SOUTHLAND DISTRICT COUNCIL

Practice and guidance note

National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (NES-CS) – DDT in the Te Anau Basin

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Te Rohe Pōtae o Murihiku

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Document Revision

Date	Amendment	Amended by	Approved by	Approval date
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1. Introduction

1.1 Background

The Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011 (**NES-CS**) came into effect on 1 January 2012. Its purpose is to ensure that land affected by contaminants in soil is appropriately identified and assessed at the time of being developed and, if necessary, remediated or the contaminants contained to make the land safe for human use.

In the 1960s, the Te Anau Basin area in Southland was extensively farmed by the government (Landcorp), with anecdotal evidence suggesting that broad-acre application of organochlorine pesticides, including Dichloro-Diphenyl-Trichloroethane (DDT), occurred between 1963 and 1965.

DDT can persist in the environment for a long time and accumulate in the food chain. Exposure to DDT can have adverse effects on human health, such as cancer, reproductive problems, neurological disorders, and immune system disruption. It is important to assess and manage the potential risks of DDT contamination in soil, especially for sensitive land uses, including residential activities.

In 2013, Southland District Council (**SDC**) engaged GHD to undertake a statistical analysis of DDT contaminant distribution in shallow soil in the Te Anau Basin area. GHD prepared a report (**2013 GHD Report**) on its analysis and findings titled "*Statistical analysis of DDT in shallow soil in Te Anau Basin Area*". The report concluded that based on GHD's statistical analysis, the probability of soil DDT concentrations exceeding the NES-CS residential land use standard of 45 mg/kg appears to be less than 1 in 100,000.

The 2013 GHD Report provides useful information on the level of risk posed by DDT in shallow soil in the Te Anau Basin area. However, it does not override consideration of the NES-CS for sites that were subject to broad-acre DDT application. As such, unless specific exclusions apply, the requirements of the NES-CS continue to apply to the relevant sites within the Te Anau Basin area.

1.2 Purpose of practice and guidance note

This practice and guidance note explains how SDC will consider subdivision, change of use and soil disturbance activities for sites in the Te Anau Basin area that may have been affected by historical use of DDT pesticides. It covers the following topics:

a. The purpose and applicability of the NES-CS;
b. How to identify whether a site may have been subject to broad-acre application of DDT; and
c. SDC approach for dealing with sites that have a history of DDT application.

This practice and guidance note aims to assist SDC in meeting its statutory obligations while minimising the information and cost burden to landowners and developers in the area.

1.3 Limitations

This practice and guidance note focuses on the issue of historical DDT use on land in the Te Anau Basin in Southland. It does not cover other potential sources or types of contamination that may trigger the applicability of the NES-CS. Landowners and developers should be aware that there may be other activities that have taken place on land that could make the NES-CS relevant, such as hazardous waste disposal, industrial activities, or fuel storage. This practice and guidance note is not specific to those activities. It also does not address soil sampling or removal or replacing of fuel storage systems.

This practice and guidance note also does not repeat information contained in the Ministry for the Environment (MfE) Users' Guide to the NES-CS or the MfE leaflet on NES-CS for landowners and developers.

2. Purpose and Applicability of the NES-CS

2.1 Land covered by the NES-CS and HAIL (Regulation 5)

The NES-CS applies to land where an activity or industry described in the Hazardous Activities and Industries List (**HAIL**) is being, has been, or is more likely than not to have been undertaken (Regulation 5(7)). This includes the broad application of persistent pesticides, such as DDT, which falls under category A(10) of the HAIL: "Persistent pesticide bulk storage or use including sport turfs, market gardens, orchards, glass houses or spray sheds."

The NES-CS does not apply to all activities on production land that is potentially contaminated by HAIL activities. Regulation 5(8) specifies the circumstances when the NES-CS applies to production land, which are:

- removing or replacing a fuel storage system;
- sampling or disturbing soil under or near existing or proposed residential buildings;
- subdividing land or changing its use in a way that causes it to stop being production land.

The latter circumstances reflect the situations where there is a higher potential for human exposure to contaminants on production land, or where the change of land use may increase the risk of contaminant mobilisation or migration.

For example, if a person wants to sample or disturb soil on production land that has been subject to broad-acre DDT application, the NES-CS would only apply if the soil is under or near existing or proposed residential buildings or areas. If the soil being disturbed will be in an area that will continue to form part of the productive area of the land, the NES-CS would not apply.

2.2 Activities covered by the NES-CS (Regulation 5)

The activities that the NES-CS applies to are specified in Regulation 5(2)-(6). These include:

- Removing or replacing a fuel storage system from the piece of land, or any part of it, or any soil associated with it. This also includes any sampling, investigation, remediation, validation, or management of the land for the purposes of removing or replacing the fuel storage system.
- Sampling the soil of the piece of land to determine whether it is contaminated and, if so, the type and extent of contamination.
- Disturbing the soil of the piece of land for any purpose, except if the land is subject to the Resource Management (National Environmental Standard for Electricity Transmission Activities) Regulations 2009.
- Subdividing land that has the same boundaries as the piece of land, or contains all or part of the piece of land within its boundaries.

- Changing the use of the piece of land to a use that is reasonably likely to harm human health, because the land meets one of the criteria in Regulation 5(7).

The last activity, changing the use of the piece of land, requires some explanation. The NES-CS does not apply to every change of land use, but only to those that pose a risk of harming human health. This risk depends on the level and nature of contamination on the land, and the exposure pathways that the new land use might create. SDC considers that, as a general rule, a change in use from production land to residential use might increase everyday risk of exposure through ingestion, inhalation, or dermal contact with contaminated soil.

2.3 Methods for establishing piece of land under NES-CS applies (Regulation 6)

If a person wants to establish whether a site in the Te Anau basin is a piece of land subject to the NES-CS, they must use one of the two methods prescribed in Regulation 6 and must meet all the costs involved in using that method.

1. The first method is to use the information that SDC holds, including the information that it has available to it from Environment Southland (**ES**) identifying the areas where DDT was potentially applied. This is the starting point for identification (see “Identifying whether a site may have been subject to broad-acre application”).
2. The second method is to rely on the report of a preliminary site investigation (**PSI**) that assesses the likelihood of DDT having been aerially applied on the piece of land. The PSI must be in accordance with the definition in Regulation 3 of the NES-CS, and must state whether the aerial application of DDT is, was, or is likely to have been undertaken on the land. If the PSI reports that DDT was or is likely to have been applied on the land, then the NES-CS applies to that land.

The person may choose to use the PSI method if they believe that the information from ES is inaccurate or incomplete, or if they want to demonstrate that the land is not affected by DDT. In the absence of a PSI, SDC will rely on information that it holds about locations where historic aerial spraying of DDT may have occurred, as identified in the ES Contaminated Site Register, to determine whether the NES-CS applies to the land.

SDC anticipates that there may be situations where clear evidence exists that aerial spraying of DDT did not occur, or is unlikely to have occurred, on a particular piece of land. For example, if the piece of land in question was clearly located around an old farmhouse or yard, where aerial spraying would presumably not have taken place. In such cases, a PSI might conclude that a HAIL activity is unlikely to have occurred on that specific piece of land.

3. Identifying whether a site may have been subject to broad-acre application

Sites which may have been subject to broad-acre application, and to which this practice and guidance note applies, are identified with a notice headed **‘Former Landcorp Farm within the Te Anau Basin’** in the Beacon mapping platform under the ‘Contaminated Land Disclaimer Areas’ layer of the ES Selected Land Use Sites Register (SLUS).

This notice (see Figure 1) can be found by searching for the property address within Beacon.

These sites are not shown as 'Contaminated Land Sites' in SLUS. However, the administration of the NES-CS is a territorial function under section 31 of the RMA. SDC, as the territorial authority, has the responsibility to interpret and apply the NES-CS, including making final decisions on what constitutes HAIL and whether the NES-CS applies to specific sites.

Figure 1 - Example from Beacon of Landcorp Notice

In the absence of more up-to-date information that meets the criteria in Regulation 6(2)(a) or (b), or a PSI demonstrating otherwise, SDC will treat sites identified in SLUS as a 'Former Landcorp Farm within the Te Anau Basin' as a "piece of land" under Regulation 5(7) of the NES-CS on the basis that there is credible information to indicate that a HAIL activity may have occurred on these farms.

4. Southland District Council Practice and Information Requirements

4.1 Status of the 2013 GHD Report

Prior to the GHD 2013 report being generated, SDC had identified that broad-acre application of organochlorine pesticides, including DDT, had occurred in the Te Anau area (i.e. through aerial spraying application). A data set of DDT concentrations in soil existed from historical investigation works. The soil data had been collected from several clusters across the Te Anau area. Therefore, large parts of the Te Anau basin area were 'un-sampled' and presented a data gap in relation to the level of risk that residual DDT concentrations in soil may present to human health.

Given that (large) portions of the Te Anau Basin had not been investigated for levels of DDT, the 2013 GHD assessment was commissioned to provide an evaluation of the probability of whether the broad-acre application of organochlorine pesticides would have resulted in residual DDT concentrations in soil across the Te Anau Basin which exceed the NES-CS soil contaminant standards for a 'rural residential / lifestyle block' land use. In that context and noting the assumptions and limitations listed in the 2013 report, the 2013 report informs Council of the potential risk presented by the historical broad-acre application of organochlorine pesticides to human health in the area. For clarity, the 2013 report explicitly *"did not consider contamination from point source discharges of DDT (e.g. due activities such as loading, storage, and dumps of organochlorine pesticides). These potential contamination hotspot areas were considered to warrant more site specific assessments."*

Therefore, while the 2013 GHD Report provides an understanding of potential levels of DDT in soils as a result of broad-acre application of organochlorine pesticides, the 2013 GHD report:

- Is not a Preliminary Site Investigation (PSI) or Detailed Site Investigation (DSI) under Regulation 3 of the NES-CS
- Does not identify whether a HAIL activity was carried out on farms in the area.

As such, the GHD Report cannot be relied upon to argue that the farms are not "pieces of land" under the NES-CS.

As a consequence, each piece of land will require its own site-specific investigation by a Suitably Qualified and Experienced Practitioner (SQEP) to determine whether it meets the definition of a "piece of land" under the NES-CS and to assess its contamination status in relation to the applicable standards.

4.2 Te Anau Basin as a "Piece of Land"

SDC will recognise all sites within the Te Anau Basin that are identified on Beacon as former Landcorp farms as a piece of land under the NES-CS, unless a more specific PSI exists that states that no HAIL activity has been undertaken on the piece of land, and this report is sought to be relied upon under Regulation 6.

4.3 Subdivision or Change of Use

For subdivision or change of use to be a permitted activity under the NES-CS, the following requirements must be met as per Regulation 8(4):

a. A PSI report must exist.
b. The PSI must conclude it is highly unlikely there will be a risk to human health from soil contamination for the proposed activity.
c. The PSI must meet the definition in Regulation 3 of the NES-CS and be prepared in accordance with the Contaminated Land Management Guidelines No. 1: Reporting on Contaminated Sites in New Zealand.

Important notes:

- The 2013 GHD Report does not meet the requirements of a PSI under the NES-CS.
- A statement from a SQEP that solely or primarily relies on the GHD Report will not meet the PSI requirements.

If a compliant PSI does not exist, or if the PSI cannot conclude that it is highly unlikely there will be a risk to human health, the subdivision or change of use cannot be considered permitted. In such cases:

a. If a DSI exists showing soil contamination does not exceed applicable standards, the activity may be processed as a controlled activity under Regulation 9.
b. If a DSI exists showing soil contamination exceeds applicable standards, the activity may be processed as a restricted discretionary activity under Regulation 10.
c. If no DSI exists, the activity will require consent as a discretionary activity under Regulation 11.

Where consent is sought for a discretionary activity, SDC will generally consider it acceptable if a SQEP statement is provided as part of the application that:

a. Acknowledges the 2013 GHD Report as having been read and understood;
b. Confirms whether the 2013 GHD Report's findings are applicable to the specific piece of land;
c. Verifies that the piece of land subject to the activity has not been used for any other HAIL activities; and
d. States that, based on the available information, the proposed subdivision or change in use is highly unlikely to pose a risk to human health.

If a SQEP cannot provide such a statement, SDC will likely require targeted discrete soil sampling and analysis for proposed building platforms or development areas.

Note on background concentrations: If sampling confirms that any contaminants in or on the piece of land are at or below background concentrations, the land may not be subject to the NES-CS under Regulation 5(9). However, as DDT is a synthetic chemical, it is generally not part of natural background levels. Even small quantities of DDT will likely require the NES-CS to be applied.

4.4 Soil Disturbance

For disturbance of soil, volume thresholds and soil handling procedures must be adhered to in order to qualify as a permitted activity under Regulation 8(3) of the NES-CS.

For a proposal involving soil disturbance that does not meet the permitted activity requirements of Regulation 8(3), and where no DSI exists, resource consent will be required as a discretionary activity under Regulation 11.

In such cases, SDC will generally consider it acceptable if a SQEP statement is provided as part of the application, similar to that outlined for subdivision and change of use. This statement should:

a. Acknowledge the 2013 GHD Report as having been read and understood;
b. Confirm whether the 2013 GHD Report's findings are applicable to the specific piece of land;
c. Verify that the piece of land subject to the activity has not been used for any other HAIL activities; and
d. State that, based on the available information, the proposed soil disturbance is highly unlikely to pose a risk to human health.

Additionally, the application should include information on soil handling, management, and disposal arrangements along with an unexpected contamination discovery protocol. The information should be provided in general accordance with the guidance provided in CLMG 1[1] for Site Management Plans.

Where soils are to be removed from the site, the following standard conditions of consent are likely to be applied:

a. Excess soil or waste materials removed from the site must be deposited at a disposal site that holds a consent to accept the relevant level of contamination; or
b. If the soil or waste materials are demonstrated to meet the relevant waste acceptance criteria for cleanfill (as per the "Technical Guidelines for Disposal to Land" prepared by the Waste Management Institute New Zealand (WasteMINZ), September 2023), removal to a consented disposal site is not required. However, the Council must be notified prior to removal from the site, with details of how cleanfill status has been determined; and
c. Records of soil disposal from the receiving consented facility are to be retained and provided to Council upon request.

5. Conclusion

SDC recognises the unique situation in the Te Anau Basin, where historical broad-acre application of DDT has resulted in the area being considered a piece of land under the NES-CS. This practice and guidance note provides guidance on how SDC will assess subdivision, change of use, and soil disturbance activities in the Te Anau Basin.

[1] Ministry for the Environment. 2021. Contaminated land management guidelines No 1: Reporting on contaminated sites in New Zealand (Revised 2021). Wellington: Ministry for the Environment.

This practice and guidance note ensures that SDC meets its statutory obligations under the NES-CS while supporting appropriate subdivision, use and development of the affected land in the Te Anau Basin.

6. Additional Information

This practice and guidance note is intended as guidance and should be considered alongside the SDP, NES-CS, and relevant legal advice. For further information and clarification, please consult with the SDC resource consents team.

29 January 2013

Simon Moran
Southland District Council
PO Box 903
Invercargill 9840

Our ref: 51/34182/r

Your ref:

Dear Simon

Statistical analysis of DDT in shallow soil in Te Anau Basin Area

GHD Limited (GHD) was engaged by Southland District Council (SDC) to undertake a statistical analysis of DDT contaminant distribution in shallow soil in the Te Anau Basin Area.

This report summarises the Monte Carlo statistical analysis that was undertaken in accordance with our proposal dated 21 December 2013.

The analysis undertaken as part of this assessment does not provide an understanding of the spatial relationship between the concentration measurements or where exceedances occur but does provide some understanding of the level of risk of elevated levels of contamination occurring in the sites of interest. The assessment does not include consideration of potential contaminant “hotspots” (such as pesticide mixing sheds). It is focused on soil contamination resulting from broad acreage application of DDT.

1 Background

The Te Anau Basin Area was extensively farmed by LandCorp in the 1960s and 1970s with anecdotal evidence that the broad-acre application of organochlorine pesticides, including DDT, occurred between 1963 and 1965. GHD understands that the land now has multiple owners and that the presence of the DDT in soil triggers the application of the National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health, 2012 (NES).

GHD understand that the rationale to conduct this assessment is that SDC require a statistical analysis of recent soil sampling results (investigations conducted by Davis Consulting) to assess the probability of whether the broad-acre residual DDT concentrations exceed the residential land use standards set by the NES. If the assessment yields an acceptable level of confidence that the range of soil concentrations do not exceed the NES SCS(Soil), council may be in a position to reduce its regulatory requirements for Detailed Site Investigations for consent holders in the area when disturbing the land. We understand that SDC will engage with Southland Regional Council in this regard.

The current locations of interest in the Te Anau Basin Area include the Riverside Subdivision at Sandy Brown Road which is located on the edge of the Te Anau urban area, stretching to Ramparts Road which is further out of town.

1.1 Statistical Assessment

The Monte Carlo simulation assesses the probability of exceedance the Soil NES guideline.

As an initial step statistical assessment of the soil DDT data available for the Te Anau area was under taken. This was followed by Monte Carlo simulations, definition of the potential DDT concentration range over the area where aerial spraying occurred in the 1960/70's, and the risk of these exceeding the NES criteria of 45 mg/kg.

An assessment of the spatial distribution of the data suggests that DDT soil samples for analysis were collected from several clusters across the Te Anau area. Therefore, large part of the Te Anau area remain un-sampled and this was one of the key drivers for undertaken a statistical assessment to inform a decision on the need for more sampling in the area subject to aerial application of DDT in the 1960's.

2 Objective

The objective of this assessment was to estimate the potential for DDT concentrations in the Te Anau area subject to aerial application exceeding the NES criteria of 45mg/kg by use of a uni-variant Monte Carlo simulation.

3 Summation

This section provides a brief summary of findings of this investigation. The report must be read and understood in its entirety before using the information presented in this summary section for any decision making purposes.

The key elements and findings of the statistical assessment can be summarised as follows:

- The measured soil DDT concentration data set of 242 point measurements of the total population was considered sufficient to provide a reasonable estimate of the population distribution shape, with uncertainty likely to be mainly limited to the population tails;
- The statistical parameters of the 100,000 point Monte Carlo simulation showed a good correlation to the statistical parameters of the measured DDT concentration data collected. This indicates that the simulated population should be a reasonable representation of the potential DDT concentration population present in the Te Anau area subject to aerial application of DDT.
- To take into account the potential uncertainty in the match of the simulated to the actual population distribution, a relatively large range of potential concentrations was used. The maximum modelled concentration of 500mg/kg used in the simulation was a conservative upper concentration and was two orders of magnitude greater than the maximum concentration measured in the 242 point measurement DDT concentration data set available for the Te Anau area.
- The 100,000 Monte Carlo simulation had maximum DDT simulated concentration of 10.5mg/kg which was below the NES soil guideline value of 45 mg/kg.
- The result of the 100,000 point Monte Carlo simulation indicates that the probability of soil DDT concentrations exceeding 45 mg/kg on land aerially sprayed with DDT in the Te Anau area is considered low at <1 in 100,000.

- The report did not consider contamination from point source discharges of DDT due to activities such as loading, storage, and dumps. These potential contamination hotspots may warrant more site specific assessment.

4 Background to Monte Carlo Analysis

Monte Carlo simulations based on sample data that approximately describes the population distribution have seen extensive use in many fields of science since the 1970's. Population distributions utilised for Monte Carlo simulations can include normal, log-normal, triangle and various other distributions, including the beta function. The beta function was used in this stage of the assessment to describe the population distribution estimated by the sample data.

When modelling a potential population distribution using point data (such as concentration measurements) several aspects need to be considered, including:

- The data should be collected in an unbiased manner;
- The greater the number of sample data points, the closer to the sample data distribution would be to the population distribution;
- The sample point data collected is most likely from near the population centre and not likely to fully capture the full population range or define the population tails;
- Only complete sampling of the entire population would result in accurate definition of the distribution. However, this approach is generally impractical;
- Any population distribution estimate derived from sample point data will be subject to uncertainty and error. The scale of the uncertainty and error is generally related the number of data points on which the estimate is based. In general the larger the data set the lower the uncertainty and error of the distribution estimate; and
- Monte Carlo simulations are based on the estimated population distribution and range and as such need to consider the aspects outlined above in order to understand reliability of the predictions.

The mathematics of the beta function are based on probability densities / distributions. The beta function is generally defined over a probability interval of 0 to 1 and parameterised by two positive shape parameters, denoted by α and β. These appear as exponents of the random variable and control the shape of the distribution in relation of the different probabilities of occurrence. In general the beta distribution can be utilised to model the behaviour of random variables limited to intervals of finite length in a wide variety of disciplines beyond application to contaminated land problems. One of the key advantages of the beta function is its flexibility to simulate a wide variety of population distribution shapes as illustrated in Figure 1.

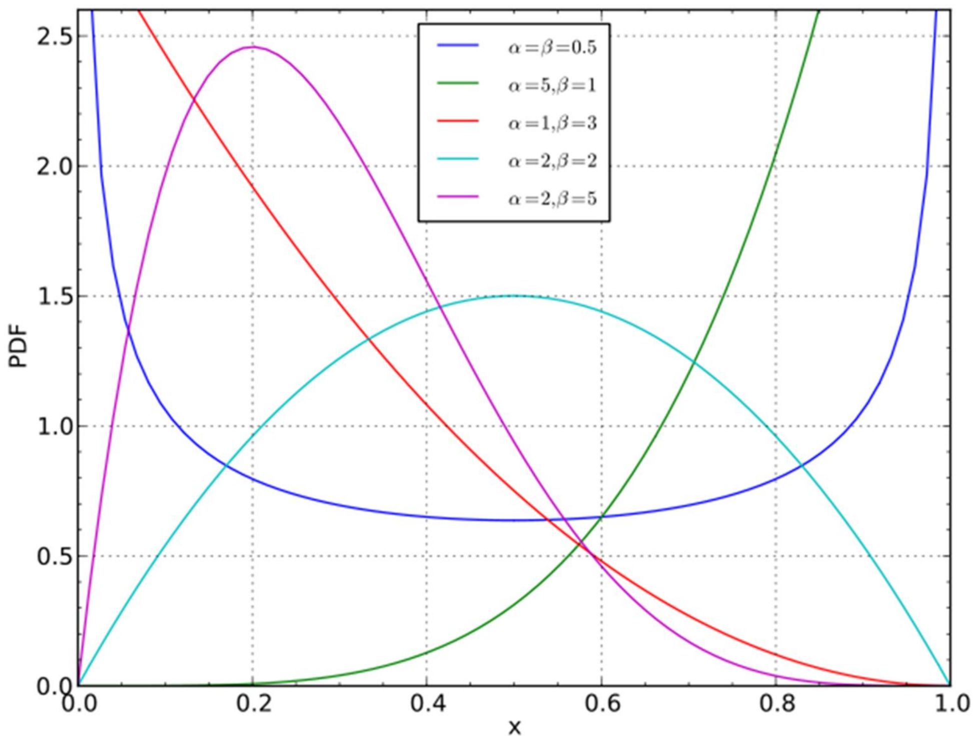

Figure 1: Beta Function Probability Density Function for various shape factors

The beta function utilised in this analysis to estimate the potential DDT concentrations was based on the estimated shape of the population distribution curve and the probability of the concentration occurring. The beta function simulates the shape of the population distribution curve by utilising the following parameters:

- Probability of occurrence (0 to 1);
- Alpha shape factor (based on DDT concentrations distribution in soil samples);
- Beta Shape factor (based on DDT concentrations distribution in soil samples);
- Assumed population minimum concentration (based on assumption of 0mg/kg);
- Assumed population maximum concentration (based on conservative interpretation of Te Anau and other similar measured soil sample concentration data);

5 Approach and Methodology

To develop the population distribution curves an Excel spread sheet model was developed by GHD using the following approach and methodology.

- Establish the statistical parameters of the existing DDT concentration data available for the Te Anau area (Table 1). The parameters included mean, median, standard deviation, minimum and maximum values. In this assessment the median was used as the most robust estimator of population centrality as the mean is prone to greater influence form outlier values. The statistical parameters for the measured DDT concentration values are presented in Table 2.

- An experimental beta function was then used to develop an estimate of the population distribution for use in a 100,000 point Monte Carlo simulation of the potential DDT concentrations present in the Te Anau area where aerial spraying of DDT occurred. The simulation assigned a random probability of occurrence to each simulation point. The statistical parameters of the Monte Carlo data set (Table 3) were then used to compare against the collected DDT concentration data statistical parameters (Table 2) to form the basis for development and refinement of the population distribution estimates in the subsequent steps.
- The alpha and beta shape factors where adjusted until the population distribution model mean, median and standard deviation values of the Monte Carlo simulated data set were similar to those of the soil sample analytical data set. For this assessment the aim was that the Relative Percent Differences (RPD) between the two parameter sets at 10% or less. This process is iterative and often requires balancing the accuracy of the mean, median and standard deviation to achieve optimal results;
- The minimum DDT concentration of the population distribution model was assumed to be zero; and
- The maximum of the DDT concentration population distribution model was assumed to be 500mg/g. This was considered to be sufficient to allow for the potential existence of very high outlier concentrations in the area. The adopted maximum was approximately 10 times greater than the values found in the literature reviewed as outlined in the reference section.

Once the population distribution model had been developed the potential for DDT concentrations exceeding the NES value of 45 mg/kg over the area subject to aerial spraying was assessed based on the results of the Monte Carlo simulation.

6 Results

This section outlines the results of the Monte Carlo and population Distribution Simulations, including the Quality Assurance and Control results.

6.1 Input Data

The DDT concentration measurements used in the analysis are summarised in **Error! Reference source not found.**. This data formed the basis for the statistical assessment outlined in this section of the report.

Table 1 DDT Concentrations Measurements in the Te Anau area (mg/kg)

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
Sandy Brown Road	100	237.569702	-45.41605362	167.7342946	1.228

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
Sandy Brown Road	102	239.011719	-45.41615395	167.7346666	1.228
Sandy Brown Road	103	237.089111	-45.41621237	167.7350592	1.228
Sandy Brown Road	104	236.608521	-45.41627641	167.735441	1.12
Sandy Brown Road	105	237.810059	-45.41634925	167.7358033	1.12
Sandy Brown Road	106	238.050415	-45.41641597	167.7361629	1.12
Sandy Brown Road	107	238.290771	-45.41651412	167.7364984	0.576
Sandy Brown Road	108				0.576
Sandy Brown Road	109	240.453735	-45.41636291	167.734111	0.576
Sandy Brown Road	110	239.49231	-45.41646592	167.7344648	1.851
Sandy Brown Road	111	239.011719	-45.41654857	167.7348546	1.851
Sandy Brown Road	112	239.252075	-45.41663264	167.7352575	1.851
Sandy Brown Road	113	238.531128	-45.41669089	167.7356461	1.395
Sandy Brown Road	114	237.329468	-45.41677597	167.7360159	1.395
Sandy Brown Road	115				1.395
Sandy Brown Road	116	234.685791	-45.41661621	167.7340101	1.789

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
Sandy Brown Road	117	234.685791	-45.41661705	167.7340132	1.789
Sandy Brown Road	118	237.329468	-45.41664689	167.7343872	1.789
Sandy Brown Road	119	237.569702	-45.41673607	167.7347939	1.493
Sandy Brown Road	120	241.414917	-45.41680078	167.7351809	1.493
Sandy Brown Road	121	240.453735	-45.41684244	167.7355926	1.493
Sandy Brown Road	122	237.089111	-45.41694294	167.7360106	2.582
Sandy Brown Road	123	237.810059	-45.41707126	167.7365936	2.582
Sandy Brown Road	124				2.582
Sandy Brown Road	125	240.213379	-45.41681863	167.7338838	1.836
Sandy Brown Road	126	240.453735	-45.41693355	167.7342429	1.836
Sandy Brown Road	127	240.69397	-45.41699382	167.7346696	1.836
Sandy Brown Road	128	241.174683	-45.41715751	167.7351238	4.399
Sandy Brown Road	129	239.49231	-45.41714259	167.7354957	4.399
Sandy Brown Road	130	242.856934	-45.41719942	167.7359954	4.399
Sandy Brown	131				1.191

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
Road					
Sandy Brown Road	132	235.406738	-45.41725047	167.736312	1.191
Sandy Brown Road	133	236.127808	-45.41715978	167.7338286	1.191
Sandy Brown Road	134	240.69397	-45.41717746	167.7342352	1.498
Sandy Brown Road	135	240.934326	-45.41730654	167.7346097	1.498
Sandy Brown Road	136	240.934326	-45.41738659	167.7349589	1.498
Sandy Brown Road	137	240.213379	-45.41747552	167.7353342	3.701
Sandy Brown Road	138	239.49231	-45.41757493	167.7357316	3.701
Sandy Brown Road	139				3.701
Sandy Brown Road	140	240.213379	-45.41760519	167.7365469	1.591
Sandy Brown Road	141	241.89563	-45.41778104	167.7360006	1.591
Sandy Brown Road	142	236.848755	-45.41768465	167.7356191	1.591
Sandy Brown Road	143	238.290771	-45.41763864	167.7352281	0.88
Sandy Brown Road	144	239.732666	-45.41757762	167.7348724	0.88
Sandy Brown Road	145	243.09729	-45.41749623	167.7345385	0.88

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
Sandy Brown Road	146	237.810059	-45.41744133	167.7341445	0.648
Sandy Brown Road	147				0.648
Sandy Brown Road	148	240.934326	-45.41764643	167.7335823	0.648
Sandy Brown Road	149	240.934326	-45.41774433	167.7339275	1.218
Sandy Brown Road	150	240.453735	-45.41781021	167.7342807	1.218
Sandy Brown Road	151	241.655273	-45.41791297	167.7346434	1.218
Sandy Brown Road	152	243.337524	-45.41797752	167.7350171	0.611
Sandy Brown Road	153	244.29895	-45.41806854	167.7353835	0.611
Sandy Brown Road	154	240.934326	-45.41786914	167.7335113	0.611
Sandy Brown Road	155	240.69397	-45.41786713	167.7335098	0.823
Sandy Brown Road	156	242.616577	-45.41796603	167.7339646	0.823
Sandy Brown Road	157	240.934326	-45.41802973	167.7343011	0.823
Sandy Brown Road	158	245.260132	-45.41813903	167.73466	1.591
Sandy Brown Road	159	243.09729	-45.41824054	167.735039	1.591
Sandy Brown Road	160	245.260132	-45.41836845	167.73579	1.591

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
Golf Course Road	161	227.956543	-45.45235598	167.6895669	1.007
Golf Course Road	162	227.716309	-45.45235564	167.68957	1.007
Golf Course Road	163	226.274292	-45.45246083	167.6902793	1.007
Golf Course Road	164	234.926025	-45.45251372	167.6909544	0.513
Golf Course Road	165	230.359863	-45.45254658	167.6916534	0.513
Golf Course Road	166	229.39856	-45.45252789	167.6922664	0.513
Golf Course Road	167	234.685791	-45.45258748	167.6929133	1.334
Golf Course Road	168	234.685791	-45.45255035	167.6935632	1.334
Golf Course Road	169	238.290771	-45.45252445	167.694226	1.334
Golf Course Road	170	238.771362	-45.45246553	167.6948875	2.287
Golf Course Road	171	239.49231	-45.45245706	167.6948664	2.287
Golf Course Road	172	241.655273	-45.45246067	167.6955389	2.287
Golf Course Road	173	238.531128	-45.45245664	167.6962032	0.812
Golf Course Road	174	243.09729	-45.45249620	167.6968654	0.812
Golf Course	175	247.182739	-45.45251867	167.6975145	0.812

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
Road					
Golf Course Road	177	246.221558	-45.45236913	167.6981215	1.782
Golf Course Road	178	250.547363	-45.45231130	167.6987579	1.782
Golf Course Road	179	251.98938	-45.45212874	167.6993788	1.782
Golf Course Road	181	236.608521	-45.45371443	167.689924	1.074
Golf Course Road	182	239.252075	-45.45368459	167.6905741	1.074
Golf Course Road	183	238.531128	-45.45364914	167.6912365	1.074
Golf Course Road	184	235.887329	-45.45374259	167.6919206	0.278
Golf Course Road	185	238.771362	-45.45360320	167.693092	0.278
Golf Course Road	186	239.973022	-45.45369063	167.6937086	0.278
Golf Course Road	187	240.453735	-45.45358627	167.6943802	0.138
Golf Course Road	188	240.453735	-45.45348552	167.6950691	0.138
Golf Course Road	189	246.461792	-45.45306651	167.6962136	0.138
Golf Course Road	191	246.702148	-45.45288588	167.6968049	1.06
Golf Course Road	192	250.066772	-45.45266292	167.697374	1.06

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
Golf Course Road	193	251.268311	-45.45238045	167.6979147	1.06
Golf Course Road	194	252.950684	-45.45229487	167.6985463	0.625
Golf Course Road	195	252.950684	-45.45229630	167.6985311	0.625
Golf Course Road	196	250.78772	-45.45238883	167.6991791	0.625
Golf Course Road	197	250.547363	-45.45396010	167.6971258	0.39
Golf Course Road	199	250.78772	-45.45395709	167.6971415	0.39
Golf Course Road	200	246.461792	-45.45437207	167.6972204	0.39
Golf Course Road	201	246.942505	-45.45480936	167.6972004	0.762
Golf Course Road	202	244.779541	-45.45524958	167.697168	0.762
Golf Course Road	203	246.461792	-45.45568703	167.6971693	0.762
Golf Course Road	204	246.942505	-45.45613487	167.6971064	0.486
Golf Course Road	205	247.663452	-45.45657450	167.6971088	0.486
Golf Course Road	206	245.981201	-45.45702260	167.6971407	0.486
Golf Course Road	207	246.702148	-45.45790999	167.6959555	1.304
Golf Course Road	208	245.500488	-45.45789155	167.6959892	1.304

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
Golf Course Road	209	243.577881	-45.45773137	167.6953765	1.304
Golf Course Road	210	243.577881	-45.45761889	167.6947694	1.063
Golf Course Road	211	244.058594	-45.45740088	167.6942164	1.063
Golf Course Road	212	240.934326	-45.45722687	167.6936256	1.063
Golf Course Road	213	242.856934	-45.45677391	167.6925557	0.452
Golf Course Road	214	237.329468	-45.45654785	167.6919931	0.452
Ramparts Road	227	396.426392	-45.47075886	167.7499877	0.06
Ramparts Road	228	396.907104	-45.47076398	167.7498763	0.06
Ramparts Road	230	404.597534	-45.47127686	167.7488623	0.06
Ramparts Road	231	403.395874	-45.47145196	167.748193	0.06
Ramparts Road	232	400.511963	-45.47153243	167.747604	0.06
Ramparts Road	234	402.194214	-45.47176243	167.7465248	0.06
Ramparts Road	235	407.721802	-45.47186653	167.7461751	0.06
Ramparts Road	236	406.279785	-45.47199268	167.7436963	0.06
Ramparts	237	401.953979	-45.47211522	167.7429752	0.06

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
Road					
Ramparts Road	238	401.23291	-45.47201112	167.742454	0.06
Ramparts Road	240	405.558838	-45.47199092	167.7415436	0.06
Ramparts Road	242	401.713623	-45.47188581	167.740499	0.06
Ramparts Road	243	401.473267	-45.47175405	167.739802	0.06
Ramparts Road	244	404.357178	-45.47164961	167.7391561	0.06
Ramparts Road	245	396.426392	-45.47165313	167.7384521	0.06
Ramparts Road	246	390.177856	-45.47154064	167.7377856	0.06
Ramparts Road	248	386.332642	-45.47098962	167.7380445	0.06
Ramparts Road	249	390.418213	-45.47060992	167.7384967	0.06
Ramparts Road	250	395.464966	-45.47015411	167.7389251	0.06
Ramparts Road	251	397.387695	-45.46977307	167.7393354	0.06
Ramparts Road	252	396.666748	-45.46942689	167.7398524	0.06
Ramparts Road	253	396.426392	-45.46905356	167.7404503	0.06
Ramparts Road	254	401.473267	-45.46878492	167.7410797	0.06

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
Ramparts Road	255	399.791016	-45.46842232	167.7414283	0.069
Ramparts Road	256	401.953979	-45.46801823	167.7419343	0.069
Ramparts Road	258	400.511963	-45.46761112	167.742911	0.069
Ramparts Road	260	406.520142	-45.46711341	167.7441369	0.069
Ramparts Road	261	408.442749	-45.46681744	167.7446892	0.133
Ramparts Road	262	403.63623	-45.46412811	167.7475635	0.133
Ramparts Road	263	396.907104	-45.46409014	167.7474981	0.842
Ramparts Road	264	408.202393	-45.46382753	167.7483127	1.282
Ramparts Road	266	402.43457	-45.45873988	167.7481734	1.809
Ramparts Road	267	402.915161	-45.45908405	167.74774	1.809
Ramparts Road	268	404.116821	-45.45946936	167.7472333	1.809
Ramparts Road	269	403.876587	-45.45980338	167.7467637	1.398
Ramparts Road	270	391.860107	-45.46013849	167.7461964	1.398
Ramparts Road	271	403.876587	-45.46058700	167.7459132	1.398
Ramparts Road	272	401.713623	-45.46103024	167.7456706	0.552

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
Ramparts Road	273	404.597534	-45.46187815	167.7446329	0.552
Ramparts Road	274	394.984375	-45.46194429	167.7446613	0.552
Ramparts Road	275	396.186157	-45.46199701	167.7445697	0.239
Ramparts Road	276	393.782715	-45.46235433	167.744193	0.239
Ramparts Road	277	400.992554	-45.46267645	167.7436465	0.239
Ramparts Road	279	401.953979	-45.46334473	167.742607	0.164
Ramparts Road	280	401.473267	-45.46369686	167.7421268	0.129
Ramparts Road	281	404.116821	-45.46408385	167.7417289	0.105
Ramparts Road	283	401.473267	-45.46539193	167.7400219	0.06
Ramparts Road	284	403.395874	-45.46576794	167.7396239	0.06
Ramparts Road	285	399.069946	-45.46612233	167.7391963	0.06
Ramparts Road	286	394.984375	-45.46651234	167.7387125	0.062
Ramparts Road	287	391.379395	-45.46684745	167.7382238	0.062
Ramparts Road	288	392.34082	-45.46720946	167.7377832	0.062
Ramparts	289	392.100464	-45.46752445	167.7372508	0.06

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
Road					
Ramparts Road	290	391.619751	-45.46787775	167.7367964	0.06
Ramparts Road	291	388.255249	-45.46820121	167.7362862	0.06
Ramparts Road	294	389.216553	-45.45752937	167.7462316	0.295
Ramparts Road	295	395.464966	-45.45789449	167.7458145	0.295
Ramparts Road	296	394.263428	-45.45832590	167.745461	0.159
Ramparts Road	297	390.177856	-45.45866185	167.7449546	0.159
Ramparts Road	298	388.976196	-45.45906393	167.7445883	0.159
Ramparts Road	299	388.73584	-45.45945964	167.7440969	0.146
Ramparts Road	300	384.410034	-45.45979969	167.7436271	0.146
Ramparts Road	301	386.813232	-45.46015559	167.7431327	0.146
Ramparts Road	302	386.332642	-45.46050972	167.7426612	0.749
Ramparts Road	303	384.410034	-45.46084156	167.7420929	0.749
Ramparts Road	304	379.603394	-45.46117022	167.741566	0.749
Woolshed 1					0.158
ASSS2					0.06

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
ASSS3					0.06
ASSS4					0.073
Eweburn	309	325.289307	-45.36144971	167.7908421	0.499
Eweburn	310	322.645752	-45.36158927	167.7904014	0.499
Eweburn	311	318.800537	-45.36172212	167.7897076	0.499
Eweburn	312	315.195557	-45.36188046	167.7890866	0.421
Eweburn	313	309.427734	-45.36179622	167.7883477	0.421
Eweburn	315	308.466431	-45.36182321	167.7878573	0.421
Eweburn	316	309.908325	-45.36194935	167.7864188	0.151
Eweburn	317	309.187378	-45.36194583	167.7864141	0.151
Eweburn	318	313.75354	-45.36201348	167.7858467	0.151
Eweburn	319	315.676147	-45.36199453	167.7858103	0.401
Eweburn	320	304.380859	-45.36204323	167.7851751	0.401
Eweburn	321	301.256592	-45.36203351	167.7845016	0.401
Eweburn	322	300.535645	-45.36213451	167.7838918	0.215
Eweburn	323	301.737305	-45.36233107	167.7831451	0.215
Eweburn	324	295.488647	-45.36239753	167.7825085	0.215
Eweburn	325	302.217896	-45.36250114	167.7818164	0.06
Eweburn	326	301.737305	-45.36269593	167.7812026	0.06
Eweburn	328	301.256592	-45.36282250	167.7805063	0.06
Eweburn	329	301.496948	-45.36300707	167.7799093	0.06
Eweburn	330	297.651611	-45.36312366	167.7792301	0.06
Eweburn	331	297.170898	-45.36323489	167.7785927	0.06

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
Eweburn	332	298.372559	-45.36329322	167.7778237	0.06
Eweburn	334	298.132324	-45.36339272	167.7771589	0.06
Eweburn	335	299.574219	-45.36350780	167.7764645	0.06
Eweburn	336	307.024414	-45.35991959	167.7807348	0.06
Eweburn	338	292.364502	-45.36003627	167.7800321	0.06
Eweburn	339	286.356323	-45.36007675	167.7792967	0.06
Eweburn	340	292.124146	-45.36017566	167.7787507	0.06
Eweburn	341	287.317627	-45.36027247	167.7780382	0.06
Eweburn	342	291.643433	-45.36030499	167.777282	0.06
Eweburn	343	292.604736	-45.36046894	167.7766149	0.06
Eweburn	344	284.674072	-45.36061755	167.7759634	0.06
Eweburn	345	288.038574	-45.36063775	167.7752107	0.06
Eweburn	346	292.364502	-45.35851889	167.7843949	0.772
Eweburn	348	292.124146	-45.35840616	167.7850839	0.772
Eweburn	349	296.690308	-45.35849400	167.7857718	0.772
Eweburn	350	303.659912	-45.35846743	167.786533	0.219
Eweburn	351	300.295288	-45.35832427	167.7872125	0.219
Eweburn	352	303.419556	-45.35792101	167.7884953	0.219
Eweburn	353	303.179199	-45.35794406	167.7884293	0.313
Eweburn	354	311.350342	-45.35761616	167.7891167	0.313
Eweburn	355	315.195557	-45.35743570	167.7896655	0.313
Eweburn	357	288.759521	-45.35414438	167.7801564	0.06
Eweburn	358	287.317627	-45.35447756	167.7806569	0.06

Group	ID	Altitude	Latitude	Longitude	Total DDT (mg/kg)
Eweburn	359	286.115967	-45.35483438	167.7810923	0.06
Eweburn	360	285.635254	-45.35513445	167.7815109	0.06
Eweburn	361	289.240234	-45.35546780	167.7820248	0.06
Eweburn	362	0	-45.35577985	167.7825102	0.06
Eweburn	364	295.248291	-45.35276874	167.782065	0.06
Eweburn	365	287.557861	-45.35245324	167.782543	0.06
Eweburn	366	291.883789	-45.35205510	167.7832268	0.06
Eweburn	367	292.604736	-45.35173601	167.7837102	0.06
Eweburn	368	289.961182	-45.34850302	167.7901797	0.06
Eweburn	369	321.924805	-45.34852624	167.790253	0.06
Eweburn	370	314.474487	-45.34880628	167.7896983	0.06
Eweburn	371	308.947021	-45.34912270	167.7892173	0.06
Eweburn	372	307.264771	-45.34939528	167.7886954	0.06
Eweburn	373	312.55188	-45.34977741	167.7882746	0.06

The DDT concentration measurement distribution for the data in Table 1 is summarised on Figure 2. As shown the distribution is highly skewed with neither a normal or log-normal distribution apparent. Therefore application of the beta function to estimate the population distribution would be appropriate given the wide range of distributions that can be simulated.

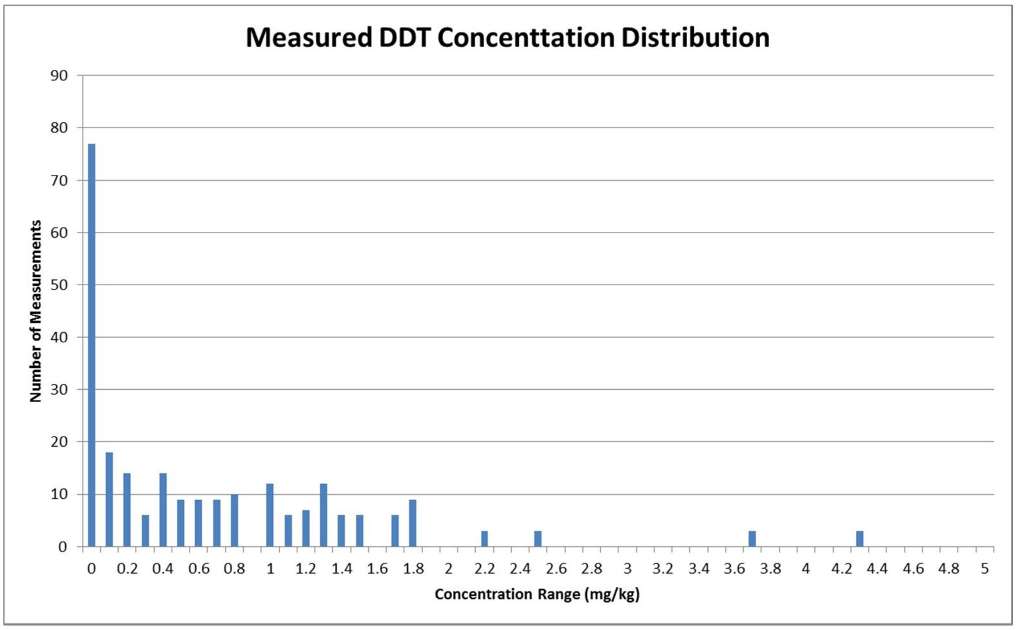

Figure 2: Measured DDT concentration distribution for Te Anau area

The statistical parameters calculated for the DDT concentration measurements presented in Table 1 are summarised in Table 2.

Table 2 Summary Statistics of Input Data

Measure	DDT
Number of measurements	242
Mean	0.72
Median	0.44
Standard Deviation	0.83
Minimum	<0.1
Maximum	4.40

A total of 242 DDT concentration measurements was available for the Te Anau area and were used in the assessment. Given the number of measurements available a reasonably good estimate of the potential population distribution was considered possible. The measured range of DDT concentrations in the Te Anau area subject to aerial spraying generally exceeds that measured in soils from forest, grassland and urban (provincial and metropolitan) areas of New Zealand reported by Buckland et al 1998. However the measurements we similar to the range measures in agricultural soils (Boul et al 1994, Buckland et al 1998, Gonga et al 2004, Martínez et al 2011, Somerville and Liebens 2011).

6.2 Monte Carlo Generated Distributions

A 100,000 point Monte Carlo simulation using the beta function was then undertaken using a population distribution estimate derived from the DDT concentration data presented in Table 1. To estimate the population distribution a beta function was used. The alpha and beta parameters in the function were adjusted while the minimum and maximum were retained at 0 and 500 mg/kg respectively until the simulation statistical parameters showed and acceptable level of correspondence to the data parameters summarised in Table 2.

The statistical parameters for the Monte Carlo simulation data sets are summarised in Table 3. As shown, there appears to be good correspondence between the mean, median and standard deviations of the measured DDT concentration data and the simulated results using the estimated population distribution. The minimum and maximum values of the Monte Carlo data set were lower and higher than the experimental data respectively, which is not unexpected given that the adopted population minimum and maximum values ranged from 0mg/kg to 500mg/kg respectively. The adopted maximum DDT concentration of 500mg/kg was two orders of magnitude greater than the maximum measured DDT concentration in the Te Anau area and an order of magnitude greater than the DDT concentration reported in the literature reviewed.

Table 3 Monte Carlo Simulation Summary Statistics

Measure	DDT
Number of measurements	100,000
Mean	0.73
Median	0.46
Standard Deviation	0.81
Minimum	0 mg/kg
Maximum	10.5 mg/kg

6.3 Quality Assurance

As a quality assurance and control measure a comparison of the statistical parameters (Table 4) of the measured DDT concentration data and Monte Carlo simulated DDT concentrations showed good correlations between the mean, median and standard deviations with no values exceeding the adopted RPD acceptance criteria of 10%.

Table 4 RPD's for Data Statistics and Monte Carlo Simulations

Measure	RPD
Mean	<1%
Median	2.4%
Standard Deviation	1%

7 Discussion

The key objective of the study was to assess the potential for presence of DDT concentrations in soils in the Te Anau area subject to historical aerial application exceeding the NES criteria of 45mg/kg. Aerial application of pesticides generally results in a diffuse source with relatively similar concentrations spread across the area of application. This study did not consider the risk of DDT concentrations in soil exceeding the NES criteria of 45mg/hg as a result of point sources such as storage, waste disposal and spill areas as the assumptions on which this analysis was based did not consider these source types. To assess the potential for point source presence and resultant DDT concentrations exceeding the NES criteria of 45mg/kg more site specific historical and environmental setting factors need to be considered.

The statistical analysis undertaken and reported in this document was based on a total of 242 DDT concentrations measurements undertaken on soil samples from across the Te Anau area. This data set was considered sufficiently large to provide a reasonable approximation of the potential shape of the DDT concentration population distribution and key statistical parameters such as mean, median and standard deviation.

The statistical information of the measured DDT concentration data set was then utilised to develop a beta function that approximated the population distribution for use in a 100,000 point Monte Carlo simulation. The information from the Monte Carlo simulation was then used to assess the potential for the occurrence of DDT concentrations in soils of the Te Anau area subject to aerial application.

The aim of the population distribution was to adjust the beta function parameters until the mean, median and standard deviation measures of the Monte Carlo simulation matched those of the measured concentration data set. The range of the potential population concentration distribution (0mg/kg to 500mg/kg) was considered large enough to incorporate the potential for high concentration outliers to occur within the 100,000 point Monte Carlo simulation.

The results of the 100,000 point Monte Carlo simulation showed a good correlation with the statistical parameters of the measured DDT concentrations. The maximum predicted DDT concentration for the Monte Carlo simulation was 10.5mg/kg which was below the NES criteria of 45mg/kg. The results indicate that the probability of DDT concentrations in soils within the Te Anau area subject to aerial application in the 1960/70's exceeding the NES criteria of 45mg/kg appears to be less than 1 in 100,000, which was considered to be a relatively low risk.

A comparison was made between the NES criteria for DDT of 45 mg/kg and published DDT concentrations measured in soils. In general the exceedences of the NES criteria was rare, and overall the concentration range measured in the Te Anau area soils was generally consistent with that measured in other agricultural soils tested and reported in the reviewed literature.

The assessment reported in this document was based on a uni-variant statistical approach and therefore did not consider any potential spatial relationship between the concentration measured in the soil sample and the location from which it was collected. This would require use of a bi-variant statistical approach, which was beyond the scope of this study.

8 Conclusions

This section presents the conclusions of the assessment undertaken. It is important to note that this report must be read and understood in its entirety before using the conclusions presented for decision making.

Based on the uni-variant statistical assessment outlined in this report GHD can draw the conclusion that the risk of DDT concentrations exceeding the NES criteria of 45mg/kg in the Te Anau area subject aerial application in the 1960's is relatively low (<1 in 100,000).

Consideration of the DDT concentration and location relationship was not included within the scope of work for this stage and therefore no conclusions can be drawn regrading where elevated concentration in the area subject to aerial spraying of DDT may occur.

9 Recommendations

Considering the findings of the assessment GHD make the following recommendations:

- Should an understanding of the likely DDT concentration distribution across the Te Anau area be desired a spatial geostatistical assessment using bi-variant statistical methods could be conducted to assess if a spatial relationship exists and whether spatial mapping is possible. This approach could also be used to identify whether there are areas where more elevated DDT concentrations in soil are present. A preliminary spatial analysis suggests that a spatial relationship may exist at least at a local scale;
- In the event that more DDT soil concentration data is collected in the Te Anau area it is important to reassess the statistical parameters of the updated data set to establish that the assumptions of this assessment are still being met. This reassessment needs to recalculate the measures concentration data set statistical parameters and then calculating the RPDs for the statistical parameters to assess whether the assumptions made in regards to the population distribution and Monte Carlo simulations are still applicable and therefore support the conclusions reached in this report. This re-analysis particularly important if higher concentration outliers are found that suggest the simulated population mean may be an underestimate.

10 Limitations

This report has been prepared by GHD for Southland District Council and may only be used and relied on by Southland District Council for the purpose agreed between GHD and Auckland Council as set out in this report.

GHD otherwise disclaims responsibility to any person other than Southland District Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

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11 Third Party Reliance

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13 Closure

Should you have any questions or would like to discuss any aspect of this document please do not hesitate to contact us.

Kind Regards

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