidelines No. 5: Site Investigation and Analysis of Soils* (Ministry for the Environment 2004a). The following subsection summarises the information contained in this guideline which is appropriate to old sheep-dip sites. **Figure 6** summarises the recommended approach to a site investigation.

Figure 6: Recommended approach to a site investigation



It is recommended that the landowner contracts a qualified environmental consultant to undertake detailed site investigations that involve sampling. It is unlikely a council would accept a site investigation if it was undertaken by the landowner. During the course of the investigation, the landowner needs to be aware of the risks the site may pose and, where necessary, restrict access to the site until the risks are mitigated to an acceptable level.

5.2 Objectives of the investigation

The first step is to identify the purpose of an investigation and set investigation objectives accordingly. There are many reasons why a local authority or landowner may want to investigate a former sheep-dip site, including:

- concern that the site represents a risk to the landowner/occupier, employees or wider public
- potential environmental liabilities need to be determined in order for a site to be sold, purchased or redeveloped
- the land is proposed to be rezoned and a change in land use will take place in the near future
- concern that the site represents a risk to crops, livestock or meat quality, or that it may have effects on the terrestrial ecosystem (bacteria, bugs, animals and plants)
- a down-gradient water source has high concentrations of dip contaminants.

Identifying the issues to be resolved will help to establish clear sampling objectives for the investigation which define why or how samples are being collected. In the context of sheep-dip sites, a common sampling objective will be to establish the nature, degree and extent of contaminant distribution (both vertically and laterally). With regard to off-site effects, locating the sources of contamination will be the first step.

5.3 Data review and conceptual model

Once the objectives for the investigation have been determined, readily available data should be reviewed. Structural evidence or anecdotal information gathered during the identification phase (see **section 4**) will be useful to include in the data collection. Other sources may include old records of the site, or previous investigation reports.

Based on the existing data, a conceptual model of potential exposure pathways needs to be developed. Experienced contaminated land consultants are usually contracted to develop the conceptual model, set the data quality objectives (such as sampling density and requirements for validation sampling), and carry out the site investigation and sampling. It will be beneficial to both sides if the landowner or council and the consultant work together closely in developing the conceptual model. The model should identify the exposure pathways, including the:

- contaminant sources (eg, previous sheep-dip location, chemical storage location and methods used to dispose of chemicals, and the likely depth of soil contamination)
- transport mechanism or exposure route, as illustrated in **Figure 4** (eg, drinking contaminated water)
- receptors (eg, a nearby surface-water body, groundwater well, farm workers, animals).

The model can be improved by gathering additional data, such as from a geophysical survey, an aerial photograph or specialised remote-sensing techniques (eg, Landsat satellite false colour image, or side-scanning radar).

Due to the complexity associated with each individual site, a summary of the recommended procedures for three site scenarios is provided in **section 7**. Each scenario specifies the recommended way of sampling, assessment of results and selection of remediation options.

5.4 Sampling design and strategy

The sampling programme is developed using the conceptual model. Visual inspection of a site, examination of photographs and maps, and information from local residents can be used to determine the best location for sampling points within an area of investigation. A site assessment may include an investigation of the soil at the site, and of groundwater and surface water within the vicinity of the site. For example, a disused sheep-dip site may contain a permanent concrete trench and an area of soil through which contaminants seep and discharge into a nearby stream. In this case, it will be necessary to sample the dipping vat and adjacent soil and water, soil and sediment in the seepage zone, surface water, and sediments.

Other possible sampling sites within an old sheep-dipping site may include:

- soil beneath the dip bath and within the bath
- soil in the splash zone around the dip
- soil in the disposal/run-off area where sludge and spent dipping chemicals may have been disposed of, and drainage to where the spent or discharged liquid dip flowed
- soil from yards where freshly dipped sheep were collected before further transport
- soil in the storage area for chemicals, and soil beneath the woolshed
- water from one or more areas of the identified site
- water from one or more groundwater wells in the area
- water and sediment from one or more areas of a seepage zone
- water and sediment from one or more areas of a stream or foreshore.

It is worth remembering there is a common pattern of three potential zones of high contamination, at increasing distance:

- nearby contamination – associated with dipping and dripping (the “splash zone” and the draining platform)
- one-overarm-shovel distance – contamination associated with digging out the sludge (the “scooping mound”)
- one pipe-length away (pipes found at dip sites include 4- or 6-inch metal irrigation pipes, three-foot concrete pipes, 21-foot galvanised pipes and field tiles) – contamination may be associated with emptying the bath quickly and in such a way that the liquid did not inundate the dip site; for example, dip wastewater may have been emptied down slopes or banks.

Previous assessments of historical sheep-dip sites in New Zealand have used judgemental sampling strategies due to the high costs associated with systematic sampling (McBride 1994; Wilson 1998; McBride et al 1998; Hadfield and Smith 2000; Environment Canterbury 2003). There are a number of different sampling strategies and techniques, and each has certain advantages and disadvantages. **Appendix 8** describes the outcomes of a study that compared four different sampling strategies (judgemental, systematic grid, sniffer dog and portable XRF sampling) in order to assess the most appropriate sampling regime for historical sheep-dip sites. It was found that the *systematic sampling approach provides current best practice* for assessing contamination at old sheep-dip sites.

5.5 Collection of samples

The aim of sampling is to identify the three-dimensional extent of any contamination that exceeds the soil guideline values. The sampling results will provide important information for the development of a remediation plan. When collecting soil samples from an undisturbed sheep-dip site (eg, no previous clean-up, no placement of fill nor development), shallow sampling (0 to 15 cm) may be sufficient to determine the horizontal extent of contamination. For disturbed sites, sampling at varying depths may be required to establish the horizontal extent, because fill material may cover the contamination.

Soil samples should be collected at the depth where contamination is most likely to occur, based on known site conditions. Soil samples need to be collected from inside the base of the sheep-dip bath, and in the natural material underlying any soil back-fill. Soil samples should also be collected within the surface soil of the splash zone and from the exit zone of the dip, in the vicinity of the draining platform or holding pens, and from the area where the sheep-dip chemicals were stored and the spent dipping fluid disposed. Careful sampling procedures need to be used because the actual amount of soil or water analysed by the laboratory is extremely small.

Depending on the purpose of the investigation, it may be appropriate for the soil profile to be classified during soil sampling and a soil log produced to ensure that soil samples are collected at the appropriate soil horizons (eg, within any fill material and in the natural underlying soils). Based on the sampling design, the location of each sample point should be recorded on a site plan, with reference to permanent features and structures, if possible. Sample points or dip features can be recorded accurately in the field using a GPS mapping system. Usually an experienced contaminated land practitioner or consultant is employed to carry out the sampling.

A chain of custody procedure is required to ensure the legitimacy of the samples, and the laboratory chosen for analysing the samples should be IANZ accredited to ISO/IEC guide 17025.

5.6 Data interpretation

Assessing the results

The first step in interpreting analytical results of samples collected from various locations around the site is to examine them for patterns that identify the likely nature and spread of contaminants. The results of chemical analysis of samples taken from soil, sediment or water are typically compared with guideline values to assess whether a site is contaminated. This assessment forms the basis for deciding if further investigations are required, or which remediation or risk management options are feasible for the site. This subsection provides a review of relevant guideline values and how they might be applied.

Appropriate soil guideline values may include those developed to provide protection for receptors living on the site (eg, people, worms, plants) or off the site (eg, fish, algae). Soil guideline values are soil concentrations that are protective of people or ecological receptors, and they are based on generic exposure scenarios.

More specifically, for the protection of human health, soil guideline values are derived by defining some critical receptor (eg, a child of certain age and weight) and defining a tolerable daily intake for that receptor for the particular contaminant. Then, using assumptions for exposure (eg, duration, exposure pathway), the soil concentrations that would equal the acceptable daily intake for the assumed exposure are calculated. As a result, the selection of an appropriate soil guideline value must consider the proposed or current land use. For example, if the site is to be developed for general residential use, the results should be compared to a residential value for protecting human health.

For ecological receptors, soil guideline values are developed to provide a certain level of protection for terrestrial species (plants, soil invertebrates and wildlife) and soil microbial functions. Such guideline values are considered to be most applicable to land uses where a functioning ecosystem is desirable. Soil guideline values for the protection of on-site ecological receptors could also be used to provide target values for long-term soil quality.

Consideration should also be given to the protection of off-site receptors such as surface water and groundwater. For example, if the site is located close to a sensitive ecological receptor (eg, a stream) and a discharge of contaminants is suspected, then it would be appropriate to collect water or sediment samples and compare these results to appropriate guidelines, such as those presented in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ, 2000) (see **Table 6**).

Applying soil guideline values

Soil guideline values for the protection of human health or ecological receptors, or both, have been developed by a number of countries, including New Zealand. *Contaminated Land Management Guidelines No. 2: Hierarchy and Application in New Zealand of Environmental Guideline Values* (Ministry for the Environment 2003b) was developed to provide consistency across New Zealand when selecting appropriate guideline values for contaminants. Under this guideline, New Zealand risk-based guideline values are the preferred choice. Where these do not exist, overseas risk-based guideline values – especially values derived in a manner similar to those in New Zealand – are the next best choice.

Where international soil guideline values are referred to, it should be noted there are differences in the methods and assumptions used to derive the guideline values, and also differences in the political and legislative backgrounds for contaminated land management in individual countries (see Cavanagh and O'Halloran 2003). This can give rise to different soil guideline values for a given contaminant.

In New Zealand, soil guideline values for a limited number of contaminants are available in three industry-based guidelines: *Health and Environmental Guidelines for Selected Timber Treatment Chemicals* (Ministry for the Environment and Ministry of Health 1997), *Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand* (Ministry for the Environment 1997), and *Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand* (Ministry for the Environment 1999). These guideline values are primarily based on the protection of human health, and of on-site ecosystems to the extent necessary to facilitate the use of the land (eg, plant growth and livestock grazing for rural properties). Existing controls based on food safety standards may be more stringent than the proposed soil guideline values. Where food is being produced commercially, standards set by the New Zealand Food Safety Authority (maximum residue limits and maximum permissible

levels) will apply, and in situations where sheep farms are converted to dairying, the Fonterra thresholds would become a remediation goal.

Of the contaminants of concern at disused sheep-dip sites, New Zealand soil guideline values are only available for arsenic. This guideline therefore provides additional indicative soil guideline values for selected sheep-dip contaminants of concern (see **Table 4**). These indicative values will be superseded by any national environmental standards that may be developed in the future. (Refer to www.mfe.govt.nz for the latest information on guidelines and national environmental standards.)

Soil guideline values for selected land uses were derived using an updated method based on that provided in existing industry-based guidelines. An overview of the five land-use categories, exposure parameters for the different land uses, contaminant-specific parameters, and guideline values for individual pathways of exposure are provided in **Appendix 6**.

Table 4: Soil guideline values for human health (mg/kg)

Chemical	Lifestyle block ¹	Standard residential	High-density urban residential ²	Parks/recreation	Commercial/industrial (unpaved)
Arsenic ³	30	30	100	– ⁴	500
∑DDTs ⁵	8.4	28	70	140	1,700
Dieldrin	0.7	2.7	12	23	190
Lindane	33	140	700	1,400	14,000

- 1 Based on the assumption that 50 percent of the produce consumed by residents is grown on-site. Consumption of products (eggs, milk, meat) from animals raised on-site is excluded and should be considered on a site-specific basis.
- 2 Based on a residential value with no produce consumption.
- 3 Values provided in *Health and Environmental Guidelines for Selected Timber Treatment Chemicals* (Ministry of Health and Ministry for the Environment 1997).
- 4 No value has been derived for this land use in New Zealand; refer to international guidelines (eg, National Environmental Protection Council 1999; or CCME 2003.)
- 5 Sum of all DDT and DDT metabolites (DDD and DDE).

For land uses where a functioning ecosystem is desirable (eg, residential land use, parkland), it may also be relevant to consider protecting on-site ecological receptors. No national guidelines have been developed specifically for the protection of on-site ecological receptors at contaminated sites in New Zealand, but several other jurisdictions have developed such soil guideline values (see **Appendix 6, table A.6**), which may be referred to.

In comparing site investigation results to the appropriate soil guideline value, *Contaminated Land Management Guidelines No. 5: Site Investigation and Analysis of Soils* (Ministry for the Environment 2004a, p.62) should be followed. If a systematic sampling approach has been used, the 95 percent upper confidence limit of the arithmetic mean of soil contaminant concentrations can be compared to the selected soil guideline value. However, this approach is not appropriate if judgemental sampling has been undertaken, because the sample design is biased.

Guideline values for off-site receptors

Off-site impacts of contaminants may occur as a result of leaching to groundwater, or from the movement of contaminants through surface water run-off or wind. The significance of these discharges is highly site-specific because it depends on a number of factors, including the proximity of the sheep-dip site to the aquatic system of concern, the proximity of a groundwater bore to the sheep dip, the soil type, the slope of the land, or whether earthworks are being undertaken. It is therefore appropriate to assess the potential impact on off-site receptors on a site-specific basis.

The primary concern for contaminants discharged to groundwater is typically whether this would result in contaminants exceeding the drinking-water standards. However, contaminants present in groundwater – particularly shallow groundwater – may also ultimately discharge into surface water systems, meaning that it may also be relevant to consider their potential impact on ecological receptors.

Where surface water or groundwater is used for drinking water for people (primarily groundwater) or for livestock, the results of water quality analyses are most appropriately compared to drinking-water standards or guidelines (**Table 5**).

Table 5: Guideline values for drinking water

Chemical	New Zealand drinking-water standards ¹ (µg/L)	Livestock drinking-water protection ² (µg/L)
Arsenic	10	50
DDT	1	
Aldrin	0.04 ³	–
Dieldrin		77 ⁴
Lindane	2	–

1 *Drinking-water Standards for New Zealand 2005* (Ministry of Health 2005).

2 These figures were derived from Kim (2003) by applying a safety factor of 10 to the approximate minimum concentrations that could correspond to minimum lethal body burdens in stock.

3 Combined total concentrations for aldrin + dieldrin.

4 Note that the dieldrin limit for stock drinking water is not designed to protect against dieldrin limits being exceeded in any farm produce (milk or meat).

Comparison of the results of analysing water and sediment samples with guideline values provides a first step in determining whether an impact on the environment may be occurring. Where the protection of ecological receptors is the issue, the results of water and sediment samples are most appropriately compared to the water and sediment quality guidelines provided in *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ 2000). **Table 6** provides an overview of the recommended surface water and sediment values for the protection of ecological receptors for contaminants associated with old sheep-dip sites.

Table 6: Guideline values for surface water and sediment

Chemical	ANZECC trigger values for surface freshwater ^{1,2} (µg/L)	ANZECC trigger values for marine water ^{2,3} (µg/L)	ANZECC sediment quality guidelines ⁴ (µg/kg dry wt)	
			ISQG-low	ISQG-high
Arsenic (As III/As V)	24/13	2.3 ⁵ /4.5 ⁵	20,000	70,000
DDT/DDE	0.01/0.03 ⁵	0.0004 ⁵ /0.0005 ⁵	1.6/2.2	46/27
Aldrin	0.001 ⁵	0.003 ⁵	–	–
Dieldrin	0.01 ⁵	0.01 ⁵	0.02	8
Lindane	0.2	0.007 ⁵	0.32	1

- 1 Trigger values for a 95 percent level of protection for freshwater water (ANZECC and ARMCANZ 2000).
- 2 The guideline values for water have been listed in µg/L (as provided in ANZECC and ARMCANZ 2000). However, care must be taken because the laboratories may provide results in mg/L.
- 3 Trigger values for a 95 percent level of protection for marine water (ANZECC and ARMCANZ 2000).
- 4 Sediment quality guidelines (ANZECC and ARMCANZ 2000). ISQG = interim sediment quality guideline. The ISQG-Low is a level below which adverse effects are not expected; the ISQG-High is a level at which significant adverse effects are expected in 50 percent of organisms. Note that these are primarily developed for marine and estuarine systems and should be used only as indicative interim threshold values for freshwater systems.
- 5 Low reliability trigger value; this should be used only as an indicative interim working level (ANZECC and ARMCANZ 2000).

Site-specific risk assessment

Site-specific risk assessment is useful for establishing the risk posed by contaminants to people, livestock or ecological receptors currently present on the site. It focuses on modifying the actual exposure of those receptors (eg, time spent on the site, activities occurring). However, where future use of a site is being considered, a given exposure scenario is assumed for a particular land use and there is no basis for modifying the exposure parameters.

It would be appropriate to undertake a site-specific risk assessment if meat, milk or eggs from livestock raised on lifestyle blocks are being consumed by residents on those sites, because organochlorine compounds such as DDT and dieldrin are known to bioaccumulate in the food chain. In addition, site-specific risk assessment would be appropriate for the commercial/industrial land-use category where paving has been used as a means of reducing exposure to on-site contaminants.

Site-specific assessments may also be relevant where the naturally occurring concentrations of chemicals exceed the relevant guideline values. In New Zealand, some soils have naturally high arsenic concentrations, which may result in the guideline values for arsenic being lower than the natural ranges of arsenic concentrations in surface water, groundwater and sediment. In such instances, it is not appropriate to require remediation to concentrations below naturally occurring concentrations. A site is considered to be above background concentrations when the concentration of a contaminant is clearly higher than its background concentration. Reference can be made to factors such as the upper confidence limit (95 percent UCL) of the background concentration, the number of samples collected and their representativeness, observed or expected variability associated with sampling and analysis, and applicable guideline values.

Soil guideline values typically assume that all of a contaminant measured in the soil by chemical analysis will cause toxicity. However, usually only a small fraction is available for biological uptake. Determination of this bioavailable fraction provides a basis for modifying the exposure of receptors on-site. Presently, there is no generally accepted method for determining the bioavailability of contaminants. The plant uptake factor may be used to derive the generic soil guideline values for a particular site. However, plant uptake of contaminants is highly variable and depends on the species examined and the soil type, among other things.

5.7 Report data

The following checklist (**Table 7**) outlines the sections that should be included in a detailed site investigation report of a disused sheep-dip site. This information should be collected by a local authority when they are involved in investigations into former sheep-dip sites (eg, during subdivision or change in land use, or otherwise according to rules in a plan). The information contained in this subsection summarises the information given in *Contaminated Land Management Guidelines No. 1: Reporting on Contaminated Sites in New Zealand* (Ministry for the Environment 2003a), and all sheep-dip site reports should be consistent with the requirements outlined there.

Table 7: Checklist of reporting requirements

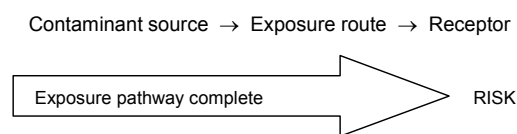
Report section
<p>Executive summary</p> <ul style="list-style-type: none"> • Background • Objectives • Scope of works • Summary and conclusions
<p>Scope of works</p> <ul style="list-style-type: none"> • Clear statement of the scope of the works
<p>Site identification</p> <ul style="list-style-type: none"> • Site address • Legal description • Geographic coordinates • Site plan • Locality map
<p>Site history</p> <ul style="list-style-type: none"> • List of site owners, including both previous landowners/occupiers and current landowners/occupiers, and previous and current land uses • List of contaminants of concern • Zoning (present and proposed) • Location of ground- and surface-water bodies • Location of relevant sheep-dip structures • Anecdotal information regarding the site, where possible • History of the neighbouring property and site usage • Review of aerial photographs, where appropriate

Report section
<p>Site conditions</p> <ul style="list-style-type: none"> • Topography • Soil • Geology • Hydrogeology • Observations, including site vegetation • Access/risk potential – people, livestock, produce, ecosystems
<p>Sampling and analyses plan</p> <ul style="list-style-type: none"> • Sampling and analytical data objectives • Rationale for sampling pattern, sampling number and analysis programme
<p>Basis of guideline values</p> <ul style="list-style-type: none"> • Table indicating guideline values used • Assumptions and limitations of guideline values
<p>Results</p> <ul style="list-style-type: none"> • Site plan showing sample locations and exceedances of guideline values • Tabulated results showing guideline exceedances and other statistical information
<p>Conclusions and recommendations</p> <ul style="list-style-type: none"> • Brief summary of the results • Assumptions and uncertainties • Recommendations for additional works (if required) • List of appropriate site uses

6 Risk Management

6.1 Overview

The aim of any risk management carried out on a site is to control the potential health and environmental risks to any receptors, whether they be site users, maintenance and/or excavation workers, or people off-site (eg, those affected by the migration of contaminants in dust, groundwater or surface water). Potential health risks arise from exposure to contaminated soil, groundwater or vapours. For an actual risk to occur, however, a complete exposure pathway must exist between the contaminant source and the receptor.



Remediation acts by reducing the concentrations of contaminants to such a level that exposure to the affected media (eg, soil) will not result in a significant risk to the relevant receptors. Remediation options include removing the contaminated soil to safe disposal (whether on- or off-site) or treating the soil to reduce the contaminant concentrations to safe levels.

Managing a contaminated site, on the other hand, implies controlling the exposure pathway and/or the behaviour of potential receptors. That is, although the hazardous contaminants may remain in the soil, the management controls prevent them from affecting the receptors. *In situ* management options include:

- implementing physical barriers such as fencing, placing a sufficiently thick soil or cement cap, or sealing the site with an impervious pavement (contaminant isolation)
- setting aside the site as reserve land (for which less frequent exposure can be expected and therefore less stringent guidelines can apply)
- implementing institutional controls such as management plans, or zoning the land to prevent sensitive uses.

In many instances, a combination of remediation and/or management approaches may be appropriate. For instance, where a soil cap is used to isolate users from affected soil (blocking the exposure pathway), a management plan should be implemented at the same time to control any excavations into the underlying affected soil (control on people's behaviour).

Remediation or management of a known disused sheep-dip site needs to be undertaken if a site investigation report identifies contaminant concentrations that pose a risk to human health or the environment. However, in some cases where contaminants are present at concentrations below guideline criteria but elevated above the background concentrations, an owner or developer may still choose to implement management or remediation options to reduce risk or allay adverse perceptions of potential purchasers. It is considered best practice for landowners to undertake remedial activities with the knowledge and agreement of territorial authorities.

The selection of a remediation or management option is very site-specific and depends on many factors, including the:

- type, extent and depth of contamination
- location of contamination relative to receptors
- area and volume of the contamination relative to the size of the property (or subdivision development) the sheep-dip site is part of
- proximity to a safe disposal location (including on-site disposal) if excavation and replacement are being contemplated
- availability of clean soil for capping or dilution
- future use of the site
- financial resources available.

Ideally, the option that best reduces the risk, maximises environmental merit and minimises costs would be chosen. Clearly, there are more options available for dealing with a small dip site in a large subdivision development than for a dip within a single residential lot, where removal or sealing over may be the only practical options.

6.2 Requirement for resource consent

A range of resource or discharge consents may be required for old sheep dips in relation to current off-site discharges, remediation activities, and the moving or transport of contaminated material, depending on the requirements of district and regional plans. Landowners should consult with both territorial authorities and regional councils to determine appropriate remediation options and consenting requirements. Territorial local authority officers should consult their regional council for guidance on regional plan requirements. In turn, regional councils should consult with the territorial local authority regarding what district plan provisions might be relevant.

Resource consent may be required when:

- the soil contamination, whether left undisturbed or subjected to some management or remediation action, is likely to cause an off-site discharge to groundwater or surface water through the action of rain infiltration or run-off
- remediation involves the transfer of soil to an area that is not a disposal facility consented to receive such material
- remediation involves disturbing a soil volume or area in excess of thresholds in the relevant plan
- remediation is likely to cause a discharge of contaminants to air (dust) or to water (as sediment in run-off).

In the case of land-use change or the subdivision of former farmland, the territorial authority needs to consider if resource consents may be required and should consult the relevant regional council at that time.

6.3 Remediation action plans

When site remediation is the chosen option, a local authority should advise the applicant to submit a remediation action plan as part of the resource consent application. The preparation of a remediation action plan is discussed in *Contaminated Land Management Guidelines No. 1* (Ministry for the Environment 2003a). The identification of all potential physical and chemical hazards and steps that will be taken to eliminate, isolate or minimise these hazards should be part of the plan, to inform workers undertaking the remediation. The complexity of some situations is likely to require an owner or developer to employ specialist expertise when preparing remediation action plans. The local authority may seek independent review of the proposed plan(s) or advice from a contaminated site officer at the relevant regional council. Regardless of which method is proposed by a developer, the success of the remediation must be confirmed by validation sampling and/or ongoing monitoring, as outlined in **sections 6.6 and 6.11**.

A landowner or developer may initiate a site investigation and remediation voluntarily to minimise the risks from an old sheep-dip site on her or his land. Outside the resource consent process there are often no requirements for the landowner to follow best practice procedures or to inform the council about the course of action. To encourage the landowner to involve the council in the investigation and remediation, councils could provide a certificate of compliance upon successful site remediation free of charge. This would give assurances to both parties: the landowner has confirmation from the council that the land is not contaminated, and the council has confirmation that the criteria for a successful remediation were met.

6.4 Soil remediation options

Remediating a site involves undertaking work to reduce the concentrations of contaminants at the site. Sometimes the contaminant concentrations can be reduced to background levels for the area under consideration, but it is more usual for the concentrations to be reduced so that they comply with the guideline criteria or standard for the proposed land use. Care needs to be taken to ensure remediation goals are appropriate to the local situation, because some contaminants (such as arsenic) can naturally occur at concentrations above guideline criteria. The selection of remediation goals and guideline values should only be undertaken by experienced contaminated land professionals.

The degree of remediation necessary will vary from site to site. At one extreme, soil contamination may be limited to a small, discrete area (eg, immediately under the dip area, amounting to a few cubic metres of soil). In this case, it would be possible to complete a full remediation by removing all the affected soil and replacing it with clean soil. Provided the chemicals have not migrated down into groundwater, removal and replacement of the soil beneath and around the dip site would remove or reduce the contaminants to a level that is safe for people and the environment.

At the other end of the spectrum, a large dip site might have high concentrations of contaminants down to several metres over a small area under the dip, and moderate concentrations over a more extensive but shallow yard area. Such a situation might lend itself to a range of methods that result in only partial remediation, rendering a site suitable for its intended use, perhaps with the assistance of a management plan to ensure that any residual risks are accounted for and managed appropriately. For example, one remediation approach may involve a combination of digging out the highly contaminated soils down to a “safe” depth, with disposal off-site, and the remainder of the yard area made safe by soil treatment, such as sieving and backfilling the large soil particles and land-filling the fine particles.

The common combination of arsenic and organochlorines does limit the options for achieving remediation via an all-inclusive soil treatment. The most appropriate site remediation methods for disused sheep dips are likely to involve:

- the physical removal of contaminated materials and soil and their relocation to a more suitable area (on- site or off-site) with long-term management, or disposal to landfill
- soil treatment to reduce the contaminant concentration to safe levels.

A range of alternative options should be considered, and a selection of remediation options is provided below. The list is not exhaustive, and there may be more appropriate remediation techniques that can be applied at a particular site.

Excavation and replacement (dig and dump)

Excavation is commonly used where a detailed site investigation has identified significant contamination in the soil or unacceptable discharges to water bodies. For this remediation method the contaminated soil is removed to a licensed landfill, or to an area that has consents to receive contaminated material. The removed soils or sediments may need to be analysed to confirm they comply with landfill waste acceptance criteria as specified in the *Hazardous Waste Guidelines* (Ministry for the Environment 2004b). Where soils from sheep-dip sites fail the toxicity characteristic leaching procedure (TCLP) tests required by most landfills, prior treatment to reduce the contamination will be necessary. Concrete (eg, from the draining platform) can also adsorb dip chemicals, so where no risk management plan is to be instituted for a site, old dip-bath structures should be removed together with the soil.

Validation samples will need to be collected from the soil remaining at the site to prove that the contaminant concentrations comply with the remediation goals (see **section 5.6**). Remaining holes or depressions may then be covered with clean material. This option is practical in a farming context. In the past, private landowners often “decommissioned” their old sheep dips by doing the dig and dump themselves without supervision, often unaware of proper remediation procedures.

This option is likely to be economic mainly for small volumes of soil, but may also be appropriate for extensive contamination on large developments where the developer considers the economic benefits justify the expense.

Soil screening and soil washing

Soil screening is a process that attempts to physically separate the contaminated material from the rest of the soil. Physical separation is an *ex situ* process that requires soil excavation before treatment. It is an effective soil treatment for contaminants adsorbed to soil particles that occur in a particular size fraction of the soil. The majority of contaminated material is often contained in the finer clay and silt particles (< 63 µm) because they bind contaminants strongly due to their large and reactive surface area. However, not all soils are amenable to this treatment and the potential application of this technology is usually ascertained by laboratory treatability tests and pilot scale tests. Soil screening and soil washing are often used to reduce the amount of material for subsequent treatment or disposal.

Screening separates soils according to particle size by passing the material through a sieve with a particular mesh size. Normally soil undergoes preliminary screening by separating large rocks and debris from the soil matrix. Any residual fines adhering to the surface of large rocks are washed off, and it is verified that the coarse fraction is clean before returning it to the site. During the subsequent screening process, finer soil particles pass through the sieve and leave larger particles behind. Screening may be performed as a stationary process or with motion.

Where the separation is not complete due to larger clay conglomerates or particle coatings (eg, metal oxide on particles in larger size fractions) dry sieving is often followed by wet sieving or soil washing to separate the fine fraction with the contaminants from the remainder of the soil matrix more effectively.

Soil washing involves adding water to the soil and then wet sieving the resulting slurry. Most soil washing processes employ secondary screening to segregate the particles into different-sized fractions, usually between 5 mm and 60 mm. After the contaminated fine particles are separated from the clean coarse particles, both fractions are dewatered with a filter press. The contaminated fraction and/or the process water is further treated or disposed of in a landfill, while the larger particle fraction can be returned to the site if considered clean. In general terms, soil washing is cost-effective for soils where the clay and silt contents are less than 30–35 percent of the soil (Pearl et al. 2006). Soil washing is suitable for removing both organochlorines and arsenic.

In situ biological treatment/bio-remediation

Modern dip chemicals will naturally break down due to biological activity in the soil over a period of weeks or months, provided the concentrations of historical and/or currently registered chemicals are not so high as to prevent biological activity. An appropriate strategy for modern dip chemicals is therefore to wait for natural attenuation to occur, taking samples at intervals to ensure the natural reduction in contaminant concentration is indeed happening. It may be appropriate to fence the site during this process, depending on its location and accessibility.

In contrast, some of the historical dip chemicals, such as the organochlorines DDT and dieldrin, break down very slowly, and the metalloid arsenic does not break down at all. Leaching of these chemicals out of the soil is also generally slow. Although bio-remediation of organochlorines is accelerated in strict anaerobic environments, such as found in black pond or drain sediments, most organochlorine pesticides at dip sites are normally found in the topsoil under mainly aerobic conditions. Thus, in the case of DDT and dieldrin, attenuation will occur slowly over years, while arsenic will attenuate only minimally.

Some contaminants are accumulated in the leaves of suitable plant species. Arsenic, for example, accumulates in high concentrations in water plants such as watercress. There are also a few land-based plants that, given the right conditions, can produce very high concentrations of arsenic in their leaves. The leaves then require harvesting and off-site disposal, otherwise they will drop on the ground where they break down and redeposit the arsenic. Such a remediation technique is slow (taking years, possibly decades) and requires consistent maintenance to lower concentrations significantly. This would only be feasible where a long-term gardening programme is in place, such as for a retirement village or a council reserve.

Research into phytoremediation in New Zealand is still in its early stages. Given that proposals require detailed technical evaluation, and due to their nature would require long-term monitoring and validation sampling, phytoremediation is unlikely to be viable for most sites at this time.

Electro-osmosis

Electro-osmosis is the only *in situ* technique that can yield clean soil in relatively short timeframes (one to three years) when metals such as arsenic are the prime target. Electro-osmosis is the movement of water through soil by applying a low-intensity direct current between electrodes placed in the soil. Contaminants are mobilised in the form of charged particles, or ions, in the pore water. This technology works well in soils with poor permeability and at a depth where contamination in the hot spot areas is normally encountered. It is also very suited to the treatment of excavated soil, either on-site or off-site at a central treatment facility. On the down side, the technique requires rather intensive, and therefore costly, instrumentation and monitoring. Electro-osmosis is likely only to be suitable for sites where arsenic is the sole contaminant of concern and the extent of contamination is large enough for this *in situ* technique to be cost-effective compared with land-filling the contaminated soil.

***In situ* soil mixing**

In some circumstances, it is possible to reduce contaminant concentrations to below guideline concentrations by vertically mixing the contaminated soil with underlying uncontaminated soil; in other words, by diluting the contaminant concentrations on the surface. Soil mixing should not be used for hot spots, and should be limited to contaminant concentrations less than two to three times the guideline level. For example, for large yard areas where contamination only marginally exceeds soil guideline values and is probably restricted to near the surface, soil mixing may be practical provided there is sufficient clean underlying soil available for mixing and no potentially contaminated dip structure remaining in the ground. Mixing can be achieved by using a large, sturdy rotary hoe, or by repeated scarifying, windrowing and re-spreading with a grader. Strict controls need to be in place to manage sediment run-off during soil mixing and to avoid contaminating the wider environment.

There are practical difficulties for sheep-dip remediation when attempting to mix depths of soil greater than about 30–40 cm. If there is any deeper contamination, such as under the dip, then excavation will be necessary to achieve mixing, in which case it is probably just as practical (and certainly more desirable) to remove the material from the site.

There are other practical limitations of soil mixing.

- The soil needs to have a suitable texture and moisture content to break down to a fine state when cultivated ie, the soil must be intimately mixed together to achieve homogeneity throughout the profile, rather than just mixing soil clods or clumps together. Any clay-rich soils will need extensive drying and grinding to allow good mixing, and repeated scarifying in dry weather over sufficient time to allow the lumps to disintegrate. Successful mixing is difficult to achieve with heavy clay soils, whereas silt loams and sandy soils are more readily mixed.
- There must be a sufficient depth of clean soil underlying the contaminated soil to create a composite soil. A thin top soil overlying large gravels, or heavy clay, is unlikely to provide a satisfactory mixed soil.

Field-mixing trials need to demonstrate that the soil can be adequately broken down and mixed, and the results need to show consistent lateral and horizontal distribution. They should be checked independently by the local authority, either by trained council staff or by a different contaminated site professional from the one involved in the remediation process.

In situ soil mixing is a rather controversial remediation method. Although the overall concentration of contaminants is reduced, it leads to a larger amount of soil being contaminated, which is not a desirable option. On the other hand, this method could be considered as a sort of resource recovery to achieve beneficial use of the soil rather than creating soil waste to go to landfill. Vertical soil mixing is practised in Australia for agricultural land that is being redeveloped for residential use. The New South Wales Environment Protection Authority (NSW EPA) has issued guidelines which describe the application and limitations in more detail (see <http://www.epa.nsw.gov.au/resources/vertmix.pdf>). However, with the high natural background concentration of arsenic in New Zealand, the efficiency of mixing may be greatly reduced.

6.5 Management of discharges during earthworks

Earthworks for remediating dip sites will generally be at the smaller end of the scale, and so will be the potential for off-site discharges. Discharges of contaminated dust during windy conditions are most likely to cause nuisance issues for neighbours as opposed to health issues, unless the soil is heavily contaminated. Discharges of contaminated sediment during heavy rainfall and tracking of contaminated material off-site by vehicles are possible. Significant discharges to groundwater as a result of earthworks are generally unlikely, but good practice should be followed to avoid any discharges.

Four basic best practice principles are:

- stage the excavation
- stabilise exposed areas rapidly
- install perimeter controls to divert stormwater
- employ retention devices.

Staging the excavation involves minimising the area of soil exposed, so that the opportunity for sediment or dust generation is minimised. For small excavations, the most effective strategy is to carry out all excavation during dry, calm conditions. The smallest remediation projects can be carried out in a single day. Otherwise, loose soil should be protected from erosion by *stabilising exposed areas rapidly*. This will generally involve compacting at the end of each day, and covering stockpiles of contaminated material in adverse conditions.

Perimeter controls such as diversion drains should be installed above the site to keep clean run-off out of the work area during the excavation process. Perimeter controls can also retain or direct sediment-laden run-off within the site; typically this will involve diversion drains, silt fences and earth bunds. *Retention devices* such as settling ponds may be necessary. Water collected in the excavated area, either from rain or other sources, should be treated as potentially contaminated. Before disposal it should be tested and then disposed of in an appropriate manner. In the case of vehicles leaving sites, wheels should be cleaned, soil should not be piled so high that it might spill, and loads should be covered and sealed to prevent spillage and dust. Guidance on controls for earthworks is given in regional council guidelines, such as ARC 1999.

Health and safety considerations are also an important part of any contaminated site investigation or clean-up. The risks – such as toxic effects, physical injury and harm to workers on-site – must be assessed and managed. Where the soil is heavily contaminated, the duration and extent of exposure may be important in determining whether a human health impact is likely. In this case, protection of on-site workers is also relevant. For disused sheep-dip sites it is likely that exposure would only occur over a short period of time. For example, to avoid operators in open excavators or bulldozers being exposed to clouds of potentially contaminated dust, it is recommended that earthmoving machinery have pressurised cabins with GAC filters on air inlets. Occupational health and safety requirements for field works are covered under the Health and Safety in Employment Act 1992 (see **Appendix 3** for further information).

6.6 Site validation investigation

Whenever remedial action is taking place, validation sampling must be carried out to determine whether the clean-up goals have been achieved. Validation sampling should preferably be carried out by an independent party (ie, independent from the party who carried out the investigation and the remedial design).

The validation has to be undertaken with a sharp eye for unidentified contamination or possible missed hot spots. Therefore, the investigator should not only verify the remediation works systematically, but should also validate the remaining soil and/or groundwater, and the backfill soil if applicable. While often carried out together, validation sampling and verification of remediation goals are two different activities.

Samples are then analysed for selected chemicals of concern. Normally a single chemical is selected from those previously analysed at a site, which will be the contaminant of concern that exceeded its guideline more often and by a greater amount than any other substance. It is expected that any other chemicals would automatically be below their respective guidelines if the critical chemical is below its guideline. However, in the context of old sheep dips it is recommended *not* to substitute dieldrin and arsenic for each other because they may have a different mobility in the soil profile due to their physicochemical characteristics.

In the case of soil excavation, the base and sides of the excavation should be sampled to ensure a sufficient volume of soil has been removed for the remaining soil to be below guideline concentrations. The number of samples will depend on the size of the excavation. For example, for a small excavation the samples should include at least one sample from each of the base and four walls of the excavation. In the case of soil mixing, validation samples must be taken from the mixed soil and the soil immediately below the mixing zone to show that both the underlying soil and the mixed soil are below guideline values for the contaminants of concern.

The number of validation samples proposed and the target concentrations should be specified in the remediation action plan. More information on validation sampling can be found under *Contaminated Land Management Guidelines No. 5: Site Investigation and Analysis of Soils* (Ministry for the Environment 2004a).

6.7 Site management options and strategies

The management of a contaminated site limits the exposure of people or environmental receptors to a hazardous substance by controlling access and contact to the contaminant. The two main options are:

- imposing a physical barrier to isolate the contaminated material and prevent exposure (eg, *in situ* burial and/or capping)
- finding an alternative lower-risk land use.

Contaminant isolation involves the use of an effective barrier to prevent people getting in contact with the contaminated site. An effective barrier is one that blocks the exposure pathway between a contamination source and a receptor. Barrier types include fencing to prevent uncontrolled access to an affected site, and sealing or capping an affected area. Discharges may still occur, however, and so these options may require a discharge permit.

When considering site management options for an identified sheep-dip site, it is important to take the current and proposed land use into account. For ongoing farming practices, capping may be the most practical option, while capping as a remediation option in residential areas (including schools) is more problematic, because it is difficult to ensure the cap is not dug up again.

Fencing

Fencing a site may be appropriate in a rural location where few people reside and control of the site can be readily exercised by the property owner. This option may be suitable for land where the location of a sheep-dip site is known and where the land is to continue in agricultural or low-intensity use.

Fencing is less satisfactory in a residential area as curious children are more likely to enter the site. Here, an additional means of preventing exposure such as capping is recommended, and child-proof fences in residential areas should consist of chain-link netting at least 2 m high. Permanent signs should be erected, or attached to the fence at clearly visible places, to warn the public of the contamination. Placing the site on the LIM would help to ensure that fencing is maintained. The council may instigate a site visit routine to check that warning signs and fencing are still in good order. Fenced areas ideally need some form of maintenance-free

vegetation cover to avoid erosion or slips. Bushy or prickly plants may act as a further deterrent to children entering the site.

Capping

Capping is usually only done where the contaminant concentrations are not higher than a few times the guideline concentration. There are two main forms of capping a former sheep-dip site: soil capping, and sealing using asphalt or concrete. Soil caps with a low-permeability base layer are common, cheap to install and, when vegetated, easy to maintain. A soil cap must be of sufficient thickness that excavation through the cap would be rare, and should involve using something like a geotextile membrane to separate clean from contaminated soil. Asphalt, concrete, or buildings directly block a receptor from contact with the ground. Low-permeability sealing materials can also be used to prevent water getting in, thereby preventing leaching of mobile contaminants into the groundwater system.

In a rural situation where the owner can exercise additional control over access, a soil or impervious gravel capping layer of an appropriate depth could be satisfactory. The thickness of the capping layer should be determined to provide sufficient depth for grass to be established without the roots penetrating the contaminated soil. If there are several disused sheep dips on one farm property, it may be an option for the farmer to excavate them all and encapsulate the contaminated soil material from the various sites in one spot. However, this would require a resource consent from the regional council unless specifically allowed by a rule in the regional plan.

Soil capping within residential subdivisions is generally not advised because it is not possible to control what future homeowners and tenants will do in their backyards. If capping in a residential situation is done regardless, soil caps of at least 600 mm and up to 1 m, depending on the contaminant concentrations, may be necessary to ensure minimal access. A geotextile separation and marker layer should be placed between the contaminated soil and the soil cap. On reserve land used for passive recreation, a capping layer of 400 mm may be sufficient, where cultivation or excavation, other than initially to plant grass, is unlikely. Plants planted in capped areas need to be selected with care as deeper-rooted plants (eg, trees) may disturb the cap.

Excavation and on-site disposal

Proposals for on-site disposal require evidence that the disposal site will not create adverse effects or present risks to potential receptors. In general, chemicals from old sheep dips are not particularly mobile in the environment, so on-site disposal away from water courses and above the water table may be an effective solution. A resource consent may be required, as described in **section 6.2**.

Moderately contaminated material could be disposed of on-site to a passive recreational reserve, with an appropriate layer of clean soil cover to ensure contact with contaminated soil is unlikely. A geotextile layer would normally be placed above the contaminated soil to separate it from the clean capping layer and to act as a warning in the event of excavation. A management plan would be implemented to control excavation. Development of the reserve may be prohibited by means of a notice on the title, or the LIM.

Highly contaminated material (concentrations several times the guideline values, and with a high potential for leaching) would need to be encapsulated on all sides if on-site disposal was contemplated. Often the soil is treated with a binder such as cement for stabilisation or solidification before it is placed in an engineered impermeable cell. This option would require detailed technical proposals.

Alternative land use

Finding an alternative use for the affected area means a less sensitive land use for which higher contaminant concentrations can be tolerated, because people will experience less frequent exposure. Such uses include:

- reserve areas, where people generally spend less time compared with the residential land-use scenario, and hence the exposure is limited
- under roads, where management plans are in place to ensure that no casual exposure to ground contaminants can occur, and to control any excavations.

Note, however, that topsoil contaminated with pesticides often has high humus levels and is difficult to compact, which precludes its use as road base. Caution is also required with respect to the proximity to services such as water/sewer pipes, telecommunications and electricity lines, and access for maintenance workers. The use of concrete U-ducts would allow future modifications to cabling or pipes without frequent re-excavation.

6.8 Risk management plans

Risk management plans contain information about the contamination on a site. This information can then be easily transferred to new property owners or site users. Management plans are designed to avoid people, stock or other environmental receptors coming into contact with the contaminant (eg, by imposing a physical barrier). Risk management plans are mainly employed to control excavation activities and to ensure the contamination is kept securely contained. They may address caps on slopes that are prone to slips and erosion. Some management plans also specify ongoing monitoring requirements. The contents of a management plan are discussed in *Contaminated Land Management Guidelines No. 1* (Ministry for the Environment 2003a).

One limitation of a risk management plan is that it relies on a responsible party being given the authority to control a site. A risk management plan is therefore most appropriate where a corporate body (eg, a company or a local authority) is in control of the land. Management of a contaminated site may also be appropriate for a bigger parcel of land or a lifestyle block. For owner–occupier residential sites, a risk management plan may be imposed on a subdivision by way of a consent notice on the certificate of title, or as a condition on a land-use consent as an ongoing requirement. Risk management plans should have a review clause to ensure the plan continues to provide adequate protection of human health and the environment in the future.

As a protection to future owners, any site that is not returned to a fully remediated state, and thereby still falls under the definition of contaminated land, should be recorded in council files and appropriate information should appear on property files or LIMs/PIMs. Private landowners should always be informed if such a notice is put on the property title. If a risk management plan is in place, it is the primary responsibility of the site owner to make it available to site users, where appropriate.

6.9 Contamination below existing barriers

Where contamination exists (or is thought to exist) below previously constructed barriers, such as woolsheds, these barriers can effectively cap the contamination and preclude exposure to contaminated soils (NSW Agriculture 1996, p 26). Anecdotal information suggests, however, that in some cases the dip liquid was purposefully disposed of under the woolshed in order to get rid of insects.

There are two options to deal with this situation:

- remove the contamination, which would involve destroying the associated structure, or
- leave the contamination in place and put a notice on the title or LIM as to the possible presence of contamination, coupled with an appropriate risk management plan.

6.10 Groundwater contamination

In most dips, contaminated soil has been exposed to similar conditions over the past 40 years or more, and chemical reactions between soil and contaminant are therefore expected to have reached some form of equilibrium. In other words, most of the contaminants that would leach under present circumstances have probably already done so (Dupen et al 1994, p 17). To ensure that groundwater has not been significantly affected, it is recommended that the groundwater below a dip site always be assessed by a technical expert unless it can be proven that a minimum of three metres of unfractured clean soil or low-permeable solid rock separates the contaminated zone from the water table.

Investigations are also warranted when one or more of the following conditions apply:

- the site is close to a stream or lake, which is the receiving water for groundwater passing under the site
- the site is close to a water-supply well, the most likely situation being a farm bore
- the concentration of dipping chemicals used on the site is very high

If groundwater contamination is found, the follow-up investigations require detailed consideration of the impacts and possible remediation measures. This is beyond the scope of this guideline. In general, source removal (ie, soil excavation) will reduce future impacts on groundwater, and improvements could be rapid (a matter of months) where ground permeability is high.

Appendix 7 contains a case study where groundwater was investigated for arsenic contamination in relation to suspected contaminant leaching from old dip sites.

6.11 Monitoring

Most on-site or *in situ* remediation involves careful *monitoring* of the remedial system, the remediation processes and the effects of the processes. Monitoring of the effects (eg, measures of dissolved oxygen for aerobic processes, the distribution of added substances, etc) can give an early warning that the clean-up level will not be reached if the system or process keeps running as it is, which allows the process to be corrected or a change of contractor/consultant made.

Verification monitoring (third party) focuses on the reduction of contaminants achieved. In practice, verification monitoring often provides data when most of the money has been spent and the remediation is completed. Due to the time lag between actual remediation and receiving the sampling results, verification monitoring is not a good tool to assess the progress of remedial processes. For this reason, it is recommended that larger remediation projects not rely on verification monitoring alone, but also monitor the remedial system, the processes or effects during the remediation phase.

Environmental monitoring may be appropriate if the site is of sufficient scale that effects on groundwater or surface water are likely, or during remedial earthworks where run-off may affect surface water. If these circumstances arise, it is likely that resource consents for the discharge to water will be required, which provides the opportunity to impose monitoring conditions.

Always give careful consideration to the need for *ongoing monitoring*, especially if capping or fencing is chosen to manage the site, in order to ensure that barriers are still intact and in place. Monitoring conditions should not be imposed automatically though, and each case must be treated on its merits. For example, if a dip site is particularly large and concentrations are significantly elevated, or a drinking-water supply is at risk, a requirement to investigate and monitor groundwater will be necessary. Monitoring of groundwater in sedimentary areas, where groundwater is expected between three and five metres, could require the installation of groundwater monitoring wells to about 5–7 metres.

Surface-water monitoring may be appropriate if there is a nearby water body and the site layout and topography are conducive to sediment run-off reaching it. Taking sediment samples at suspected points of entry at regular intervals is an effective way to determine if there are any remaining risks to the environment.

7 Best Practice Tips for Common Sheep-dip Scenarios

Three scenarios that may be commonly encountered by local authorities are illustrated below. For each scenario, recommendations are given for the appropriate site investigation, sampling and remediation. However, note that not every former sheep-dip site will fall within these three scenarios, and each site must be assessed on an individual basis. Indications of costs are given as a rough guide. The collection of case studies in **Appendix 7** illustrates different dip situations and the specific findings when the sites were assessed. **Appendix 10** shows photographs of sheep-dip structures.

The scenarios are as follows.

- **Scenario 1:** anecdotal information suggests that a sheep-dip site was previously located on council-owned parkland, but the exact location is unknown.
- **Scenario 2:** the location of the disused sheep-dip site is known (ie, associated structures are in place or the sheep-dip location is known) and the site has continued to be used as parkland.
- **Scenario 3:** the location of the disused sheep-dip site is known (ie, associated structures are in place) and the site is to be developed for residential use.

7.1 Scenario 1

The council owns parkland that can be accessed by the public. The land was previously owned by a sheep farmer and was acquired by the council in 1975. Information has been provided that a sheep dip was previously located on the land. The location of the sheep-dip site is not known.

Best practice tips

There are benefits in taking immediate action to gather the existing information about the former sheep-dip site (eg, anecdotal information). The council has a primary interest in protecting public health and wants to make sure there are no public health risks arising from a potential sheep-dip site. Also, if the land is later subdivided or there is a change in land use, the local authorities will benefit from having access to recorded information about the site. It also ensures that councils can supply the best information available to future purchasers of the land.

The council contacts previous landowners to ask when they owned the property and what the land use was at the time.

Best practice tips

If the site has been a sheep farm, the council needs to find out if a sheep dip was used (or more than one), and if so, during which period it was operated. Other important questions in this context are:

- what type of sheep dip was operated?
- where was the sheep dip located?
- where were the chemicals stored?
- where did the discharges go?

The council also accesses old aerial photographs in its database to identify structures associated with sheep dips. Once the potential locations of sheep dips and associated structures are identified, an on-site visit verifies sheep-dip structures above and in the ground.

Best practice tips

An initial visit to the site to see if sheep-dip structures are still present may save some of the research steps above, unless multiple dip sites are suspected.

Another way to locate the old sheep dip is a 'walk over' survey, which would take about a day for an area of 50 x 100 metres. The following surveys are available.

- A survey with a ground-penetrating radar over the suspected area can identify buried structures, concrete slabs, etc.
- An electro-magnetic survey over the suspected area looks for areas with significantly high metal content at some depth. This is useful when the site is covered and high arsenic concentrations are suspected, but is no use for organochlorines. Neither can it be used if metal junk is buried, or if the site is covered with reinforced concrete.
- An X-ray fluorescence survey can be used if contaminants are expected close to or mixed into the surface. Again, it is no use for organochlorines.

Other sources of information the council could use to confirm the location of the historical sheep-dip site are stock and station agents, knowledgeable neighbours or local residents. However, the council should be cautious about potential erroneous or malicious information, and should try to verify any claims made by third parties.

If no anecdotal or other information on the location of the dip site(s) can be found, the council could still consider, as a precautionary action, surface sampling of areas where the public (children in particular) may get in contact with soil or dust. Composite samples (eg, along path-sections or playfields) can help identify whether risks are present, even if the location of the dip is unknown. Given the size of a regular dip site, sampling every 10 m would give a fair chance of including at least one contaminated sample. Skilled park or council staff may do the sampling of surface soils, so the only costs would be the analysis. The laboratory will be able to help with the decision on the number of sub-samples per composite, based on a pre-analysis of a few composites to determine background levels.

If the sampler marks a waypoint on a geographical positioning system (GPS) while going through the park taking samples, and enters the sample number in the GPS at every sampling point, even mapping the results will be very straightforward. The number of each waypoint can later be changed for the analysis result and printed on an overlay of an aerial photograph or topographical map without the need for sophisticated mapping skills.

At this stage, it needs to be emphasised that in some cases, although an area is identified as a previous sheep-dip site location, this does not necessarily mean that the site is contaminated (ie, levels of contaminants above relevant criteria for protection of human health or the environment).

See **section 4** for more detail on the identification of former sheep-dip sites.

7.2 Scenario 2

In this scenario, the location of the disused sheep dip is known and the council-owned land is being used as a public park. The council has established that the sheep dip operated between 1940 and 1955.

The council's main concern here is that the site may present a risk to the wider public visiting the park. Before initiating any site investigations, the council gets some quotes for the costs to dig and dump all the contaminated soil, based on estimated volumes. The council is considering hiring an excavator to look at soil profiles and to sample the soil at the same time. Then the council compares the quotes with the approximate costs for developing a conceptual model (an excavator can often be hired for three hours for the cost of one hour of a senior risk consultant's time, and the excavator may be owned and operated by the council) and possible follow-on management measures. This gives the council a rough indication of whether the "dig and dump" option would be more economical than developing multiple reports to assess other options. In this case, the transport and landfilling costs are high because the landfill is a good distance away and the potentially contaminated area is large.

Therefore, the site investigation focuses on:

- developing a conceptual model that identifies contamination sources and potential exposure pathways
- undertaking site investigations to delineate the extent of the contamination
- assessing whether groundwater is at risk, and sampling if risk is identified
- assessing the risk posed by the site, based on the conceptual model and the sampling results.

The council engages the help of a consultant and develops a conceptual model for this particular site based on the information already gathered at an earlier stage. The model includes the old sheep dip and associated structures as the contaminant sources, the receptors, and the potential exposure pathways (see **Figure 4**). There are no private or public bores in the 200 m radius of the site and no crops are grown on the land. However, contaminants could potentially have run off into or otherwise entered a little stream nearby and accumulated in the sediments. Direct contact of people with the soil is considered to be the most critical pathway in this scenario, with the most sensitive receptor being children.

Following this evaluation, the site investigation is planned to gather information on the level of contamination at the site and the level of risk the site presents to human health and the environment. It is established that the water table is more than 3 m below the contamination zone and the soil exhibits low permeability and no cracks, resulting in a good barrier between the contamination and the groundwater. Together with the fact that the sheep dip was only operating for 15 years, the council expects that no substantial leaching into groundwater has taken place at this site.

The soil, water and sediment are sampled and submitted for analyses for arsenic and organochlorine pesticides. The results of the soil analysis are compared with Table 4 for soil guideline values under the current land use, which in this case is parkland. The surface water and sediment samples from the stream are then compared with Table 6 to establish any risk to the environment.

The sediment and water samples are all below the soil guideline values. However, the concentration of dieldrin/aldrin in a number of soil samples is above 23 mg/kg, which is the selected soil guideline value for the protection of people for this land use. This means the council has to take measures to mitigate the risk.

Viable management options under this scenario

1. *The contaminants are left buried in the ground.* A geotextile (this could be just a wide-woven orange netting, such as old safety barrier netting and does not need to be very costly) is placed over the contaminated site. Then the site is covered with clean soil in the form of a mound. The soil cap should have a minimum thickness of 70–100 cm. The council can then replant the hump and write a management plan that ensures the site is not disturbed in the future. This option is preferable if the park is frequented by children. The cost will be similar to the cost of replanting an area after laying pipes or cables, with the addition of importing some clean soil. The project could be planned when soil elsewhere has to be disposed of. The use of clean surplus soil from a new subdivision could benefit both council and developer.
2. *The area is fenced off from people or larger livestock* and the spot is marked on the LIM. A permanent warning sign is erected. Consideration could be given to planting a dense, spiny scrub cover or a rose variety not requiring too much maintenance over the whole site to discourage playing in the enclosed area. This option would be less costly than option 1, and the costs are mainly incurred by the internal activity of the parks department. Since the location of the dip site is known, very limited outside assistance would be needed.
3. When adverse off-site effects are expected, or the on-site risks are difficult to ascertain (eg, children playing and digging in the park), the council may choose to *dig the contaminated soil out to go to landfill* after all. A resource consent is likely to be required to do that. An appropriate site validation programme must be implemented following remediation of the dip site. The potential costs of liability may be another reason for the council as owner of the land to choose this option.

7.3 Scenario 3

A property that includes a known former sheep-dip site is to be developed for residential use. Consequently, an approach must be taken to ensure that human health is protected to a level consistent with residential land use.

Best practice tips

An investigation report may be needed as part of a sale and purchase agreement or an application for resource consent. The sampling procedure adopted should follow best practice, and the results must confirm that the site does not represent a risk to human health, a drinking-water source or the environment. If an unacceptable risk is identified some form of risk management needs to be adopted for the site that adequately protects people and the environment from contaminant exposure.

The assumptions under this scenario are as follows:

- the dip consisted of a concrete plunge bath (approximate depth 2 m)
- the dip has been backfilled with either surrounding soils or other materials
- the water table is 4 m below the surface, 2 m below the sheep-dip base
- the dip is located up-gradient of a waterway (small stream)
- arsenic and organochlorine chemicals were used in the dip.

Because the location of the old sheep dip is known, the site investigation focuses on:

- delineating the three-dimensional extent of contaminated soil present
- identifying any migration routes
- assessing groundwater quality below hot spots, below depressions and at places where groundwater is shallow (within or close to the contaminated soil layer).

The sampling programme takes into account that the contamination source is at depth (ie, at the base of the former plunge bath), as well as around the splash zones and the drainage platform. Therefore, soil samples are collected from any backfill material, from depths at and beneath the former plunge pool base, and in the underlying natural material. Use of a hand auger or drilling rig allows these soil samples to be collected at the required depth.

Best practice tip

In relation to residential subdivision, the important human exposure pathways are ingestion of soil and dust, and consumption of home-grown produce. These pathways relate to contaminants in soils at or near the ground surface. Systematic sampling is recommended to avoid sampling bias and to provide site coverage.

For this residential scenario, a 7.5 m sampling and validation grid is placed across the area of concern (ie, the former sheep-dip site, including the draining platform and the discharge zone and any areas of chemical storage). This sampling pattern allows samples to be collected from the area where contaminants are likely to be the highest, and also from background areas up-gradient of the plunge bath. The size of the grid depends on the information known about the site and the size of the dip site. Because a surface-water body is located down-gradient of the sheep dip, sediment and surface-water samples are collected. The dip contains liquid (collected rainfall), which is analysed to determine if contaminants are present above relevant water quality guidelines (eg, ANZECC and ARMCANZ, 2000).

Because the sheep dip operated on that location for a number of years, the area in the direct vicinity of the sheep dip has some hard fill. To save sampling time, a small (2–5 tonne) excavator is used to dig small holes (one scoop with a narrow bucket) or shallow trenches in the more central areas. This also allows good inspection of the soil layers, and possible discolorations can be observed with ease. The area is relatively small (50 x 100 m) and one day's work is sufficient.

Groundwater samples are taken from below the former plunge bath, and below two depressions close-by, where infiltration of used liquids may have taken place. Due to the water table being 4 m below the surface and the soil type suggesting a low permeability, it is decided that no other groundwater samples need to be taken unless the preliminary sampling results show unacceptable groundwater contamination. No groundwater contamination is detected.

Elevated contaminant levels for arsenic and lindane are found in a number of soil samples. Usually the depth (and therefore volume) of soil that needs to be excavated for site remediation is determined by contaminant levels that are judged to be comfortably below applicable guideline values for human health.

Viability management options under this scenario

1. *The contaminated soil is removed and relocated beneath a sealed car parking area.* As part of a resource consent, a condition may say that prior to occupation the developer needs to vest ownership of this "common area" in a legal entity, such as a *body corporate*. All residential owners will be shareholders in the upkeep of common property and pay an annual insurance premium against the risk that the contaminated material would need to be excavated and disposed. A bond could be posted in establishing the insurance scheme held against the risk that remedial work is needed at some stage in the future. A risk management plan is written to ensure that the sealed surface is maintained and any disturbances during maintenance works are controlled. The spot is marked on the LIM.
2. *The top 0.5 m of soil is remediated to meet the residential soil criteria.* A management plan is put in place and the spot is marked on the LIM.
3. *The soil is excavated to the whole depth of contamination and disposed to landfill.* An appropriate site validation programme must be implemented following remediation of the dip site. No management plan is needed. The remediation report and validation report can be issued with the LIM.

7.4 Sampling tips from a professional contaminated land practitioner

- Overall guidance on sampling can be sought from the *Contaminated Land Management Guidelines No. 5* (Ministry for the Environment 2004a).
- Initially, samples may be composited; sub-samples should preferably be taken from adjacent locations, from similar depths and with a similar site history (eg, the area where a former draining pen is confirmed) to give an idea of where individual analysis would be most beneficial.
- After the shallow holes are excavated, deeper investigation can be done using a hand auger as the hard surface is taken away.
- With deeper holes (over 3 m) a drilling rig may be needed if soils are too hard for a hand auger.
- A small digger with posthole attachment is a good option for sampling in the first few metres, because it is much faster to set up, can drive over uneven ground, sampling from depth intervals will be quite precise as the auger can be taken from the borehole in seconds avoiding smearing and mixing (often the case with auger rigs), and a digger can push soil back in the hole quickly after the completion of sampling. (For more details on costs, see **section 7.5**).
- When sampling with large-diameter augers or using an excavator, consider the mixing effect of the backfill in these deeper holes. The deeper layers may be found to be clean, but the surface layer has high concentrations and these are now likely to be found in the fill of these investigation holes, giving rise to the need for remediation of investigation holes later on! When the surface is highly contaminated, consider filling deeper holes with clean fill brought to the site beforehand.

Overall, take care:

- not to aggravate the contaminant situation by investigation works
- not to encourage infiltration (in poorly compacted or open investigation bore-holes)
- not to create cross-flow of shallow water into deeper groundwater.

7.5 Cost estimates for investigation, reporting and remediation

The following subsection may only be relevant for sites that require an extensive assessment and possibly subsequent remediation. Estimated costs are given as of 2006, are GST exclusive, and indicative only.

Investigation costs

These costs are location- and duration-dependent (usually taking between one and four days), and hence the following are rough estimates to assist in the projection of costs only:

- excavator: \$60–\$80/hour, plus mobilisation \$50–\$100
- sampling by environmental engineer: \$70–\$90/hour, plus travel expenses
- hand augering around the centre area and possible migration pathways: one to two persons, \$120–\$180/hour
- power augering using a digger plus one person sampling: combined \$140–\$190/hour
- placement of some shallow monitoring wells in pre-augered holes: \$200–\$300 each (this covers 3 to 10 wells per site, but note that surveying the level of the well tops to determine the flow direction may be needed if groundwater flow direction is not evident)
- analysis of samples (30–80 samples): heavy metal screen \$30, organochlorine pesticides screen \$90.

Reporting costs (mapping, cross-sections, text)

A rough estimate is \$3,000 for phase 1 surface sampling and \$8,000 for the final report. However, costs are very dependent on the level of graphics required, the precision of the sample locations (use of a surveyor, or quick GPS record of coordinates, downloaded on to a topographic map or aerial photo overlay), and how elaborate the report is.

Basic reports, which would include a brief text, data mainly in attachments, maps and cross-sections mostly hand-drawn or basic GPS plots, cost between \$2,000 and \$4,000. Full reports (many pages, well indexed, many CAD maps, diagrams, contour maps, etc) may cost up to \$15,000 and more. Full reports may be necessary, for example, when the final plan needs to go through public hearings.

Remediation costs

These are very case-specific, but the following should give some idea of what might be involved.

- Generally, a 20-tonne excavator per day, given an adequate number of trucks, can excavate 200–300 m³ of soil. A 20-tonne excavator will cost \$80–110/hour.
- Most dip sites will be excavated within one to three days. If a lot of shallow soil contamination is present, a bulldozer and front-end loader to load trucks may shorten the work.
- In order to know whether to excavate further, sampling results are required, but there is often a hold-up due to the turnaround time of the lab. For this reason, on-site X-ray fluorescence (see **Appendix 8**) capable of detecting at least half of the desired arsenic concentration is very useful for indicating the extent of the contamination in the field.
- One way to avoid a third phase is to use a hand auger to take a second sample 0.5 m deeper into the floors and walls of the excavation, in effect creating a second envelope outside the excavated surface being sampled. The extra effort will pay for itself when a third mobilisation can be avoided.

- There are potential costs from the extra analysis, but not all samples need to be analysed in one go: a further set of samples for analysis is needed only from walls or floor areas of the excavation where the surface is still contaminated.
- Backfilling and compaction (levelling out shallow excavated parts, less than 400 mm) will usually be part of further development costs of the site, not part of remediation.
- There may be costs to compact and cap the soil.
- Pre-treatment of the contaminated soil may become necessary to comply with landfill acceptance criteria – allow for the associated costs.
- Disposal fees for contaminated soil are likely to make up the majority of the costs of dig-and-dump remediation.
- Transport costs will be significant when the approved landfill or treatment facility is located some distance away (trucks cost on average \$90/hour and can carry 15–25 tonnes of soil). Sometimes trucks can take some clean fill back on a round trip if there is sufficient space on site to stockpile it.

In addition, there might be costs incurred for initial investigations, consultancy fees, erosion controls, validation, peer reviews, consent applications and ongoing monitoring (if required).

Landowners may want to contact their regional council to explore possibilities to apply for funding to investigate or remediate a high-risk site.

Appendix 1: Checklist for Landowners to Assess Sheep-dip Sites and Management Options

1. Background information
<p>How many years have you owned the property?</p> <p>What is the current land use where the disused sheep dip is located?</p> <ul style="list-style-type: none">• sheep and/or beef• dairy• viticulture• horticulture• agriculture• lifestyle block• subdivided for residential• other (eg, parkland). <p>To help identify the chemicals used and relevant toxicity of the former dip site it is useful to establish the following:</p> <ol style="list-style-type: none">1) What is the age of the dip?2) What was the historical use of the dip?<ul style="list-style-type: none">• regular on-farm treatment (eg, plunge dip)• portable units• communal dip used by surrounding farms• spraying unit• other – specify here. <p>If this was a communal dip there is potential for higher levels of contamination.</p> <ol style="list-style-type: none">3) Do you know which chemicals or products were used in the dips? (Refer to Table A.1 for a list of sheep-dipping chemicals and products.)
2. Locating the former sheep dip or dips (<i>note: some properties may have had several dip sites</i>)

- 1) Is it located near a woolshed?
- 2) Is it located near sheep yards?
- 3) Is it located near a water supply?
- 4) Check for visible signs of structures:
 - concrete structures either intact or residual/destroyed structures
 - timber structures or corrugated iron spray booths
 - water races going nowhere
 - old pipes
 - a depression that has been backfilled.
- 5) What dip types or associated structures can you identify:
 - (i) below-ground structures:
 - swim-through dips
 - pot dips
 - plunge dips
 - (ii) above-ground structures:
 - spray dips (both race type and circular).

Other associated structures include:

- a draining platform drip pen near the dip (this may or may not have been concreted)
- a below-ground storage tank made of concrete (there may be a visible drainage outlet).

3. Contacting local people

Are you able to confirm the location of the sheep-dip site through talking to neighbouring farmers or local residents?

Yes

No

4. Chemical storage location

Do you know where chemicals were stored for the sheep dip?

Yes

No

If yes, have you checked that chemicals are no longer stored on the property and are disposed of appropriately?

Yes

No

Note: some chemicals no longer in use are recognised as being persistent in the environment. Call your council for free disposal advice.

5. What to do when a dip site is found

- 1) Identify the buffer zone of the draining platform, potential run-off area and discharge points. Ten metres is recommended as an adequate buffer zone from the dip.
- 2) If located near a bore, is this water bore in use today?

Yes

No
- 3) Is there potential concern for groundwater movement in relation to the dip site?

Yes

No
- 4) Are there any surface water bodies?

Yes

No
- 5) Check if the water gradient of the dip site might have caused contamination down-gradient.

Note: if contaminants are identified in the water, any risks for exposure of people or animals to this water supply need to be assessed. It may be necessary to divert run-off or disconnect receiving waters.

6. When is a site investigation required?

<p>A site investigation is required:</p> <ul style="list-style-type: none"> • for application to subdivide • for potential land sale • for land-use change • for discharge of contaminants to waterways and groundwater. <p><i>Note:</i> It will be necessary in most cases to resort to an environmental assessment by a qualified experienced practitioner.</p>
<p>7. What areas need assessment?</p> <p>Areas that need assessment include:</p> <ul style="list-style-type: none"> • soil beneath the bath • structures used for dipping • soil in the splash zone • soil in the disposal/run-off area and where dip liquid was drained • any bores in proximity to the dip site • draining platform area. <p>Soil analysis will confirm the presence of contaminants.</p>
<p>8. Management options (to be determined in conjunction with council or specialist advice)</p> <ol style="list-style-type: none"> 1) Isolate the site from people, crops and animals by: <ul style="list-style-type: none"> • fencing off • planting (plantation forest). 2) Dig and dump to an approved landfill: material needs to meet acceptance criteria and the site requires validation. 3) Cap or encapsulate: this may require an impervious membrane. 4) Do nothing: accept the risk to the environment (including people) and produce.

Table A.1: List of historical sheep-dipping chemicals and products (not exhaustive)

Source	Location	Vol	Page	Year	Product name	Active ingredient	Manufacturer
NZJAg	RuakLib	71	397	1945	Viper	Derris (= Rotenone)	Osmond and Sons (NZ) Limited
NZJAg	RuakLib	71	410	1945	Cooper's quick acting powder	Derris (+ arsenic?)	Cooper McDougall & Robertson
			410	1945	McDougall's premier powder	Derris (+ arsenic?)	Cooper McDougall & Robertson
NZJAg	RuakLib	97	?	1958	Altas	Aldrin, contains antiseptic	Tasman Vaccine Laboratory Limited
		97	?	1958	Dieltas	Dieldrin, contains antiseptic	Tasman Vaccine Laboratory Limited
NZJAg	RuakLib	B181	47?	1955	Cleanso ditox	Gammexane (lindane) + DDT	Farmers Industries Limited, Wanganui
			47?	1955	Cleanso	Arsenic powder + derris	Farmers Industries Limited, Wanganui
			47?	1955	Cleanso	Arsenic paste + derris	Farmers Industries Limited, Wanganui
			47?	1955	Cleanso	Arsenic fluid	Farmers Industries Limited, Wanganui
SFAnn	RuakLib		89	1948	Green label paste	Gammexane (lindane)	Young's
			89	1948	Improved powder	Arsenic with Gammexane (lindane)	Young's
			89	1948	Red label paste	Arsenic with derris	Young's
SFAnn	RuakLib		94	1948		Arsenical liquid	Murtons
SFAnn	RuakLib		25	1948	Cooper's louse powder	Gammexane (lindane)	Cooper McDougall & Robertson
NZJAg	RuakLib	97	378	1958	Young's sheep-dip, dust and spray	Dieldrin	Young's
NZJAg	RuakLib	97	418	1958	Elliotts dips and spray rig	Dieldrin	Elliotts New Zealand company, ELLCO Limited

Source	Location	Vol	Page	Year	Product name	Active ingredient	Manufacturer
NZJAg	RuakLib	97	448	1958	Not applicable	Aldrin and dieldrin	Shell Agricultural Chemicals
NZJAg	RuakLib	93	309	1956	Cooper's louse powder	BHC – Gammexane (lindane)	Cooper McDougall & Robertson
NZJAg	RuakLib	93	330	1956	Nexa sheep-dip	BHC – Gammexane (lindane)	Weedone Services – Ivon Watkins Limited
NZJAg	RuakLib	93	444	1956	Elliotts all-dip	Aldrin	Elliotts New Zealand company, ELLCO Limited
NZJAg	RuakLib	93	464	1956	Dieldrin dips	Dieldrin	Cooper McDougall & Robertson
NZJAg	RuakLib	93	532	1956	Cooper's dieldrin dips	Dieldrin	Cooper McDougall & Robertson
NZJAg	RuakLib	93	546	1956	Tartan aldrin and dieldrin sheep dips	Aldrin and dieldrin	Farm Chemicals Company, Nelson
NZJAg	RuakLib	93	556	1956	Young's sheep-dip	Dieldrin, DDT, BHC, derris, arsenic	Young's
Young Farm	Arch		286	1957	Tartan dieldrin sheep dust	Dieldrin	Farm Chemicals Company, Nelson
NZFarm	AlexTurn		221	1916	McDougall's sheep-dip	Arsenic and sulphur (+ some carbolic acid)	Cooper McDougall & Robertson

Source: Stage 1 report, App 7.1 Advertisements for sheep-dipping chemicals and equipment (altered).

Notes: NZJAg = New Zealand Journal of Agriculture; SFAnn = Sheepfarmers Annual; Young Farm = Young Farmer; NZFarm = New Zealand Farmer; RuakLib = Ruakura Library; Arch = National Archives, Wellington; AlexTurn = Alexander Turnbull Library.

Appendix 2: Draft District Plan Provisions for Disused Sheep Dips

Territorial authorities may choose to integrate these draft provisions in their district plans to address contamination issues from the historical use of the land. One aspect highlighted here is the risks associated with a change in land use involving properties containing former sheep dips.

Issue: Health risks associated with land contamination (not mandatory part of plan)

The presence of contaminants on land has the potential to affect human health when the land use changes to a more sensitive activity.

Explanation (not mandatory part of plan)

The potential for hazardous contaminants to be present on land needs to be considered and assessed before approving a subdivision or land-use application that will result in an increased likelihood of human exposure to contaminants. The historical use of the land (eg, sheep farm, orchard, garage, workshop, fertiliser store, pit, landfill, etc) should also be considered.

Objective: Hazard management – old sheep-dip sites (could be one of a number of objectives under hazard management)

To avoid or minimise human health risks from the development, subdivision, or use of contaminated land associated with sheep dips that were in operation prior to 1980.

Explanation (not mandatory part of plan)

Old sheep-dip sites (pre-1980) are typically contaminated due to the historical use of persistent and toxic chemicals, including arsenic, dieldrin, DDT, aldrin and lindane. These chemicals are likely to be hazardous to people, particularly infants and children, being the most vulnerable to exposure. Potential risks arise from contact with and ingestion of contaminated soils, contaminated ground or surface water, eating food grown in contaminated soil, or eating animals or products from animals that have eaten contaminated soil.

Policy – Assessment of environmental effects

The potential health effects associated with the presence of contaminants from former sheep dips will be assessed when considering resource consents or plan change requests for a change in the use of rural land (eg, from rural to residential or lifestyle block).

Policy – remediation

Where contaminant levels exceed appropriate guideline values or a national environmental standard, the applicant will remediate the site and/or manage the health risk.

Methods – Former sheep-dip sites

- (1) Resource consent applications for activities on rural land that may increase the risk to human health, such as:
 - subdivision of rural land
 - conversion of an existing rural accessory building to a residential use, or construction of an additional dwelling on an existing rural siteshould be accompanied by information on the location of any former sheep-dip sites on the land. If a former sheep dip is present, soil testing may be required to determine whether any human health or environmental risk exists.
- (2) When considering changes in the status of rural land (rezoning), an assessment will be made of the likelihood of contamination being present due to former sheep dips and the feasibility of remedying or mitigating any health risks.
- (3) Practical guidelines and advice will be available to raise awareness among landowners about the potential risks old sheep-dip sites pose to people and the environment, such as children who live on farms, exposure of stock or contaminant residues in produce.

(Note: methods are not mandatory, rules are mandatory.)

Appendix 3: Current Legislation and the Role of Local Authorities

The functions local authorities have with respect to contaminated land are defined in the Resource Management Act 1991 (RMA). The RMA is a significant piece of legislation addressing environmental management in New Zealand. In addition, the New Zealand Building Code contained in the First Schedule of the Building Regulations 1992 prompts territorial authorities to assess building sites to determine the presence of hazardous agents or contaminants to safeguard people.

This section provides a brief overview of the roles of local authorities (regional councils, city and district councils) and the different pieces of legislation they need to consider with respect to potential contamination from historical sheep-dip sites.

Role of city and district councils (territorial authorities)

City and district councils (including unitary authorities) are responsible for authorising subdivisions and changes in land use. In particular, they are responsible for controlling land uses to prevent or mitigate any adverse effects of the development, subdivision or use of contaminated land. This takes on particular importance in relation to sheep-dip sites, because most new subdivisions and land-use changes occur on urban fringes, often in former agricultural areas. Commonly, land-use changes are from agricultural to residential or from agricultural to rural–residential (lifestyle blocks).

When considering resource consents for subdivisions, or any change in land use, territorial authorities are responsible for ensuring that the land is suitable for its new intended purpose. One aspect of suitability is that any residual contaminant concentrations in the soil are acceptable for residential development from a human health perspective. To confirm that the land is safe for people, the territorial authority may require the applicant to assess areas where contaminants may be present, including where a sheep dip exists or may have been located.

Some territorial authorities have specific plan rules in place to address known contaminated sites. For example, Wellington City Council, in its District Plan rule 5.4.4, controls activities on contaminated sites by stating that any activity, use or construction, alteration of, and addition to buildings or structures on a contaminated site is a discretionary activity (unrestricted). **Appendix 2** proposes a district plan provision that is specifically targeted at the management of risks associated with properties containing former sheep dips.

Territorial authorities also have an obligation to gather information and keep records relating to hazards within their district or city area. Further guidance on information management can be found under **section 3.2**.

Role of regional councils

Regional councils (including unitary authorities) are responsible for ensuring that contaminated sites are investigated. The purpose of that function is to be able to identify and monitor contaminated land. Regional councils also have a role in controlling discharges to water, air and land of contaminants that may cause an adverse effect, including discharges of contaminants from sheep-dip sites. The primary role of regional councils is environmental management, which includes the protection of human health.

Contaminants may discharge or leach from sheep-dip sites into local groundwater or surface water. The effect of these discharges is not always regarded as significant, particularly in relation to the effects of sheep-dip sites on the wider environment as a whole. However, there are local exceptions, and in some cases these “passive” discharges from sheep-dip sites would be regarded as locally significant; for example:

- where the residual discharge to groundwater is causing ongoing contamination of a private or public drinking-water supply, or
- where the discharge is to surface water, and the resulting concentrations in surface water and sediments exceed guidelines for the protection of freshwater or marine species.

During the remediation process itself, precautions should be taken to avoid the discharge of contaminants into the wider environment. A common situation might be where earthworks on an excavation site have the potential to disperse contaminated dust, or cause sediment run-off resulting in the contamination of a nearby stream. Another concern is the discharge of soil contaminants back to soil, through using contaminated material for fill elsewhere. This concern is generally addressed by regional plan rules controlling the discharge of contaminants to land. To encourage site remediation, the Waikato Regional Plan, for example, allows for the remediation of contaminated land as a permitted activity provided disposal is to a licensed landfill and certain other conditions are met.

Regional councils also have the obligation to gather information and keep records relating to hazards within their region. As with other contaminated sites, this may entail compiling a register of sheep-dip sites as this information becomes known. Further guidance on information management can be found under **section 3.2**.

Unitary authorities have the responsibilities of both territorial authorities and regional councils for managing contaminated land.

Resource Management Act 1991 (RMA)

Regional and territorial authorities have responsibilities for managing contaminated land under the RMA. The following excerpts from the Act highlight the sections that have particular relevance to contaminated sites.

Definition of contaminants and contaminated land

The provisions under the RMA relating specifically to contamination are found under section 15 – discharge of contaminants into environment.

The RMA defines “contaminant” under section 2(1) as follows.

“Contaminant” includes any substance (including gases, odorous compounds, liquids, solids, and micro-organisms) or energy (excluding noise) or heat, that either by itself or in combination with the same, similar, or other substances, energy, or heat —

- (a) When discharged into water, changes or is likely to change the physical, chemical, or biological condition of water; or*
- (b) When discharged onto or into land or into air, changes or is likely to change the physical, chemical or biological condition of the land or air onto or into which it is discharged.*

The RMA defines “contaminated land” under section 2(1) as follows.

“contaminated land” means land of one of the following kinds:

- (a) if there is an applicable national environmental standard on contaminants in soil, the land is more contaminated than the standard allows; or*
- (b) if there is no applicable national environmental standard on contaminants in soil, the land has a hazardous substance in or on it that —*
 - (i) has significant adverse effects on the environment; or*
 - (ii) is reasonably likely to have significant adverse effects on the environment.*

Section 30 makes particular reference to the investigation of contaminated land and the duty to control discharges of contaminants, which can also be applied to contaminants from disused sheep-dip sites.

- (1) Every regional council shall have the following functions for the purpose of giving effect to this Act in its region:*
 - ...*
 - (c) the control of the use of land for the purpose of —*
 - ...*
 - (v) the prevention or mitigation of any adverse effects of the storage, use, disposal, or transportation of hazardous substances:*
 - (ca) the investigation of land for the purposes of identifying and monitoring contaminated land:*
 - ...*
 - (f) The control of discharges of contaminants into or onto land, air or water and discharges of water into water:*

The functions of territorial authorities are defined under **section 31** of the RMA. These functions generally include the integrated management of the effects of the use, development, or protection of land. Section 31 includes the following paragraph:

- (1) *Every territorial authority shall have the following functions for the purpose of giving effect to this Act in its district:*
- ...
- (b) *the control of any actual or potential effects of the use, development, or protection of land, including for the purpose of –*
- ...
- (ii) *the prevention or mitigation of any adverse effects of the storage, use, disposal, or transportation of hazardous substances; and*
- (iia) *the prevention or mitigation of any adverse effects of the development, subdivision, or use of contaminated land.*

Section 35 states the general duty of local authorities to gather information, monitor and keep records.

Regional councils and territorial authorities have identified functions to control land use to prevent or mitigate the adverse effects of the storage, use, disposal or transportation of hazardous substances. The regional policy statement is required to state which authority is responsible for specifying objectives, policies and methods to exercise this function (section 62(1)(i)(ii) of the RMA).

National environmental standards

Under sections 43 to 44 of the RMA, the Minister for the Environment has the power to prepare and recommend national environmental standards (NES). The appropriateness of an NES for contaminated land is currently being considered. This guideline will complement any NES developed for contaminated land in the future.

Regional rules

Section 68 of the RMA includes the following subsection:

- (11) *If paragraph (b) of the definition of **contaminated land** applies, a rule may exempt from its coverage an area or class of contaminated land if the rule –*
- (a) *provides how the significant adverse effects on the environment that the hazardous substance has are to be remedied or mitigated; or*
- (b) *provides how the significant adverse effects on the environment that the hazardous substance has are to be avoided; or*
- (c) *treats the land as not contaminated for purposes stated in the rule.*

District rules

Section 76 of the RMA includes the following subsection:

- (5) *If paragraph (b) of the definition of **contaminated land** applies, a rule may exempt from its coverage an area or class of contaminated land if the rule –*
- (a) *provides how the significant adverse effects on the environment that the hazardous substance has are to be remedied or mitigated; or*
- (b) *provides how the significant adverse effects on the environment that the hazardous substance has are to be avoided; or*
- (c) *treats the land as not contaminated for purposes stated in the rule.*

Local Government Official Information and Meetings Act 1987 (LGOIMA)

Under section 44A(1) of the LGOIMA, a territorial authority must issue a Land Information Memorandum (LIM) “in relation to matters affecting any land in the district of the authority”. Section 44A (2) specifies the matters to be included in a LIM which include:

- (a) *Information identifying each (if any) special feature or characteristic of the land concerned, including but not limited to potential erosion, avulsion, filling debris, subsidence, slippage, alluvion, or inundation, or **likely presence of hazardous contaminants**, being a feature or characteristic that –*
 - (i) *Is **known** to the territorial authority; but*
 - (ii) *Is not apparent from the district scheme under the Town and Country Planning Act 1977 or a district plan under the Resource Management Act 1991:*
- ...
- (g) *Information which, in terms of any other Act, has been notified to the territorial authority by any statutory organisation having the power to classify land or buildings for any purpose.*

Hazardous Substances and New Organisms Act 1996 (HSNO)

The purpose of the HSNO is to protect the environment, and the health and safety of people and communities, by preventing or managing the adverse effects of hazardous substances and new organisms (including genetically modified organisms) in New Zealand.

Territorial authorities are enforcement agencies under the HSNO. They work with other enforcement agencies (eg, Occupational Safety and Health – OSH) and regional councils to ensure a coordinated approach is taken to hazardous substances management. With regard to contaminated sites, the primary role of local government under the HSNO is the prevention of new contaminated sites arising from the use, storage or manufacture of hazardous substances.

The Stockholm Convention on Persistent Organic Pollutants (POPs), to which New Zealand is a party, is enforced through HSNO. POPs are prohibited substances and strict controls are placed on the use, storage and disposal of any POPs remaining in New Zealand. Included within the (current) 12 organochlorine substances listed under the convention are DDT and dieldrin, which means the Convention is relevant to the application of the guideline on managing historical sheep-dip sites. New Zealand has an obligation under the convention, Article 6.1(e) to: “endeavour to develop strategies for identifying sites contaminated by chemicals listed (under the convention); if remediation of those sites is undertaken it shall be performed in an environmentally sound manner”.

Building Regulations 1992

Building inspectors can apply clause F1 of the Building Code when the territorial authority has identified an old sheep-dip site on the same parcel of land that is subject to building activity. Clause F1: Hazardous Agents on Site, is extracted from the New Zealand Building Code contained in the First Schedule of the Building Regulations 1992.

F1.1 The objective of this provision is to safeguard people from injury or illness caused by hazardous agents or contaminants on a site.

F1.2 Buildings shall be constructed to avoid the likelihood of people within the building being adversely affected by hazardous agents or contaminants on the site.

F1.3.1 Sites shall be assessed to determine the presence and potential threat of any hazardous agents or contaminants.

F1.3.2 The likely effect of any hazardous agents or contaminants on people shall be determined taking account of:

- a) the intended use of the building*
- b) the nature, potency or toxicity of the hazardous agent or contaminant, and*
- c) the protection afforded by the building envelope and building systems.*

Health Act 1956

The Health Act 1956 includes provision for territorial authorities to:

- improve, promote and protect the public health
- cause steps to be taken to identify and abate nuisances or to remove conditions likely to be injurious to health or offensive
- enforce regulations under the Health Act
- make bylaws for the protection of public health
- issue cleansing orders or obtain closing orders.

Section 29 of the Health Act defines health “nuisances” and generally includes matters “likely to be injurious to health”. Particularly relevant are references to:

- accumulations or deposits
- the situation or state of premises
- the conduct of any trade, business, manufacture or other undertaking.

Enforcement is determined by the District Court if a nuisance is not abated voluntarily, except where immediate action is necessary. Works undertaken by a territorial authority to abate a nuisance may result in costs being recovered from the owner or occupier. It should be noted, however, that any person can initiate a prosecution regarding a nuisance. A nuisance has to exist before any action can be taken, although a situation has to be “likely to be injurious to health” to meet the requirement for action.

Under section 41 of the Health Act, the territorial authority may serve a cleansing order on the owner or occupier, specifying the work to be carried out and the time in which to complete it. A closing order made under sections 42 or 44 can be issued as a last resort to protect the occupants or the public, but such action will not, of course, resolve any contamination issues.

Health and Safety in Employment Act 1992 (HSEA)

The object of the Health and Safety in Employment Act 1992 (HSEA) is to promote the prevention of harm to all people at work, and others in, or in the vicinity of, places of work. It places emphasis on employees and employers to take responsibility for the well-being of themselves and others at work. In some cases, a person may be liable for prosecution under the HSEA where a landowner or occupier:

- has knowledge of a contaminated sheep dip on their property
- has failed to take all practical steps to ensure the safety of their employees on their worksite
- has failed to systematically identify the hazard, and has failed to take all practical steps to eliminate, isolate, or minimise the hazard.

A health, safety and environment plan should be prepared as part of the planning for site work. It is very unlikely under the HSEA to be able to enforce a clean-up of a contaminated sheep-dip site. For further information refer to the relevant legislations, approved codes of practices or Occupational Safety and Health guidance, such as the *Health and Safety Guidelines on the Clean-up of Contaminated Sites* (OSH 1994).

Appendix 4: The Historical and Legal Context for Sheep Dipping

The dipping of sheep can be traced back to the days of shepherding and is recorded in Britain as far back as 1280 AD, when tar was rubbed into the fleeces of the sheep as a remedy for scab. During the 19th century, sheep owners began to include other substances such as grease and rancid butter with the tar. This procedure was known as “salving”. Understandably, this method was very time consuming and was not a very efficient method to manage outbreaks of scab.

The focus on protecting sheep welfare has been a matter of national importance in New Zealand from less than a decade after the signing of the Treaty of Waitangi (1840), and has continued through to the present. Legislation was developed to ensure that external parasites were eliminated, but little consideration was given to the adequate management of the chemicals used, disposal of chemical waste, and protection of human health and the environment.

After the first commercial sheep flocks were introduced to New Zealand in the 1840s, the colonial government in 1849 passed the Scab Ordinance, which endeavoured to control the infectious disease called sheep scab. This ordinance imposed fines on owners with scab-infected sheep and gave inspectors the power to order the destruction of infected animals. Although this ordinance did not enforce compulsory dipping, sheep dipping was undertaken to control scab.

The Sheep Act 1878 was the first legislation that imposed an obligation on farmers to dip sheep. Under this Act, penalties were imposed on any sheep owner found to have scabby sheep, and the Act specified that dipping must involve plunging or immersing. The Act did not require farmers to dip their sheep regularly – farmers were merely required to dip animals whenever necessary to avoid having infected animals. The number of infected sheep fell quickly in the early 1880s, so that by 1894 New Zealand was declared scab-free. The focus of dipping then shifted to the control of lice, flies and keds.

The Stock Act 1908 required every sheep owner to dip their sheep every year between a specified period, and penalties were issued for sheep that had not been dipped. This Act also stated that if any sheep being offered for sale were infected with lice, the owner would be penalised.

The Animal Remedies Act 1967 imposed an obligation on sheep owners to either dip or dust their sheep at least once a year. This Act specified that dipping must involve plunging or immersing the sheep in the dip, and that the dipping should be carried out within a specified period after the sheep had been shorn. An amendment to the Animal Remedies Act in 1982 also required that all sheep be dipped in accordance with the directions provided on the label of the dip chemicals.

Today, sheep dipping is no longer an annual legal requirement, but sheep need to be regularly inspected and any early infestation treated promptly. Pour-ons are less stressful than plunge dips and saturation shower dips according to the Code of Recommendations and Minimum Standards for the Welfare of Sheep.

Heritage dip sites are an important part of New Zealand's history, and some classic examples may qualify for heritage status. The Department of Conservation has recently protected a dip site on Quailburn Station, a former large sheep leasehold run in the high country near Lindis Pass.

Appendix 5: Applied Chemicals and their Toxicity

The chemicals used in sheep dips have evolved from very basic to more sophisticated products over the past 160 years. There were not many changes from the onset of dipping, when arsenic was the major chemical, until the manufacture of organochlorine pesticides in the mid-1940s (initially DDT, then lindane). The next major change was the appearance of dieldrin and aldrin on the market in 1955. The use of organochlorines only lasted 16 years until they were banned by regulation in 1961. Arsenic remained on the market until 1978, when it was deregistered. Synthetic pyrethroids and organophosphate pesticides continue to be used today.

The risk to human health and the environment from chemicals like carbolic acid, potash and sulphur is much less than the risk from arsenic, organophosphates and organochlorines. The following discussion highlights the history of these latter chemicals, their use in sheep dips in New Zealand and their toxic effects.

Arsenic

Arsenic was one of the earliest chemicals used for lice and blowfly control in sheep. Arsenic is a stomach poison and is only effective for the control of parasites once the target pest ingests it. Derris (see below) was often mixed into the arsenic to try to control keds. Arsenic combined with derris remained one of the standard chemicals used in sheep dips until around 1952, when derris began to be used in combination with other chemicals.

Arsenic had many drawbacks. In the early days, it was already recognised as a hazard to human and animal health, although the full extent of its toxicity was often not realised. Arsenic poisoning in dipped sheep was reasonably common. The sheep could become poisoned in a number of ways, either through direct swallowing and ingestion of the dip contents, absorption through the skin, or aspiration when arsenic was applied in powder form. When sheep were hot from the muster, or even from the sun on a hot day, arsenic could easily scald their skin. As well as adversely affecting livestock, arsenic polluted the soil and water surrounding dip sites, both due to dipping operations and poor disposal methods for the spent dipping fluids and sludges.

Arsenic was withdrawn from the commercial market as a dipping chemical in 1978, with remaining stocks being sold until June 1980. However, it is understood that arsenic sheep dips continued to be used for a number of years as farmers used up supplies of arsenic they had previously bought.

Copper

In the 1950s, copper was used for three main reasons in conjunction with pest control of sheep: as a bacteriostat, as a preventive for mycotic dermatitis, and as footrot fluid in a bath. However, copper left high residues in the wool of sheep. These were very hard to remove, and the dyes used to colour the wool would often react with copper residues leaving the wool improperly dyed. Over time, the copper also turned to copper sulphide, which led to discoloration of the

wool. When used as a bacteriostat the common name for the copper sulphate used was bluestone.

In small concentrations, copper is an essential element for humans (1–2 mg daily diet intake), but it is toxic to many bacteria and viruses. The free copper (II) ion is potentially very toxic to aquatic life. Copper is normally tightly bound to the soil, greatly diminishing its toxicity, and the likelihood of off-site discharges.

Derris



Derris elliptica (poison vine) is native from India to Indonesia and has mainly been cultivated in the tropics for its roots, a source of the insecticide Rotenone (Bailey and Bailey 1976). Derris (Rotenone) was first used in New Zealand in approximately 1911 and was often mixed with arsenic to kill both keds and lice. This made it the most popular and effective dip before World War II.

Because World War II interfered with the supply of the plant, other chemicals came onto the market, including DDT and other synthetic insecticides, as discussed below. By 1961, derris use had declined significantly from its use before the war. More effective chemicals were available, and derris uptake also suffered from not having the necessary lasting effect required to kill larvae hatching from the pupal stage.

Figure A.1: Advertisement for derris-based dip in New Zealand *Journal of Agriculture*, 1945

Organochlorines

The organochlorines group includes DDT and its derivatives, chlorinated cyclodienes (aldrin, dieldrin and heptachlor) and lindane (the commercial name for formulations based on purified γ -hexachlorocyclohexane). All of these chemicals became hugely popular for sheep dipping because they allowed new methods of dipping to be developed due to their ability to dissolve in the wool grease and migrate down towards the skin. This meant that saturation was not necessary to successfully treat sheep, and the traditional dip was often replaced with spray showers.

Organochlorines accumulate in the body fat of animals and can be very persistent (especially aldrin and dieldrin) because they are not excreted rapidly and remain stored in body tissue. As a result, these chemicals can accumulate in the food chain, allowing higher concentrations to occur higher up the food chain. Organochlorines are also very persistent in the environment, often remaining in soil for years or even decades.

Chlorobenzene derivatives used in sheep dips were DDT and lindane. These chemicals are insoluble in water and so were used in suspension in the dips. As sheep passed through the dip, their fleeces removed chemicals, so the dip became weaker and less effective during the course of the dipping operations. To maintain the dip at the appropriate strength, additional chemicals had to be added.

Although DDT was found to be much better in sheep dips than arsenic and derris, it was not used for very long because lindane was discovered to be much more effective at killing parasites. Lindane was first used in sheep dips around the mid-1940s and rapidly took over from DDT as the newest and most effective dipping chemical.

Aldrin and dieldrin were first used in sheep dips in approximately 1955. These chemicals have the ability to dissolve into the wool grease and then diffuse to the skin, where the parasites are located. Dieldrin was found to be more toxic to invertebrate insects than aldrin, and was therefore used much more extensively as a sheep dip.



Aldrin and dieldrin are structurally related. Sunlight and bacteria in the environment convert aldrin to dieldrin reasonably quickly. Freedman (1989) estimated the half-life of aldrin to be 0.3 years, with 95 percent disappearance in three years. For this reason, aldrin is not commonly found in the soil around old contaminated dip sites. Dieldrin attaches to soil and may stay there unchanged for many years. It is not very soluble in water. However, the mobility of aldrin and dieldrin in the soil environment can be enhanced at hazardous waste sites where organic solvents may be present that have the ability to increase their water solubility (Sawhney 1989).

Figure A.2: Advertisement for aldrin-based dip in *New Zealand Journal of Agriculture*, 1956

The organochlorines aldrin, dieldrin, DDT and lindane were prohibited as active ingredients in stock treatment under the Stock (Insecticides and Oestrogens) Regulations 1961 due to their persistence in animal fat and concerns about residues which may accumulate in food and impact on the markets. The consequent unavailability of organochlorines in the market led to a rise in the usage of organophosphates (see below), while arsenic and derris dips continued to be used.

Organophosphates

Organophosphates such as diazinon or nankor came into use as sheep-dipping chemicals in the 1960s. They became more popular after organochlorines were banned, and in many ways were much better than organochlorines because they were not as persistent: within a relatively short time after dipping the sheep, meat would have no detectable chemical residues. However, the major drawback of organophosphates was their lack of ability to diffuse down the wool, as organochlorines had done, so the treatment methods which had been developed to use with the organochlorines (not including saturation) were almost useless with organophosphates. Some organophosphates, such as diazinon, were still effective in tip-sprayers and dusters.

Organophosphates are still in common use today because they readily break down in the environment in most situations. Complications can occur, however, when organophosphates are used in places where arsenic-based dips have already contaminated the soil. The arsenic residue may remain biotoxic to soil micro-organisms, thereby preventing the breakdown of organophosphates by micro-organisms that normally occurs in the soil.

Synthetic pyrethroids

Synthetic pyrethroids, which were developed after organophosphates in the 1970s, are a synthetic form of naturally occurring pyrethroid chemicals that are found in the flower heads of chrysanthemums. Synthetic pyrethroids present relatively lower risks compared to arsenic or the organochlorines because they have very low dermal toxicity and are used at much lower concentrations. Under normal soil conditions (ie, in the absence of heavy metals such as arsenic), synthetic pyrethroids break down very rapidly. However, they are highly toxic to aquatic species and non-target invertebrates, and care needs to be taken at the time of application and when disposing of used dip wash, especially near waterways.

Insect growth regulators

Insect growth regulators are the most common chemicals used today to treat flies and lice (especially maggots and nymphs). They do not constitute a distinctive chemical class, and are commonly applied by hand-jetting, saturation or spray-on.

Insect growth regulators have very low toxicity for mammals, making them extremely safe to use for both the farmer and the sheep. However, they are toxic to aquatic invertebrates and take a long time to break down in the environment, so special precautions must be taken when disposing of used dip wash.

Toxicity of chemicals

The human health and ecological effects of sheep-dip chemicals of concern – such as arsenic, DDT and its metabolites DDD, DDE (Σ DDT), dieldrin and lindane – are summarised in **Table A.2**. For more detail, refer to the sources shown in the table.

Table A.2: Summary of toxicological effects of chemicals of primary concern

Chemical	Toxicological effects	Sources
Human health		
Arsenic	Arsenic can cause cancer and non-cancer effects. Skin cancer is a well-documented effect, and more recently chronic ingestion of inorganic arsenic has been linked with bladder and lung cancer. Non-cancer effects include dermal lesions, pigmentation, keratoses and peripheral vascular disease. Arsenic is classified as a known human carcinogen by the IARC (Class 1; IARC 1987) and the US EPA (Class A, US EPA 1993).	NRC 1999/2001; WHO 2001; Baars et al 2001
Σ DDT	DDT acts on the central nervous system, and has been shown to cause developmental, reproductive and liver toxicity, primarily lesions or tumours. The limited data on DDD and DDE indicate a similar pattern of toxicity at exposure levels to DDT. DDT is classified as a possible human carcinogen (class 2B) by IARC (1987), and a probable human carcinogen (Class B2) by the US EPA (1988).	Baars et al 2001; ATSDR 2002a
Dieldrin	The primary site of action of dieldrin is considered to be the central nervous system, although chronic exposure to low concentrations can result in liver damage. Dieldrin is a potent inducer of liver enzymes, and can cause suppression of the immune system. Dieldrin was unable to be classified (Class 3) by the IARC (1987), while the US EPA (1993) classified dieldrin as a probable human carcinogen (Class B2).	ATSDR 2002b; Baars et al 2001; IARC 1987; US EPA 1993

Chemical	Toxicological effects	Sources
Lindane (γ -HCH)	The chronic effects of lindane are primarily liver and kidney damage, although neurotoxic (eg, tremors) and immunotoxic effects may also be observed. Three isomers of hexachlorocyclohexanes (α , β , γ) were classified as possibly carcinogenic to humans (Class 2B) by the IARC. The US EPA did not classify γ -HCH, while α -HCH was classified probably carcinogenic to humans (Class B2) and β -HCH was classified as possibly carcinogenic to humans (Class C).	Baars et al 2001; ATSDR 2005
Ecological receptors Arsenic Σ DDT Aldrin/dieldrin Lindane	Arsenic compounds can cause acute and chronic effects in animal and plant individuals, populations and communities, including death; inhibition of growth, photosynthesis and reproduction; and behavioural effects. The toxicity of arsenic is largely dependent on the form (eg, inorganic or organic) and the oxidation state of the arsenic compound. In general, inorganic arsenicals are more toxic than organoarsenicals, and arsenite is more toxic than arsenate. The primary mechanism of arsenite toxicity is considered to result from its binding to protein sulfhydryl groups. Arsenate is known to affect oxidative phosphorylation by competition with phosphate, because they are structurally similar. In environments containing high phosphate levels, arsenate toxicity to biota is generally reduced. In plants, phosphate can decrease arsenate uptake due to competitive uptake. Toxicity to plants typically occurs at lower concentrations than toxic effects on soil organisms. Current environmental concerns regarding organochlorine insecticide residues primarily arise from the accumulation of residues through the food chain and sub-lethal effects of exposure. Numerous sub-lethal effects on animals have been observed, including growth impairment or deformities, tumour growth, impairment of immune systems, and impairment of reproductive systems, including eggshell thinning. Other sub-lethal effects include suppression of the immune response, which can lower resistance to disease and infection; or induction of the immune response, which can cause hypersensitivity. Dieldrin has been found to depress the immune system. Eggshell thinning in birds has been the most widely documented form of reproductive impairment, primarily as a result of exposure to DDE. Toxicity to soil organisms and terrestrial vertebrates occurs at much lower concentrations than toxicity to plants.	US EPA 2005b; CCME 1999 Carey et al 1998; de Bruijn et al 1999

Appendix 6: Soil Guideline Values

Derivation of dip-site-specific soil guideline values to protect human health

The general methodology provided in the Timber Treatment Guidelines (Ministry for the Environment and Ministry of Health 1997) and the Gasworks Guidelines (Ministry for the Environment 1997) was used to derive the indicative soil guideline values provided in section 5, which are consistent with existing New Zealand guidelines.

In contrast to previous guidelines, this guideline explicitly includes lifestyle-block land use as a typical New Zealand land use, which assumes that 50 percent of the produce consumed by residents is grown on-site (consumption of meat, milk and eggs of animals raised on-site is excluded). Previously this land use has been a subset of residential land use. The standard residential land-use category considered here assumes that 10 percent of the produce consumed by residents is grown on-site, while the remaining categories do not consider consumption of produce grown on-site.

The following five land-use categories were adopted.

- Lifestyle block – residential property where 50 percent of vegetables consumed are assumed to be grown on-site. The consumption of products (eggs, milk, meat) from animals raised on-site is excluded and should be considered on a site-specific basis.
- Standard residential – low-density residential property with home-grown vegetables contributing 10 percent of the total intake.
- High-density urban residential – residential with minimum opportunity for exposure to soil; no produce consumption; includes daycare centres, kindergartens, preschools and primary schools, where no gardens are present.
- Parks/recreation – parks, recreational open space, playing fields; includes secondary schools.
- Commercial/industrial (unpaved) – unpaved commercial and industrial properties. Where paving is present, its integrity and likely effectiveness in reducing exposure must be considered on a site-specific basis. No consideration of the protection of plant life has been included.

The exposure scenarios considered are largely based on those provided in the Gasworks Guidelines, while the parameter values used are based on those contained in both guidelines. They are consistent with those used internationally and are also generally considered to be representative of New Zealand for the purpose of deriving generic values. However, different parameters have been used for the dermal exposure and produce consumption pathways.

Table A.3 provides a summary of the exposure parameters used for each scenario. The equations used to derive soil guideline values are provided in Cavanagh and Proffitt (2005).

Table A.3: Summary of the exposure parameters for each land-use scenario

Pathway	Lifestyle block (50% produce consumption)	Residential (10% produce consumption)	High-density residential	Parkland/recreational	Commercial/industrial unpaved
Exposure frequency (days/year)	350	350	350	350	240
Exposure duration – child (years)	6	6	6	6	–
Exposure duration – adult (years)	24	24	24	24	20
Averaging time – non-threshold (years)	70	70	70	70	70
Body weight (kg):					
• child	15	15	15	15	–
• adult	70	70	70	70	70
Ingestion pathway					
Soil ingestion rate (mg/day):					
• child	100	100	100 ^a	50	–
• adult	25	25	25 ^a	10	25
Produce (kg/day): ^b					
• child	0.077 (0.011)	0.077 (0.011)	–	–	–
• adult	0.254 (0.034)	0.254 (0.034)	–	–	–
Portion home-grown (%)	50	10	–	–	–
Inhalation pathway					
Exposure duration (hours/day)	24	24	24	5	8
Particulate concentration ($\mu\text{g}/\text{m}^3$)	50	50	50	50	142
Inhalation rate (m^3/day):					
• child	7.6	7.6	7.6	7.6	–
• adult	25	25	25	25	1.3 ^c
Dermal pathway					
Exposure duration (hours/day)	12	12	12	8	8
Exposed skin surface area (cm^2):					
• child	2,625	2,625	2,625	2,625	–
• adult	4,700	4,700	4,700	4,700	4,700
Soil adherence factor (mg/cm^2):					
• child	0.2	0.2	0.2	0.2	0.2
• adult	0.07	0.07	0.07	0.07	–

Notes:

a Soil ingestion rates are different from the Gasworks Guidelines, to achieve consistency with the arsenic guideline values.

b Wet weight (dry weight).

c m^3/hour .

‘–’ Not applicable

Contaminant-specific parameters used to derive soil guideline values in the current report are summarised in Table A.4, and a brief discussion is provided below.

Table A.4: Contaminant-specific parameters used to derive soil guideline values

Pathway	DDT	Dieldrin	Lindane
Tolerable daily intake (mg/kg-bw/day)	0.0005	0.0001	0.005
Background exposure (mg/kg-bw/day)*	0.000041	–	–
Dermal absorption factor	0.01	0.1	0.04
Plant uptake factor	0.136	0.41	0.41

* Subtracted from the TDI.

The toxicological intake values provided by the World Health Organisation were generally used in the current report to provide consistency with toxicological intake values adopted by other government agencies such as the Ministry of Health, Environmental Risk Management Authority and New Zealand Food Safety Authority. With the exception of DDT, the intake values are consistent with those values used in the *Drinking-water Standards for New Zealand 2005* (Ministry of Health 2005). **Table A.5** provides a summary of the soil guideline values derived for individual pathways, and the final combined value.

Table A.5: Summary of soil guideline values (mg/kg) for individual pathways

Contaminant	Scenario	Soil ingestion	Dermal absorption	Produce ingestion	Combined*
ΣDDTs	Rural/lifestyle	72	2,735	9.6	8.4
	Standard residential	72	2,735	48	28
	High-density urban residential	72	2,735	–	70
	Parks/recreation	143	4,100	–	139
	Commercial/industrial	1,955	15,600	–	1,740
Dieldrin	Rural/lifestyle	16	60	0.7	0.7
	Standard residential	16	60	3.4	2.7
	High-density urban residential	16	60	–	12
	Parks/recreation	31	89	–	23
	Commercial/industrial	425	339	–	190
Lindane	Rural/lifestyle	782	7,450	35	33
	Standard residential	782	7,450	173	139
	High-density urban residential	782	7,450	–	707
	Parks/recreation	1,560	11,200	–	1,370
	Commercial/industrial	> 20,000	> 20,000	–	14,180

* The combined value is calculated by taking the inverse of the sum of the inverse value of each pathway.

The Ministry for the Environment holds more detailed information on the derivation of the soil guideline values for individual contaminants. This information can be provided on request.

Soil guideline values to protect on-site ecological receptors

A summary of the existing national and international soil guideline values for the protection of ecological receptors for the sheep-dip contaminants of concern are shown below.

Table A.6: Soil guideline values protective of on-site ecological receptors (mg/kg)

Country	Value name	Arsenic	DDT	Dieldrin	Lindane	Source
New Zealand	Minimal risk guideline value	12	1.8	0.002	0.006 ^x	Cavanagh and O'Halloran 2006
	Serious risk guideline value	22	13	0.5	2.1 ^x	
	Soil limit ^a	20	–	–	–	NZWWA 2003
	Waste-screening criteria ^b	12, 1.2	500	8, 0.8	–	Ministry for the Environment 2004b
Australia	EIL	20	–	–	–	NEPC 1999
Canada	SQG _e – residential	17	0.7	–	–	CCME 1999
	Commercial/industrial	26	12	–	–	
USA	Eco-SSL – plants	18	P	NA	–	US EPA 2005b, c, d
	Invertebrates	NA	P	NA	–	
	Birds	43	P	0.0069	–	
	Mammals	46	P	0.000032	–	
The Netherlands	SRC _{eco}	40 (85 ^c)	4 ^d	4 ^e	–	Lijzen et al 2001
	IV	55	4 ^d	4 ^e	–	
	MPC	34	0.01 ^d	0.005 ^e	0.05	de Bruijn et al 1999
	TV	29	1 × 10 ^{-4,d}	5 × 10 ^{-4,e}	5 × 10 ⁻⁵	VROM 2000

EIL – ecological investigation level; SQG_e – soil quality guideline environmental; Eco-SSL – ecological soil screening level; P – pending; NA – not available, insufficient data for derivation of an Eco-SSL; SRC_{eco} – serious risk concentration ecotox; IV – intervention value; MPC – maximum permissible concentration; TV – target value.

a Allowable limits in soil to which biosolids have been applied.

b Based on protection of off-site receptors.

c Revised value (Lijzen et al 2001).

d Sum of DDT, DDD and DDE.

e Sum of aldrin, dieldrin and endrin.

Appendix 7: Case Studies

The wide variation of natural parameters, historical dip construction, operation and regulatory oversight demonstrated by the different case studies in this section may help to explain why a site-by-site assessment is necessary in managing the risks from old sheep-dip sites. The guideline aims to provide best practice to achieve good outcomes for future site assessments.

The case studies have been taken from reports produced for the Ministry for the Environment's Sustainable Management Fund Project on sheep-dip sites (including Stage 1 Preliminary Report: *A Chronology of Site Discovery and Investigation into Contaminated Animal Dipping Sites in New Zealand 1993–2002* by McBride 2003).

Detailed investigations of selected Waikato sites

An initial study undertaken in 1994 demonstrated that significant contamination of soil by arsenic and organochlorines had occurred at seven selected dip sites. The investigation found no detectable levels of organophosphate compounds in soil, and did not show the distribution of the organochlorine and arsenical contamination. The Waikato Pesticides Awareness Committee (WaiPAC)⁷ concluded that more information was needed to determine the risk that old sheep-dip sites pose to the surrounding environment and human health.

In 1997, WaiPAC received funding from Environment Waikato's Environmental Initiatives Fund to further investigate contaminated dipping sites in the region. Study objectives included determining the likely extent of soil contamination around known sheep-dipping sites, and evaluating risks to surface and groundwater, grazing animals and human health. As a result, the study focused on the more persistent chemicals: arsenic and members of the organochlorine family. The project was a collaboration, with HortResearch and the University of Waikato providing technical inputs.

Study sites

Four historical sheep-dip sites were selected from around the Waikato region to be included in the more detailed study. Site 1 was selected due to indications of dieldrin appearing in the groundwater supply in 1995. Sites 2 and 3 were part of the 1994 WaiPAC scoping study. A crucial factor in selecting sites for this study was the cooperation of the landowners, and keeping the specific locations of each site confidential facilitated this. An overview of the sites included in the 1997/98 works is as follows.

⁷ WaiPAC is a multi-stakeholder community group that seeks consensus on agrichemical issues in which members' views may initially be very divergent. In particular, the group's strengths and successes are built on an ability to influence parent organisations. Although originally established to address agrichemical issues in the Waikato, WaiPAC is now achieving wider recognition of its work. Raising awareness of environmental issues and protecting human health are key components of WaiPAC's *raison d'être*.

- **Site 1:** A dip sump on the property was identified as the likely source of contamination during a pesticides survey by Environment Waikato in 1995. It was operated between 1954 and 1961, dipping 500–600 sheep annually, and the spent dip solution was pumped onto land adjacent to the sump. The site is flat and has been extensively cultivated, and is currently covered in a deep-rooted vegetable crop. The farm water well is located approximately 15 m from the dip site and groundwater flow from the dip is towards the well. Soils are free-draining Horotiu sandy loam.
- **Site 2:** This site was identified by WaiPAC in 1994 as being very heavily contaminated by arsenic, dieldrin and lindane (with some DDT) and was included in this study in order to determine the distribution of the contamination. The site was operated as a sheep farm from around 1932 until 1970, when it was converted to dairying. There is evidence that this dip was in communal use. The old dip was clearly visible, situated on the edge of a small gully.
- **Site 3:** Environment Waikato brought this site to the attention of WaiPAC in 1993, when two heifers died from arsenic ingestion and others were chronically poisoned. Nothing was known about the use or exact location of old sheep dips on the site, although some broken concrete and rubble was evident at the head of the adjacent gully. Stockyards had been built on a flat area near the edge of a steep gully in which a small spring-fed stream forms. Most of the area was covered in pasture, except for the head of the gully, which was overrun with blackberry and scrub. Significant levels of dieldrin and lindane were discovered in the soil and associated stream.
- **Site 4:** This site was included because it lies within the urban boundary of Hamilton, and so is a potential target for urban development. An old dip and draining mound were clearly visible. It appears that a woolshed and/or sheep yards may have existed on the site a long time ago and the dip facility has not been used for many years. The relatively flat land is completely covered in pasture. Soils are based on Hamilton clay loam, with areas of Te Rapa peaty sand in a nearby shallow gully.

Sampling and analysis

Soil samples were collected from the four sites using a 25 mm diameter soil corer. At each sampling location three cores to 30 cm depth were taken within an area of 1 m diameter. Cores were sectioned and composited in 10 cm increments. The main sampling took place in May 1997, with additional samples taken from some sites in the period June to August 1998. In addition, deep cores were taken from sites 1, 2 and 4 in June 1998 using a Humax soil sampler (5 cm diameter). Single cores were taken to 125 cm depth at three locations at each of the three sites, with samples comprising the five 25 cm core depth increments. All soil samples were air-dried and ground for chemical analysis. Pasture and surface water samples were collected from June to August 1998. Samples were analysed for arsenic and organochlorines using standard methods.

Results

All four sites close to the original dips were heavily contaminated with arsenic and organochlorine residues. Surrounding areas contained less contamination, but water samples still exceeded the New Zealand drinking-water standards (see **Table 5** for values). These residues had persisted for at least 25 years, and it was thought likely that losses by degradation in the soil were proceeding very slowly. At site 1 the dieldrin contamination was severe enough to have led to contamination of local groundwater, even though this chemical is relatively immobile in soil. Contamination by arsenic and organochlorines was extensive at the Hamilton site, with topsoil being above guideline values over an area of at least 20 m by 40 m. At sites 2 and 3, movement of arsenic and organochlorines had occurred down the gullies and into drainage areas. Pasture samples were contaminated, and surface water samples also contained residues well above the ANZECC guidelines. The shallow core sections revealed that contamination at all sites was often uniform to 30 cm depth, particularly for arsenic. The deep core sections showed that the contamination reached greater depths in areas close to the dip baths.

One finding of this survey was that there could be considerable differences in contaminant profiles between sites, and unexpected areas of contamination at some distance from the main dipping area. The following is a more detailed overview of the results for each site.

Site 1

Soil sampled near the dip sump was contaminated with dieldrin, with levels exceeding 50 mg/kg in the top 20 cm. Lindane was also present at high levels. A deep core taken near the sump showed that dieldrin had permeated the profile, with 23–36 mg/kg found at 0–75 cm, 9.2 mg/kg at 75–100 cm and 0.09 mg/kg at 100–125 cm. Leaching of dieldrin from this area to groundwater at about 4 m depth had occurred. This had led to dieldrin contamination in the well water (15 m away) of up to 0.18 µg/L (compare to New Zealand drinking-water standards of 0.04 µg/L). Five further shallow soil samples at distances of 2 to 10 m from the sump showed a rapid fall-off in dieldrin contamination, from 5 mg/kg to 0.25 mg/kg (mean levels 0–30 cm depth). Arsenic levels were at background levels in all samples, indicating arsenic dips had not been used at this site.

Site 2

Twenty soil samples showed a broad distribution of arsenic contamination, from as high as 1200–3500 mg/kg just below the dip outfall, to 130–280 mg/kg in the vicinity of the dip and 20–40 mg/kg further down the bank towards the stream. Stream-bed sediments generally had background levels (1–7 mg/kg), but a hot spot 100 m downstream at 90–150 mg/kg showed that contamination may have been more widespread but had been eroded or overlaid by sediment. Lindane (1–10 mg/kg), and to a lesser extent dieldrin (0.05–0.22 mg/kg), residues were also present at the site, but were more localised to the vicinity of the dip. Deep cores showed that the soil strata in these areas were highly contaminated by arsenic (5–3500 mg/kg) and lindane, with significant residues to depths of over 1 m. Pasture samples surrounding the dip contained arsenic (13 mg/kg), dieldrin (0.015 mg/kg) and lindane (0.007 mg/kg), while surface water obtained 20 m from the dip outfall contained 0.5 µg/L of lindane.

Site 3

Soil samples at the head of the gully leading to the stream were heavily contaminated with arsenic (325–2620 mg/kg) and small amounts of dieldrin (0.04–0.19 mg/kg). The adjacent stockyards and races were also contaminated (arsenic 10–167 mg/kg, dieldrin 0.05–2.1 mg/kg). Soil samples from 20–100 m down the gully showed a generally decreasing trend in arsenic (80–4 mg/kg) and no significant organochlorine residues. Pasture samples from the sheep yards contained mean values of 0.006 mg/kg lindane and 0.02 mg/kg dieldrin. A surface water sample from the spring outfall contained lindane (1 µg/L) and dieldrin (9 µg/L).

Site 4

The soil samples revealed this site was contaminated by arsenic, dieldrin and lindane over a large area. Adjacent to the large dip bath and race, residues in the 0–30 cm top soil samples were in the range: arsenic 100–2560 mg/kg (with many samples exceeding 300 mg/kg), dieldrin 0.15–3.1 mg/kg, and lindane 0.26–10.6 mg/kg. The contamination gradually decreased with distance from the dip, but samples at 10 m still had significant residues (arsenic 14–125 mg/kg, mean 50; dieldrin 0.01–0.45 mg/kg, mean 0.07 mg/kg), and a sample in a drainage area 20 m distant contained 48 mg/kg arsenic. One area at 7 m contained dieldrin at 16 mg/kg (range 0.9–45 mg/kg). The soil samples indicated there had been physical disturbances in the soil profile in some areas. Herbage samples from beside the dip gave arsenic at 6.5 mg/kg, lindane at 0.67 mg/kg and dieldrin at 0.018 mg/kg. However, blood tests on cattle grazing this property revealed no significant residues (arsenic 1 mg/kg; organochlorines < 0.005 mg/kg).

Investigation of soil and groundwater on the Kaikoura plain

In 2000 Environment Canterbury (ECan) engaged a consultancy to undertake an investigation to determine the extent of arsenic contamination of soil in the Kaikoura area resulting from historical sheep-dipping practices, and to determine whether this was affecting groundwater quality. A sampling programme was designed to collect two or three composite soil samples from 13 sheep dip sites, four footbath sites and a wool-scouring shed.

At all dip and footbath sites, at least one soil sample returned arsenic results above guideline values for arsenic in soils used for residential and agricultural use (30 mg/kg). The concentrations ranged from 30 mg/kg to 4390 mg/kg. Arsenic concentrations were significantly higher at the dip and drip-pad exits compared to the entrance area. Three stream sediment samples collected from the creek adjacent to the wool-scouring site returned arsenic concentrations of 3 and 5 mg/kg.

In spring 2000 ECan staff undertook groundwater sampling from 22 private wells and two springs located on the Kaikoura plains. The aim of the sampling was to determine whether there was a link between the arsenic-contaminated soil found at 18 sites associated with sheep dipping and the arsenic found in groundwater samples in private wells. Of the 37 wells sampled for arsenic in the course of this sampling campaign and an earlier investigation, six yielded samples with arsenic concentrations exceeding the New Zealand drinking-water standards maximum acceptable values of 0.01 mg/L. Two of the six wells were reportedly used for domestic supply, and the well owners were advised that the water in their wells was unsuitable for drinking. The depths of wells with detectable concentrations of arsenic ranged from 4 to 44.5 m. There was no obvious relationship between well depths and arsenic concentrations in the groundwater.

To assess the lateral and vertical extent of the soil contamination and whether these arsenic “hot spots” were the source of the arsenic detected in the groundwater in the Kaikoura area, three sites were selected for further field investigation. Surface soil samples were collected at 2 to 15 m spacings, to a distance of up to 50 m from the sides and exits of the dips. At all three sites, the highest soil arsenic concentrations were recorded at the site itself, with concentrations decreasing with greater distance from the dip. Concentrations of 52 mg/kg were found even in soils 50 m from the former dip structure, which was located within a former sheep-holding yard.

The samples collected from the dip wells generally showed a decrease in arsenic concentrations with increasing depth. At two sites elevated arsenic concentrations were found at depths that were intercepted by the groundwater table (2.4 m at one of the sites).

Monitoring wells at each of the three sites were installed up-gradient, down-gradient and on-site at the three dip/footbath sites. Results showed that groundwater beneath two sites had been affected by elevated arsenic concentrations in soils at these sites: 0.197 mg/L dissolved arsenic under the footbath, and 0.031 at 25 m down-gradient; 0.92 mg/L dissolved arsenic under the dip, and 0.078 mg/L at 30 m down-gradient. Groundwater samples from the up-gradient wells returned results with little or no detectable arsenic. The third site showed little difference in arsenic concentrations between up-gradient, down-gradient and dip wells. The results, however, show that the shallow groundwater in the vicinity of old sheep dips and footbaths is at risk of contamination with arsenic, and wells should therefore be located well away from such sites.

The patterns of arsenic detection in groundwater from private wells did not show a relationship with the locations of the dips or footbaths. In the southern part of the Kaikoura plain, a number of wells yielded groundwater samples with elevated arsenic concentrations, but the patterns of arsenic in groundwater were not consistent with expected plumes of contamination from these sites. For example, arsenic was found in samples up-gradient of identified dip sites, indicating a source other than the dip. In other areas, where shallow wells were located close to dip or footbath sites, no arsenic was found in the groundwater from these wells yet arsenic was detected in groundwater from deeper wells in the area. It is likely the source of arsenic found in the groundwater from private wells is predominantly natural and originating from the greywacke rocks of the Southern Alps, tertiary coal measures and/or discrete and intermittent discharges from hydrothermal springs. These naturally occurring sources of elevated arsenic in groundwater occur along coastal areas such as Woodend, Waikuku and southern Christchurch, where marine sediments are inter-fingered with gravel strata.

In sum, the groundwater quality investigations revealed two separate issues regarding the presence of arsenic in groundwater. Results from sampling of the monitoring wells installed adjacent to the sheep dip/footbath sites indicated localised contamination of the shallow groundwater. The results of widespread sampling of groundwater from private wells located throughout the Kaikoura plain area indicate a naturally derived source of arsenic (Environment Canterbury 2003).

Coromandel residential case study

A number of former sheep-dip sites have been identified and investigated on the Coromandel Peninsula as a result of land-use changes from agricultural to residential. A significant case involved a subdivision that included a former sheep-dip operation, located on the northern coastline of the Coromandel Peninsula. Events that took place at this site will be expanded in more detail as an illustration of a typical process that has been used in dealing with old dip sites during subdivision.

The dip site operated for some 30 years as a sheep dip/shower facility from the mid- to late 1900s, using dieldrin and arsenic-based chemicals as dips and sprays. The land was situated on the coastal section of a 100-acre farm block, which was intended to be subdivided to create a number of smaller sea-side lifestyle/residential blocks. The landowner was directly linked to both the dipping activity and the planned subdivision, and was required by Environment Waikato to undertake an investigation and assessment of potential pesticide contamination on one lot in the top 1 m of soil.

The site investigation process involved an initial screening for organochlorine, organophosphate, organonitrogen and arsenical compounds. The screening process used a composite sampling method aimed at reducing costs and maximising the coverage of the sampling programme. The composite soil analyses broadly defined an area of surface soil dieldrin contamination surrounding the former dip facility. Subsequent characterisation of the soil contamination applying a site-specific sampling method more accurately defined the nature and extent of the residual chemicals. Dieldrin was present in high concentrations (up to 5 mg/kg) in only two samples; aldrin (at a maximum concentration of 0.005 mg/kg) and arsenic were detected only in low-level background concentrations.

The majority of the contamination was limited to the surface layer (0–0.5 m below ground level), with some low-level concentrations (decreasing with depth) between 0.5 and 1 m below ground level. Soils at the site were of a silty clay nature, and no groundwater contamination had resulted from the historical practices. Guideline criteria used to assess the site were based on the proposed residential land use.

Site remediation was carried out in April 2000 using the “dig and dump” approach: excavation and removal to landfill. A total of 125 tonnes of topsoil, sand and concrete were carted to Redvale Landfill in Auckland for disposal. The soils were removed from areas representing the location of the former dip/spray facility, the associated draining platform and the sump. Verification samples were collected after completion of the remedial work and it was recommended that the site be defined as suitable for the proposed residential land use. In late 2000 Environment Waikato confirmed that the lot was “remediated – suitable for residential land-use” on its Selected Land Use database.

Dip Road – case study of a sheep dip in public ownership

WaiPAC was commissioned by the Ministry for the Environment to research this case study as an example of a sheep-dip site in public ownership. It focuses on the various problems local authorities were faced with during the site investigation and remediation phases.

Land ownership

The Kaeo area was apparently the first land in New Zealand to be surveyed into allotments and there is a suggestion that it contains the oldest sheep dip in the country. The original homestead associated with the immediate area was built in 1836.

The council built a communal sheep dip and an animal pound on its property to ensure “dirty” sheep didn’t cross the county boundary. These facilities were on State Highway One, which was eventually realigned and the annexed road became formally named Dip Road. There are suggestions that the dip continued operation until 1965. The site is owned by the Far North District Council (FNDC). No council records about the council-operated dip and animal pound have survived. The Dip Road property is about three-quarters of an acre of vacant land and the communal dip was located at the lower end of the section running parallel, and immediately next, to the boundary. The dip was filled from a water tank located on the elevated side of the section. The discharge pipe was located under the boundary fence between the pound and neighbouring private land, and spent dipping fluids and run-off from the dip were discharged down-gradient onto the neighbour’s pasture, across swampy land and potentially into a farm drain.

Process of dip-site identification

The down-gradient neighbour negotiated to purchase the council land in 1999, but a visiting family friend (who worked for Waikato District Council) alerted him to the potential for assuming liability of a potentially contaminated site. FNDC requested Northland Regional Council (NRC) to undertake a site assessment of potential risks and a preliminary site investigation was initiated in November 1999.

Dip-site remediation

Arsenic was found in excess of guideline values in soil (30 mg/kg) immediately adjacent to the dip (highest at 98 mg/kg). Occasional run-off and discharge of arsenic to watercourses was also identified as a potential hazard, as was contaminated fluid within the dip structure (only tested for arsenic), which exceeded both the potable water limits and the livestock drinking standards. Organochlorines were not identified (only one initial soil sample was obtained from beside the dip and assumptions made that no further testing for organochlorines was necessary thereafter). NRC’s recommendation to FNDC was: (1) “That from a health and safety perspective, the dip be demolished, infilled and levelled to avoid any accidental misadventure” and (2) “ that further sampling be undertaken away from the dip to determine the extent of any further on-site contamination”.

A further assessment was undertaken by NRC, which found “elevated levels of arsenic up to 5 m away (ie, in the neighbour’s property) from close to the dip – but beyond this distance the levels of contamination were low to moderate and within acceptable limits.” NRC also recommended that arsenic-contaminated soil be removed from the site and disposed of in the proper manner at an approved landfill.

In February 2002, remedial work was undertaken. Some soil was removed to landfill (18 m³), and the dip structure – the drip pad and upper dip walls – were buried in the dip trench. The dip liquids were disposed of by “punching a hole in the base of the trench to allow drainage”. Validation sampling was carried out in March 2002 and further removal of two hot spots on the neighbour’s land was undertaken. Vertical mixing of the surrounding soil (“deep discing to a minimum of 300 mm”) was used, and clean backfill material was imported. Further vertical mixing well out into the neighbour’s paddock followed when results of validation sampling proved unsatisfactory (one sample at 48 mg/kg and one at 103 mg/kg). On 15 May 2002, the remediation consultants stated that the site(s) “was suitable for agricultural or future residential use”. In October 2002 FNDC requested NRC to remove both properties from their Register of Contaminated Sites. In response, NRC proposed to remove the dip site (presumably encompassing both properties) from its Selected Land Use Registry as a category V site (verified history of hazardous activity or industry) to a category V2 site (managed remediated).

Costs

FNDC, in a letter dated 28 May 2003, stated “Council has paid out the sum of \$18,627.35 for the remediation and rehabilitation of the Dip Road property over the past three years”. It is unclear which “property” the Council is referring to (either the pound or the neighbour, or both), but one assumes, in the absence of *any* staff now available who know anything about the FNDC’s involvement, that the cost relates to contamination on both lots. The breakdown of the remediation is as follows: NRC testing (\$600.00), consultants (\$16,671.85 and \$915.50), fencing contractor (new boundary fence \$250.00) and status check (\$290.00). There do not appear to be any FNDC financial charges for its oversight and time spent on the project.

Key problems in the process

(a) Property values

The neighbour felt that his property “saleability” had been seriously constrained as a result of the FNDC’s predecessor(s) expelling spent dip fluid over the boundary fence over many decades, and that in fact “he was unable to even sell his property”. As a response to this allegation, a valuer assessed the likely implications of reduced property valuation. He was able to demonstrate that there was little or no impairment in saleability value in this particular circumstance as a result of the Council’s remedial actions. This, therefore, became a non-issue in terms of getting site closure and resolving the payment of outstanding rates paid “under duress” – a related dispute in which the neighbour sought a reduction in rates due to impinged property values.

(b) Site clean-up

The completion of the remedial action pivots on the assurances of the consultants who supervised the site investigation and clean-up. The neighbour had some scepticism about the effectiveness and completeness of the remediation, as the preliminary assessment of the dip area showed markedly different soil residue levels to the later report. Some of the methods undertaken during the remediation could be debatable in the light of current knowledge. If the clean-up process was flawed, then any assurances by Council become open to future challenge.

(c) Site rehabilitation

There was some frustration evident by the landowner that the completion of the earthworks and associated minor restoration work and re-grassing had not been done. There was also some ongoing confusion as to the location of the original boundary fence (separating the dip outfall and the neighbouring land) versus its true legal position, and the erection of the replacement boundary fence in the incorrect position.

(d) Site closure

The affected neighbour appeared to find the “lack of sign-off” by Council in late 2002 as a significant source of irritation. To achieve closure in this matter, it was suggested that FNDC and NRC write to the neighbour and issue a statement to the effect that “the FNDC consider the risk of contamination has been mitigated and the site(s) is now suitable for continued agricultural use”.

Appendix 8: Comparing Different Sheep-dip Sampling Strategies

The following section summarises the outcomes of a study that was carried out by a team comprising HortResearch, Waikato University, Waikato Pesticide Awareness Committee (WaiPAC) and Environment Waikato, including the research of two Masters students. Three different sampling strategies were compared at four historical sheep-dip sites to determine which sampling approach is the most effective at detecting contaminant hot spots and contamination distribution.

Judgemental sampling

This strategy includes a visual assessment of the site to determine the most likely areas of contamination. This process was carried out with due consideration of the type of dip structure, the location of the entry point and drainage pens, likely position of entry and exit paths to each dip, and likely route(s) for off-site migration of dip contamination. Ten sample locations were selected judgementally at each site and samples were taken to a depth of 7.5 cm using a foot corer. To accommodate quality control of the sampling and subsequent analytical procedures, one blind replicate sample was taken from two single-sample locations at each of the four sheep-dip sites. The samples were analysed for the chemicals of concern (see **Table 1**) at an accredited laboratory for trace metal residues and organochlorine pesticide residues. Preliminary sampling was used to determine which contaminants were present and to provide an indication of the range of potential contaminant concentrations.

Judgemental sampling proved to be a good method for assessing the contaminants present at each site. It generally provided a reasonable indication of the contaminants present and their concentrations. However, this type of sampling relies on the experience of personnel, and by its very nature, contains inherent bias due to the way sample locations are selected. The results of the study show that it is unlikely to detect contamination that has migrated some distance from the immediate dip site. If information is available on the use of chemicals at a dip site, an experienced operator can collect judgemental samples to confirm which contaminants are present and provide a reasonable indication of contaminant levels. Judgemental sampling is often the least expensive sampling regime because it generally involves taking fewer samples.

Statistically designed systematic sampling

A common systematic sampling strategy is to place a sampling grid over the primary sheep-dip area. Contamination at historical sheep-dip sites is generally localised to the immediate dip area. An off-site zone can be included to assess the extent of offsite movement of dip contaminants (eg, along a sloping profile away from the dip structure).

A statistical software programme was used to help determine the grid spacing and number of samples to be taken to detect the presence of a single hot spot of a specified size and shape, with a specified probability of missing the hot spot. Critical input parameters for this process included:

- the shape of the grid (eg, triangle, square or rectangle)
- the size and shape of the hot spot (eg, circle, ellipse or long ellipse)
- the acceptable probability of missing the hot spot (eg, 10 percent, 20 percent, etc)
- the size of the area to be sampled (eg, 100 m², 2 m², etc).

The systematic, statistically designed grid-sampling exercise was completed at one site only, to determine whether this would provide a fuller picture of the distribution and range of contamination. Samples were taken from each grid square with a stainless steel foot corer using a five-point dice pattern. This provided five individual sub-samples from each grid square, which were combined to form a single composite sample for each individual grid square.

Results from systematic sampling provided high-quality data, and the spatial extent of contamination was best assessed with this approach. It also detected significant contaminated areas that were not identified by either judgemental or sniffer dog sampling. However, due to the high number of samples taken (137 samples over a 378 m² area), the cost associated with systematic sampling is high when using a small-diameter hot spot and high probability factor. If a smaller confidence interval and larger grid spacing are acceptable, sampling costs are significantly reduced and a larger area can be assessed.

The systematic sampling strategy employing data quality objectives proved to be the most effective method for characterising contamination at historical sheep-dip sites and provides current best practice for assessing contamination at sheep-dip sites.

Sniffer dog sampling

Dogs have been used for many years to detect trace odours at levels below the human sensitivity limit (eg, in border control operations to detect food products and narcotic drugs in the luggage of travellers). The two Australian sniffer dogs used in this trial have been trained to be sensitive to about 0.5 pbb of organochlorines (including aldrin, dieldrin and DDT isomers), all of which emit a characteristic odour. They are not able to detect arsenic contamination in soil, but sheep dips that were operational in New Zealand over the 1950s and 1960s are invariably co-contaminated with arsenic and organochlorine pesticides and so the presence of organochlorines provides a suitable tracer for corresponding arsenic contamination. This strategy has been used successfully in Australia to rapidly detect organochlorine pesticide contamination on farm properties where sheep and/or cattle dipping was either carried out, or suspected of being carried out.

The New Zealand study showed, however, that the use of sniffer dogs was not sufficiently effective as a tool for identifying areas of contamination at the dip sites. While many of the samples identified by the dogs provided measurable levels of organochlorine pesticide residues, they were generally at lower concentrations than those obtained by the preliminary judgemental sampling exercise. More importantly, the sniffer dogs did not detect previously identified hot spots of contamination where dieldrin was measured in excess of 100 mg/kg.

The sniffer dog handler/trainer believed that with further training under New Zealand conditions the dogs could adapt and learn to distinguish areas of higher organochlorine pesticide contamination at historical sheep dips. While this is an interesting strategy to provide a quick and cost-effective means of characterising contamination at sheep-dip sites, at the moment it is not suitable to detect organochlorine pesticide residues in New Zealand.

On-site characterisation methods/technologies

The costs associated with contaminated site assessment can be significantly reduced by using on-site characterisation technologies. Field analytical and site characterisation techniques offer the advantage of rapidly establishing the boundaries of contamination, providing targeted sampling and chemical analysis with significant savings in time and costs. Some of these technologies have the added advantage of on-site chemical analysis, providing almost real-time measurement of contaminants. In these situations, the costs of site assessment are largely associated with manual field sampling.

Many factors affect the technical feasibility and cost of field analytical and site characterisation technologies. These include physical constraints, site layout, data quality requirements, matrix interferences, and the expected level of contamination at a site (US EPA 1997).

There are a limited number of chemical measurement technologies suitable for on-site measurement of contaminants. These currently include the following.

- An *immunoassay* is a biochemical test that measures the level of bodily reaction to a foreign object in order to detect the presence of certain substances in a sample. Immunoassays can be divided into two groups: enzyme immunoassay (EIA) and radioimmunoassay (RIA). The former is also called enzyme-linked immunosorbent assay (ELISA) and utilises antibodies specific to the substance; these antibodies are linked to an enzyme which causes a chromogenic or fluorogenic substrate to produce a signal. The RIA test, in contrast, uses a radioisotope, which is bound to the antibody or antigen.
- A portable *gas chromatograph* is a chemical analysis instrument for identifying chemicals in a sample. A gas chromatograph uses a thin capillary fibre, known as the column, through which different chemicals pass at different rates depending on various chemical and physical properties. When the chemicals exit the end of the column, they are detected and identified electronically. The function of the column is to separate and concentrate different components in order to maximise the detection signal.
- *Infrared (IR) spectroscopy* is a type of absorption spectroscopy that uses the infrared portion of the electromagnetic spectrum to investigate the composition of a sample. IR spectroscopy works because chemical bonds vibrate at specific frequencies. In order to measure a sample, a beam of monochromatic infrared light is passed through the sample, and the amount of energy absorbed is recorded. By repeating this operation, a chart can be built up, and an experienced user can identify the substance from the information on the chart. Fourier transform spectrometers are common laboratory instruments used for spectroscopy in many diverse disciplines.
- One of the technologies currently best suited for on-site field assessments of historically contaminated sheep dips in New Zealand is *X-ray fluorescence (XRF)*. In this technique, a material under investigation is exposed to X-rays. These photons with a relatively high energy are capable of exciting (ejecting) the electrons in the core levels of the material. The induced excited state relaxes under emission of an X-ray photon with a smaller energy. This results in emitted light, which is analysed in a spectrometer. Because the core levels have very different energies for different elements, the XRF spectrum contains information on the elemental composition of the sample under investigation. XRF qualitatively and quantitatively measures metals and can be optimised to selectively detect targeted metalloid contaminants, including arsenic residues in soil.

XRF can greatly reduce sampling and analysis costs for indicating the extent of contamination. It is important to note, however, that XRF is restricted to elements, so it does not analyse for dieldrin. Soil samples can be analysed with a good deal of accuracy, quickly and on-site. The XRF technique can be influenced by a number of factors, including the sensitivity of the instrument model, sieving, and rapid drying of soil samples as opposed to using field-moist cores.

Environment Waikato funded AgResearch to conduct a field investigation at one dip site of the previous study using a field-portable X-ray fluorescence (XRF) instrument. The purpose of this investigation was to determine whether *in situ* XRF could be an effective technique for determining arsenic concentrations in soil at historical sheep-dip sites.

The comparison with previously obtained results from that dip site by traditional analysis proved problematic due to differences in the sampling procedures. However, XRF proved to be a viable method for relatively rapid on-site determination of arsenic concentrations at historical sheep-dip sites on field-moist soils. The study concluded that:

Particle size created small differences between samples, but did not appear to cause substantial differences. High concentrations of lead in soils can create errors in arsenic concentrations. However, there were low concentrations of lead at the study site. XRF can greatly reduce sampling and analysis costs for indicating the extent of contamination. Samples can be determined accurately, quickly and on site. The XRF can be used on site in conjunction with a car battery and an inverter. (Dewar and Rajendram 2005, p 12)

However, arsenic is generally not the only contaminant present at historical sheep-dip sites. Although arsenic can be used as a tracer contaminant to find the extent of contamination, further soil sampling and analyses are recommended to determine other contaminants present at the sheep-dip site. For validation of a remediated site, a council would still be required to process the samples through an IANZ accredited laboratory.

Although on-site XRF assessment may not be as accurate as traditional chemical analysis, such as acid digestions, the speed and lack of sample preparation when using field-moist samples is a significant advantage. To determine the full extent of contamination, further soil sampling and analyses are recommended to determine other contaminants present at the site.

Appendix 9: International Practices

Australia

A recent example of an effective dip-site identification programme comes from Australia, where international pressure was brought to bear in the late 1980s to eliminate pesticide residues in export beef products. A significant proportion of this pesticide contamination was thought to be derived from cattle-dipping sites. The Government instituted a management programme for cattle-dip sites in 1991 through the Cattle Tick Dip Site Management Committee, and subsequently through NSW Agriculture. Under that programme all dips were identified and, as far as possible, their locations accurately recorded, with details provided to local councils. In addition, dips were audited for such things as proximity to developments, proximity to waterways, adjacent land uses, slope and erosivity; and soil type. This information was combined with other data, such as historical chemical use on a site-by-site basis.

The Cattle-Dip Identification Programme in Australia was unique because most of the dip sites were either owned or leased by state governments and therefore records were available for the location of the dip sites. Properties indicating levels of residue in meat products were placed on trace-back and quarantine programmes, and the dipping sites were identified by information provided by farmers, the Department of Agriculture, and field reconnaissance for associated structures such as concrete plunge dips close to wells. Although this programme involved identifying cattle-dip sites and did not deal with sheep dips, the driving forces and implementation of this programme are relevant to sheep-dip sites in New Zealand.

In Australia, sniffer dogs have also been used effectively to identify a range of organochlorine contaminated sites. In areas where the approximate location of previous sheep-dip sites is known, the dogs are used to locate hotspots of contamination. (See Appendix 8 for more on this sampling strategy and its application in New Zealand.)

USA

In the United States of America, a number of states have used different methods to identify contaminated sites. The Massachusetts Department of Environmental Protection has managed a programme of identifying small-scale contaminated sites by identifying contaminated drinking-water supply wells and backtracking from these wells to find the contamination source. The Oregon Department of Environmental Quality identifies sites by a number of methods, including notification of current spills, citizen complaints, and contamination identified on neighbouring properties.

Appendix 10: Photographs of Sheep-dip Structures

Figure A.3: A typical swim-through dip with full immersion of sheep using a crutch



Source: JE Duncan, *Practical Points of Sheep Dipping*, Bulletin No. 181, New Zealand Department of Agriculture. Courtesy of the National Library of New Zealand.

Figure A.4: The U or divided swim bath



Source: JE Duncan, *Practical Points of Sheep Dipping*, Bulletin No. 181, New Zealand Department of Agriculture.

Figure A.5: Island or ring bath



Source: JE Duncan, *Practical Points of Sheep Dipping*, Bulletin No. 181, New Zealand Department of Agriculture.

Figure A.6: Pot bath with curved race and covered sump



Source: JE Duncan, *Practical Points of Sheep Dipping*, Bulletin No. 181, New Zealand Department of Agriculture.

Figure A.7: Stewart reciprocating sheep shower



Source: JE Duncan, *Practical Points of Sheep Dipping*, Bulletin No. 181, New Zealand Department of Agriculture.



Figure A.8: Cattle grazing next to disused sheep dip trench

Source: Courtesy WAIPAC.



Figure A.9: Redundant pot dip with partially collapsed yards

Pot filled in with rubble after urban landowner's pet dog fell into bath and nearly drowned.

Source: Courtesy WAIPAC



Figure A.10: Former pot dip with large, partially collapsed, holding yards

Source: Courtesy WAIPAC.



Figure A.11: Pre-1930s pot dip for manually dipping one sheep at a time

Source: Courtesy WAIPAC.



Figure A.12: Concrete remains of filled-in dip structure, still accessible to livestock

Source: Courtesy WAIPAC.



Figure A.13: 1970s/1980s mobile spray dip

Source: Courtesy WAIPAC

Glossary

Attenuation	In ecology and geochemistry, attenuation is the ability to withhold contaminants in soil and groundwater by various mechanisms such as adsorption, dilution, dispersion or biological degradation (biodegradation, bioremediation), causing a decrease in concentration and toxicity compared to the total amount of the contaminant. In environmental engineering and remediation this is often called “natural attenuation”.
Background level	An estimate of the natural concentration of a substance that would exist in the absence of any anthropogenic input, usually on a regional, sub-regional or catchment basis. For chemical elements in soils, the background concentration is expected to show some broad-scale variation depending on the nature of the geochemical parent materials.
Bioaccumulation	A general term for the process by which an organism stores a higher concentration of a substance within its body than is found in its environment.
Bioavailability	The amount of the contaminant that is available for absorption through the gastrointestinal tract (or lung surface), and is subsequently absorbed into the blood stream. The first process alone is also called bioaccessibility.
Clean-up	The removal or treatment of soil contaminated with chemicals at unacceptable concentrations.
Contaminant	This includes “any substance (including gases, odorous compounds, liquids, solids, and micro-organisms) or energy (excluding noise) or heat, that either by itself or in combination with the same, similar, or other substances, energy, or heat: (a) when discharged into water, changes or is likely to change, the physical, chemical, or biological condition of water; or (b) when discharged onto or into land or into air, changes or is likely to change the physical, chemical or biological condition of the land or air onto or into which it is discharged”. (RMA definition, see Appendix 3.)
Contaminated land	Land of one of the following kinds: “(a) if there is an applicable national environmental standard on contaminants in soil, the land is more contaminated than the standard allows; or (b) if there is no applicable national environmental standard on contaminants in soil, the land has a hazardous substance in or on it that (i) has significant adverse effects on the environment; or (ii) is reasonably likely to have significant adverse effects on the environment”. (RMA definition, see Appendix 3.)
Contamination	A condition or state which represents or potentially represents an adverse health or environmental impact because of the presence of hazardous substances.
Dip bath or vat	A structure for immersing or wetting cattle or sheep to control ectoparasites with agrichemicals. This is usually an in-ground “bath” ranging from full immersion plunge-type pot dips through to straight or U-form swim-through dips, but is sometimes a shower booth or other above-ground facility. It is typically accompanied by a draining pen.
Draining pen	An area or platform located near the exit of the dip where sheep are directed right after they are dipped to drain off the liquid in their wool. Modern draining pens are sloped to take the dip back to the bath.
Ecosystem	An area of nature, including living organisms and non-living substances, interacting to produce an exchange of material between the living and non-living parts. The term ecosystem implies interdependence between the organisms comprising the system.

Exposure	Contact with a chemical, physical or biological agent.
Exposure assessment	The estimation of the magnitude, frequency, duration, route and extent of exposure to chemical substances or a contaminant.
Hazardous	The capacity to produce any adverse health or environmental effect.
Hot spots	Areas that contain very high levels of persistent chemicals, such as chemical mixing or storage areas, or pre-1980 sheep-dip sites.
Persistent chemicals	Chemicals that were used in agriculture and horticulture for their toxic properties and from which residues may remain in the soil for some time. For the purposes of this guideline the persistent chemicals are arsenic, DDT, dieldrin and lindane, which were used prior to 1980.
Phytoremediation	The use of plant species (eg, willows, poplars) to remediate soil contamination.
Pica condition	The word pica comes from the Latin word for magpie, a bird known for its large and indiscriminate appetite. As many as 25 percent to 30 percent of children (and 20 percent of patients in mental health clinics) have an eating disorder called pica, which is characterised by persistent and compulsive cravings to eat non-food items. A discussion document on pica can be accessed from: http://www.atsdr.cdc.gov/NEWS/soilpica.html#Executive%20Summary
Receptor	An organism, plant, human or physical structure that may be exposed to a chemical or other hazardous agent.
Remediation	The clean-up or mitigation of risks from contaminants in soil.
Risk	The probability and consequence of an adverse outcome in a person, a species, a group or an ecosystem that is exposed to a hazardous agent. Risk depends on the level of toxicity of the hazardous agent, as well as the level and length of exposure.
Risk assessment	<p>a. Environmental risk assessment: the estimation of the probability and potential impact of chemicals or physical agents on a specified receptor or ecological system under a specific set of conditions.</p> <p>b. Health risk assessment: the estimation of the probability and potential impact of a chemical or physical agent on a human receptor or a specified human population under a specific set of conditions.</p> <p>The process involves reviewing existing information, identifying contaminant sources, potential exposure routes and receptors, and conducting soil sampling and analysis.</p>
Scooping mound	The ground next to the dip bath, where the sludge from the old dip was bucketed or shovelled out of the sumps to clean, empty or renew the dip.
Sheep-dip site	The actual location of the dip bath or structure; in a wider sense it also includes the immediate dip surrounding and associated areas, such as the splash area, the scooping mound or the draining pen.
Soil guideline values	Levels of contaminants that are not considered to pose an unacceptable risk to human health or to the environment. They are also referred to as “soil acceptance criteria” in existing New Zealand guidelines.
Splash zone	The area where dip solution was spread in the process of sheep dipping (eg, where the sheep jumped into the dip bath).
TDI	Tolerable daily intake.
Threshold	The dose or exposure below which a significant adverse effect is not expected.
Toxicity	The quality or degree of being poisonous or harmful to plant, animal or human life.

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The guideline is largely based on the following reports:

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- *Annual Report: Management Guidelines for Contaminated Sheep-dip Sites – 1 July 2002 – 31 December 2004, Stages 1–6 and Extension Activities Stages 3b, 4e and 5d*, NL Babbage (HortResearch) and G McBride (WaiPAC)
- *Contaminated Sheep-dip Site Discovery Methods – New Zealand’s Experience*, J Hadfield (Environment Waikato)
- *Management Guidelines for Contaminated Sheep-dip Sites – Discovery*, V Snow, B Robinson and B Clothier (HortResearch)
- *Recommendations for Soil Acceptance Criteria Protective of Ecological Receptors for Contaminants Associated with Disused Sheep-dip sites*, JH Cavanagh and LH Booth (Landcare Research)
- *Report on the Management of Contaminated Waste at Cattle Tick Dip Sites in North Eastern New South Wales*, report prepared by the Cattle Tick Dip Site Management Committee, 1992
- *Review of Liability Issues Relating to Contaminated Sheep-dip Sites*, M Harland and J Cowles (McCaw Lewis Chapman, Solicitors, Hamilton)
- *Stage 1 Preliminary Report: Project Management, NL Babbage (HortResearch): A Chronology of Site Discovery and Investigation into Contaminated Animal Dipping Sites in New Zealand 1993–2002*, G McBride (WaiPAC)
- *Stage 1 Preliminary Student Report: Historical Review of Sheep Dipping in New Zealand*, E Hofstee (Earth Sciences Student, Waikato University)
- *Stage 2 National Estimates Prepared of the Numbers of Sheep-dip Sites in New Zealand*, D Thomson (Massey University)
- *Stage 3a and 4a Characterisation – Methods Used to Characterise Contamination of Dip Sites and Typical Contaminant Profiles*, G Northcott and D McNaughton (HortResearch)
- *Stage 5a and b Meetings with Key Stakeholders and Student Project Reviewed*, NL Babbage (HortResearch) and G McBride (WaiPAC)
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