CSRF Prioritisation Tool User Manual

- Prepared for
  Ministry for the Environment

- Original - Pattle Delamore Partners - March 2011

- Revision 1 - Ministry for the Environment - Oct 2013

Quality Control Sheet

TITLE	**CSRF Prioritisation Tool User Manual**
OWNER	Ministry for the Environment
VERSION	Final - Revision 1
DATE	31 October 2013
SOURCE FILE(S)	W01813100 R01 Final.doc
	CSRF Prioritisation Tool – User Manual – Revision 1.docx

Prepared by

SIGNATURE

Reviewed by

SIGNATURE

Directed and approved by

SIGNATURE

Table of Contents

1.0 Introduction

This manual sets out the conceptual design and instructions for use of the spreadsheet tool developed to prioritise sites for funding from the Ministry for the Environment's Contaminated Site Remediation Fund. The prioritisation is on the basis of risk to human and ecological receptors.

The spreadsheet tool was developed in a Microsoft Excel™ 2003 environment and has been tested in Excel 2007, but may work on earlier or later versions. It should run on any desktop or mobile computer capable of running Excel 2003 or 2007 with Visual Basic support installed. Macros must be enabled.

The tool relies on sufficient being known about a site to determine the likely risk to receptors for various exposure pathways. The less that is known about a site the more judgement will have to be applied by the assessor. Uncertainty is dealt with using a range of scores and Monte Carlo analysis. This manual is intended to provide as great a consistency as is possible between different assessors by giving guidance on scoring the various parameters, particular for where site information is lacking or uncertain. However, no manual can give complete guidance and the tool is intended to be operated by an assessor with considerable experience in investigating and assessing contaminated land. Knowledge of the distribution of contamination of sites typically encountered in New Zealand, and fate and transport properties of typical contaminants, is essential. Detailed knowledge of the soil, water and sediment guidelines used in New Zealand for human health and ecological receptors, and a basic knowledge of hydrogeology, is advantageous.

The original manual was prepared by Pattle Delamore Partners for the Ministry for the Environment in March 2011. Revision 1 of the manual was prepared by the Ministry for the Environment in October 2013.

The current Tool file version W01813100 CSRF Prioritisation Tool mod07.xls.

2.0 Tool Design

2.1 Conceptual design

Conceptually, the prioritisation tool is similar to the Risk Screening System (RSS)[1] in that it used the **Hazard** – **Pathway**[2] – **Receptor** equation to assess for a number of pathways or exposure routes the degree to which a pathway is likely to be complete, thus creating a risk to a receptor. Unlike the RSS, the assessment includes ecological receptors as well as human receptors. In addition, a separate value may be assigned to account for perceived cultural, social and heritage values and potential economic benefit of funding a site.

For human health four exposure routes are considered:

- Direct exposure to soil as a combination of soil ingestion and dermal absorption. Inhalation of volatile substances also needs to be considered as part of this pathway.
- Indirect exposure to soil through drinking of contaminated water, whether ground or surface water. This pathway can also be used for contact recreational exposure to water.
- Indirect exposure to contaminated soil through consumption of home-grown vegetables grown in contaminated soil.
- Indirect exposure to produce other than home-grown vegetables, e.g. eggs from home-raised chickens or eating of recreationally caught fish. This has been added because several of the sites submitted by regional councils as priority sites have eating of fish as a potential exposure mechanism.

Three exposure routes are considered for ecological receptors:

- Terrestrial receptors, whether plants or animals depending on what the situation warrants. The situation of plants and animals as simultaneous important receptors was considered to be sufficiently rare as not to require separate consideration.
- Aquatic receptors at risk through transport of soil overland (i.e. as sediment) to the aquatic environment.

[1] *Risk Screening System: Contaminated Land Management Guidelines No. 3*, Ministry for the Environment, Wellington, February 2004

[2] In this document, lower case "pathway" is used as the generic term for several routes or mechanisms by which a receptor comes is exposed to site contamination, whether directly or indirectly. It is similar to "exposure mechanism" or "exposure route". The capitalised form "Pathway" is reserved for the component of the Hazard – Pathway – Receptor equation.

- Aquatic receptors at risk through leaching of the contaminant and transport in groundwater to the aquatic environment.

All the human health and ecological exposure routes have five components; two for the Hazard, two for the Pathway and one as a measure of the vulnerability of the Receptor. The cultural, social, heritage and economic benefits are each scored separately as single values, and as a total.

In all cases, the Hazard is described in term of the toxicity of the contaminant and the amount of the contaminant, the latter being a combination of both concentration and contaminated soil volume or area that a receptor could be exposed to directly, or provide a source for indirect exposure.

In all cases the Pathway's first component is a measure of the likelihood of exposure. This is the availability of the contaminants to a receptor and in the case of indirect exposure, the likelihood of the indirect exposure occurring. Examples are; whether vegetable growing is likely, whether water is used and if so how far from the contaminant source and, for an aquatic environment, the distance to and other factors affecting the likelihood of it being contaminated by the source.

The second component of the Pathway varies depending on the particular human health or ecological pathway being considered. For most of the human health pathways it is a measure of exposure frequency and duration (and referred to as Duration for simplicity), and is generally related to land use and community behaviour.

For the ecological pathways the ecological receptors are either there or not, thus duration has little meaning (except in the case of grazing animals, which move around). For the aquatic pathway it is assumed that the aquatic organisms are constantly in contact with the contaminated water or sediment and therefore duration is not relevant. Instead dilution between the source and aquatic environment is used as a measure of the degree of exposure at the point of exposure. This is separate from the concentration at the site source, which is a measure of the hazard.

The receptor vulnerability for human health is directly linked to the age of the receptor (e.g. small child, older child, adult) and hence weight, as a measure of vulnerability. For the ecological pathways, receptor vulnerability is used as a measure of the perceived value of the ecological environment and the sorts of organisms at risk. If there is no receptor for a particular exposure pathway then the pathway would not be considered.

The pathways considered are set out schematically in Figure 1.

Figure 1 – Conceptual Design of Prioritisation Tool

			Human Health	Ecological receptors
Soil	Hazard	Toxicity	Most important contaminant for human exposure	Most important contaminant for plants or animals
		X		
		Amount	Concentration and quantity, including area.	Concentration and quantity, including area
		X		
	Pathway	Exposure	Likelihood of receptors to make contact with contaminants including volatiles. Greater depth generally means less risk	Likelihood of receptors making contact – related to depth of contamination and ability to absorb contaminant
		X		
		Duration	How often as a proportion of a year (threshold substance) or a lifetime an individual is exposed	Plant = 10 if growing in soil Animal depends on grazing behaviour
		X		
	Receptor	Receptor Vulnerability	Based on age and weight of most vulnerable receptor likely for particular land use. No receptor = 0 score	Based on perceived value of terrestrial ecosystem for particular land use
		=		
		Soil Risk		
Water Use (ground and/or surface water or contact recreation)	Hazard	Toxicity	Most important contaminant for human exposure	
		X		
		Amount	Concentration and quantity, including area at source	
		X		
	Pathway	Exposure	Likelihood of exposure - whether groundwater is used and if so likelihood of contamination at point of use – contaminant mobility, aquifer properties, distance, concentrations	
		X		
		Duration	How often as a proportion of a year (threshold substance) or a lifetime an individual is exposed	
		X		
	Receptor	Receptor Vulnerability	Based on age and weight of most vulnerable receptor for potential groundwater users. No receptor = 0	
		=		
		Groundwater Risk		
Aquatic Environment - Overland pathway	Hazard	Toxicity		Most important contaminant for aquatic ecosystem
		X		
		Amount		Concentration and quantity, including area
		X		
	Pathway	Exposure		Likelihood of transport to aquatic environment. Combination of distance, topography, erosion potential, rainfall, flood risk.
		X		
		Dilution		Big river/lake/harbour, small stream
		X		
	Receptor	Receptor Vulnerability		Based on perceived value of aquatic receiving environment within range of overland transport and downstream transport effects
		=		
		Overland Aquatic Risk		
Homegrown Vegetable Consumption	Hazard	Toxicity	Most important contaminant for human exposure	
		X		
		Amount	Concentration and likelihood of plant uptake	
		X		
	Pathway	Exposure	Likelihood of exposure. No garden = 0 Vegetable garden = 10	
		X		
		Duration	How often as a proportion of a year (threshold substance) or a lifetime an individual is exposed	
		X		
	Receptor	Receptor Vulnerability	Based on age and weight of most vulnerable receptor for potential groundwater users. No receptor = 0	
		=		
		Vegetable Risk		
Aquatic Environment - Groundwater pathway	Hazard	Toxicity		Most important contaminant for aquatic ecosystem
		X		
		Amount		Concentration and Quantity, including area
		X		
	Pathway	Exposure		Likelihood of groundwater migration to aquatic environment. Combination of depth to groundwater, mobility in soil and groundwater, aquifer and distance
		X		
		Dilution		Big river/lake/harbour = high dilution, small stream = low
		X		
	Receptor	Receptor Vulnerability		Based on perceived value of aquatic receiving environment within range of groundwater transport and downstream transport effects
		=		
		Groundwater Aquatic Risk		
Other Produce Consumption (e.g. Livestock, Eggs, Fish)	Hazard	Toxicity	Most important contaminant for human exposure	
		X		
		Amount	Concentration and likelihood of produce uptake	
		X		
	Pathway	Exposure	Likelihood of exposure	
		X		
		Duration	How often as a proportion of a year (threshold substance) or a lifetime an individual is exposed	
		X		
	Receptor	Receptor Vulnerability	Based on age and weight of most vulnerable receptor for potential groundwater users. No receptor = 0	
		=		
		Other Produce Risk		

Combined Human Health Pathways Soil + Groundwater + Residential produce + Other produce	Combined Ecological Pathways = Soil risk +Overland aquatic + Groundwater aquatic

Combined Human Health and Ecological = Average Human Health and Ecological Risk

2.2 Scoring and calculation

The risk for each pathway is calculated by multiplying together each of the five components, with each component given a score between 0 and 10. A score of 0 in any component of a pathway means the overall score of that pathway must be 0, i.e. the pathway is not complete. The detail of scoring is described in Section 4.0.

The maximum score for a particular pathway is 10^5 or 100,000. To avoid such a large number the value is divided by 1000, so that each pathway may have a score between 0 and 100.

The overall score for human health or ecological receptors is obtained by adding together relevant pathways and taking the highest value. For the human health pathways, if there is no off-site water consumption or contact recreational use affected by the site (on- or off-site water use is selectable by the assessor), the score is simply the sum of the relevant on-site exposure pathways completed by the assessor, i.e. all or some of soil contact, vegetable consumption, other produce consumption and water consumption or contact

If off-site water consumption or contact recreation exposure is complete then the score is the higher of that from the on-site pathways and off-site water use. It is assumed that on-site receptors will not also be of-site receptors, i.e. on- and off-site scores are not added.

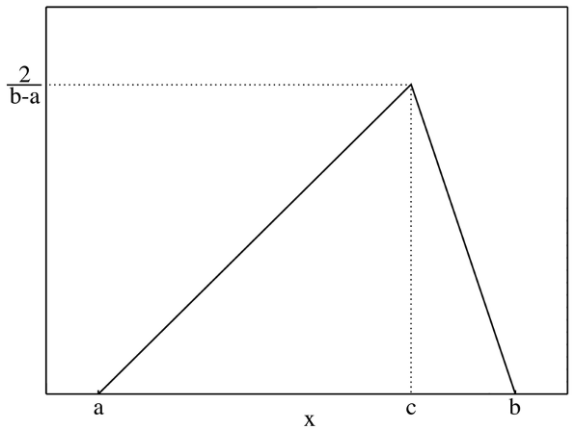
It is also assumed that on- and off-site water use will not both occur. This is not necessarily true, but if on-site water use occurs it will almost certainly result in greater contaminant exposure than off-site water use, thus scoring off-site use is pointless if on-site use exists.

For ecological pathways the score is the highest of:

- Terrestrial plants or animals.
- Aquatic overland plus aquatic groundwater pathways

The human health and ecological scores are reported separately and a combined human health and ecological score is calculated by averaging. The cultural/social/heritage score is reported separately. The cultural/social/heritage score is a value judgement, rather than a calculation of risk, and therefore cannot be combined with the human health or ecological risk values.

To deal with uncertainty of the various human health and ecological pathways, a minimum value (which may be 0) (a), a most likely value (c) and a maximum value (b) may be defined. The three values define the extremes and mode of a triangular probability density function, as shown below:



Because the tool uses a number of parameters within a defined range (0 to 10) a probability distribution with a finite range must be used. A triangular distribution fits this requirement. Triangular distributions are also commonly used for when there is little or no information on the actual probability distribution, but estimates can be made for the three values necessary to define the distribution (based on a set of scoring rules – see Section 5 – rather than physical measurements). It also has the advantage of computationally simplicity.

A Monte Carlo simulation is then used to calculate the score for each pathway. The Monte Carlo analysis method uses successive random sampling of each of the triangular probability distributions of the five components of the risk algorithm. This uses the spreadsheet's random number function. A large number of samples (thousands) results in the same number of calculated scores. These are sorted into a histogram and the mode calculated. This is the score for the particular pathway.

A measure of the uncertainty of each of the human health and ecological risk scores is also calculated using the standard deviations (SD) of the Monte Carlo simulation outputs for each pathway. The SD is a measure of the spread of the distribution and therefore a measure of the combination of the ranges of scores originally entered. A combined SD for additive items (the pathway scores) is calculated by taking the square root of the sum of the squares of the standard deviations.

However, the standard deviation will not allow a valid comparison of uncertainty of the scores between sites. To do this a normalised value such as the coefficient of variation (CV) is required. The CV is the standard deviation divided by the mean. A site with a higher CV indicates a score with a greater uncertainty than a site with a lower CV, or in other words the site

with a higher CV has, on average, a wider range of minimum and maximum scores input for each parameter than a site with a lower CV.

3.0 Spreadsheet Use

3.1 General

The spreadsheet tool has seven worksheets labelled **Site_Entry**, **Parameter_Entry**, **Site_Details**, **Data_Parameters_Sort**, **Fund_Priority_List**, **ECan_Hail** and **Lists**. The first two are where information is entered by the user and the second two are where data is stored from the first two sheets. **Data_Parameters_Sort** is also used to sort the list in order of priority. The results of sorting are reflected in the **Fund_Priority_List** sheet, which is a summary of the sites in priority order without all the scoring details. The final two worksheets store data for drop-down lists in the two data entry sheets and for other "behind the scenes" functions.

As the tool contains macros, macros must be enabled when the tool is started.

The following sections describe the use of the first four worksheets in greater detail. References to particular worksheet names, labelled cells or buttons are in **bold**.

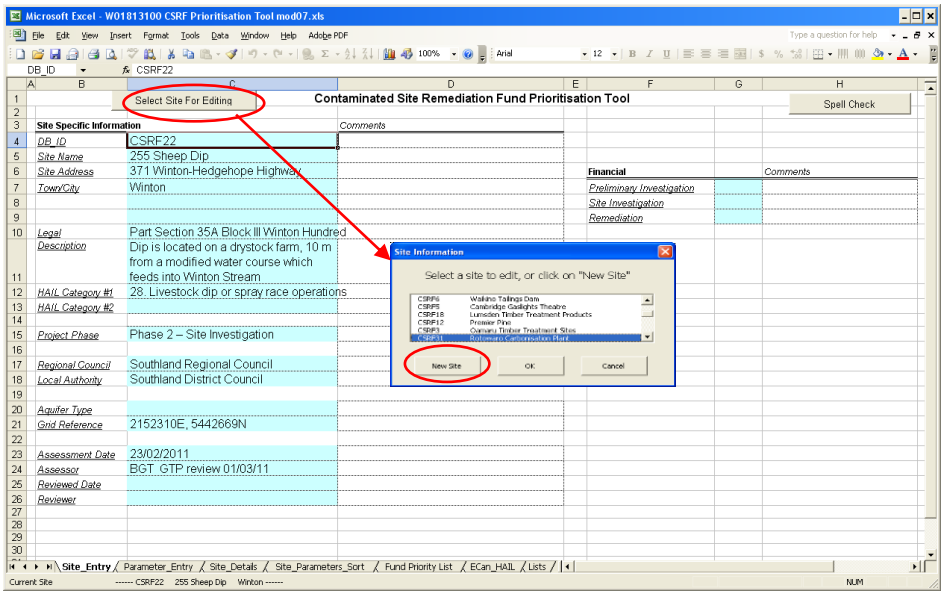
3.2 Site_Entry Worksheet

The **Site_Entry** worksheet is used to create new sites and is where general information about a site is entered. The information entered on the is page includes the following

- Site Name
- Address, grid reference and legal description of the land parcel
- Brief description of site use and HAIL category
- Project funding phase
- Regional council and territorial local authority
- Audit details including the assessor's name

The **Site_Entry** worksheet is used to:

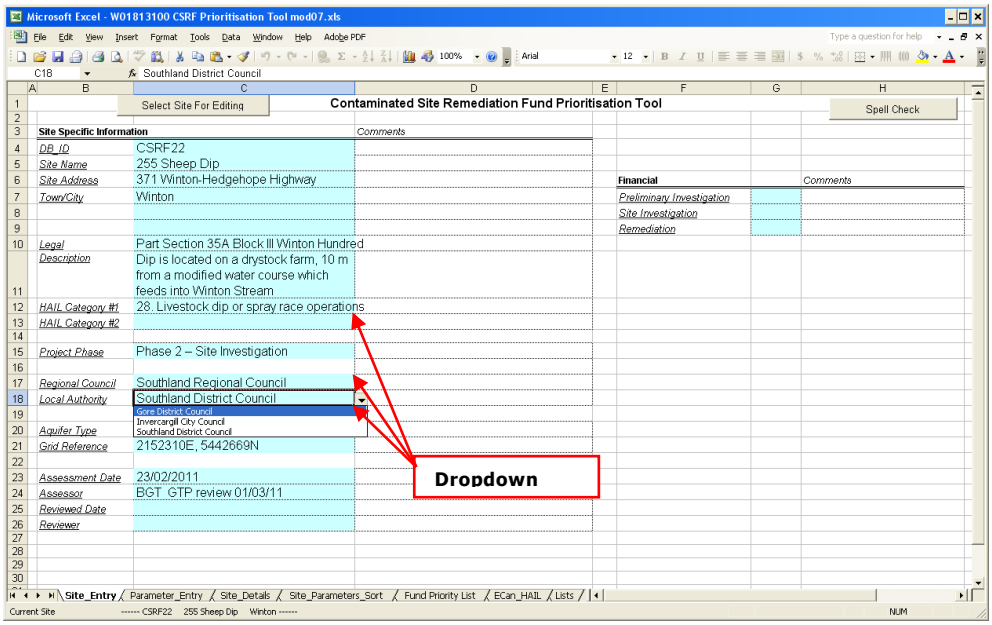
1. Create a new site by clicking on the **Select Site for Editing** button (see highlighted top left on the screenshot on the next page) and then clicking on **New Site** in the dialogue box that opens. A new sequential site number is automatically **assigned and stored (**of the form CSRFnn) when a new site is created. Data describing the site should then be entered into the labelled cells on the left side of the screen; or



2. Edit the details on a previously entered site. Click on **Select Site for Editing** button, scroll to the site of interest on the list within the dialogue box that opens and click on **OK**.

Data is stored in the **Site_Details** worksheet each time the **Enter** key is pressed or the cursor is shifted to a new cell during the entry process.

Data entry is facilitated by drop-down lists for the **HAIL Category** (two HAIL Category descriptions are available for complex sites), **Project Phase**, **Regional Council**, **Local Authority** and **Aquifer Type,** as shown below.



3.3 Parameter_Entry Worksheet

The **Parameter_Entry** worksheet is where a site is scored for prioritisation. It is similar to the conceptual design diagram in previous section. The worksheet has four human health pathways and three ecological pathways, as shown in the screenshot below.

As described in Section 2.0, each pathway has sections for **Hazard**, **Pathway** and **Receptor**, with one or two components making up each. The components are described in more detail in section 5.0 (for human health) and 6.0 (for ecological receptors).

The scoring is performed by entering a value between 0 and 10 for each relevant exposure pathway component. Each component can be scored with a minimum (**Min**), most likely (**Likely**) and maximum (**Max**) values. If an exposure pathway is not complete a zero should be entered in the **Exposure** parameter box. This will result in a zero score for that pathway.

If the **Water Use** pathway exists then the on-site or off-site button must be selected. Both cannot be selected.

Entering a value in the **Likely** box automatically puts the same value in the **Min** and **Max** boxes. The **Min** and **Max** boxes may then be overwritten with other scores, if desired. Comments should be entered into the comment boxes to justify the chosen scores. Where a pathway is deemed to be irrelevant (because it is not complete) zero (0) is entered.

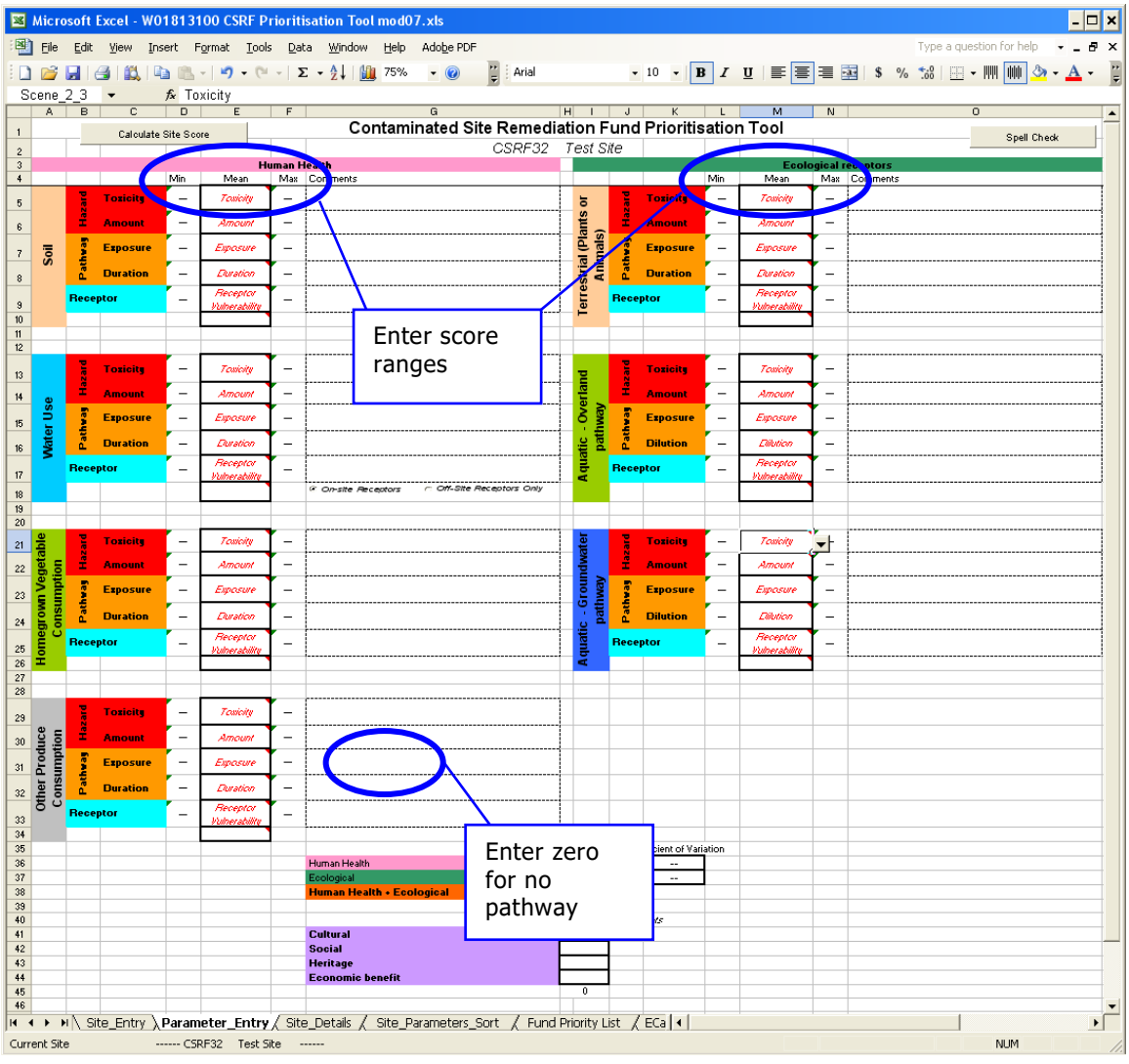
At the end of the scoring process clicking on the **Calculate Site Score** button will start the Monte Carlo analysis to produce the overall scores for human health and ecological pathways and the site overall. Repeated calculation may produce slightly different scores as the Monte Carlo calculation relies on random numbers which will be different for each recalculation.

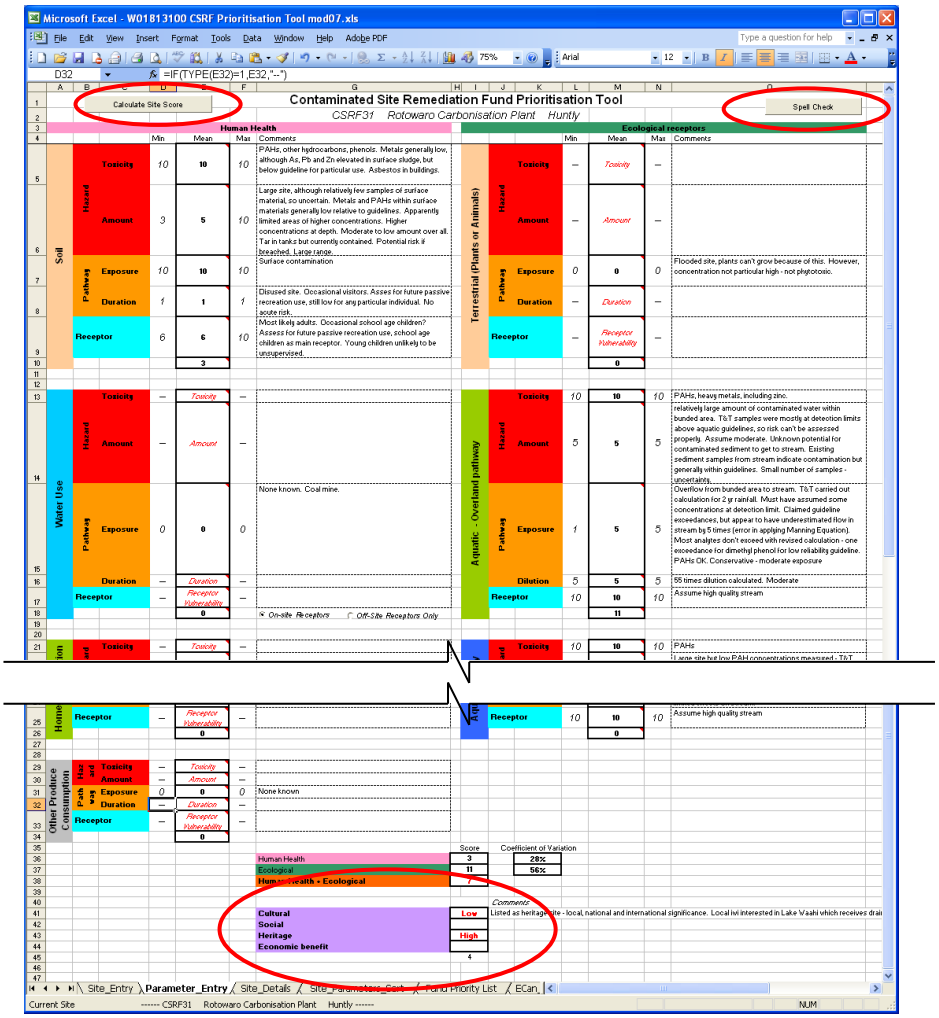
In addition to the Human Health and Ecological receptor scores, a score can be entered as a single value of either none, low, medium or high using the drop-down list in each of the **Cultural**, **Social**, **Heritage** or **Economic Benefit** boxes at the bottom of the sheet. The total **Cultural/Social/Heritage/Economic** score is a simple summation, assigning values of 0, 1, 2 and 3 to none, low, medium and high, respectively.

Part of an example **Parameter_Entry** worksheet, with scores and comments, is shown on the next page. Shown highlighted are the **Calculate Site Score** button, the **Spell Check** button, which can be used to check the spelling of all the comments, and the **Cultural**, **Social**, **Heritage** or **Economic Benefit** boxes.

In the particular example, one Human Health and two Ecological exposure pathways have been scored, although one of the ecological pathways (only partially shown) contributes nothing to the overall score. The site is a disused former industrial site and therefore the Water Use, Home-grow Vegetables and Other Produce all have zero scores as there is no complete pathway. The **Cultural** and **Heritage** boxes have been scored as the site is a listed heritage site and a nearby waterway is of some significance to local iwi.

The Coefficient of Variation values beside the total Human Health and Ecological scores are 28% and 56%, which signify low and moderate uncertainty of the respective scores (narrow range of **Min** and **Max** values). Investigation reports were available to assist the scoring. A CV of over 100% would have indicated much less certainty in the scores.

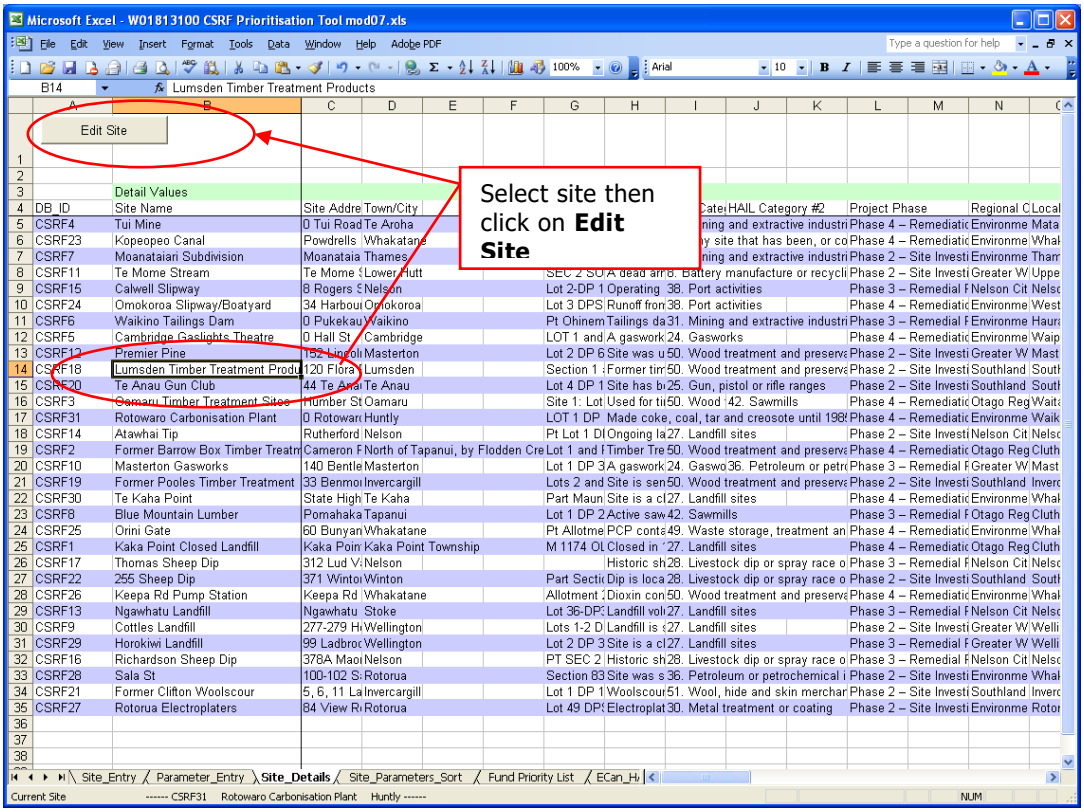




3.4 Site_Details Worksheet

The **Site_Details** worksheet is where the details from the **Site_Entry** page are stored. Part of the **Site_Details** worksheet is shown on the next page. No attempt should be made to edit the data in this worksheet (the worksheet is protected to prevent this).

The only usable part of this sheet is the **Edit Site** button. Selecting a site and then clicking on the **Edit Site** button will take the user back to the **Site_Entry** worksheet in order to edit the descriptive information for the selected site. Alternatively, the user may select the **Parameter_Entry** worksheet for editing the parameters scores for the particular site.

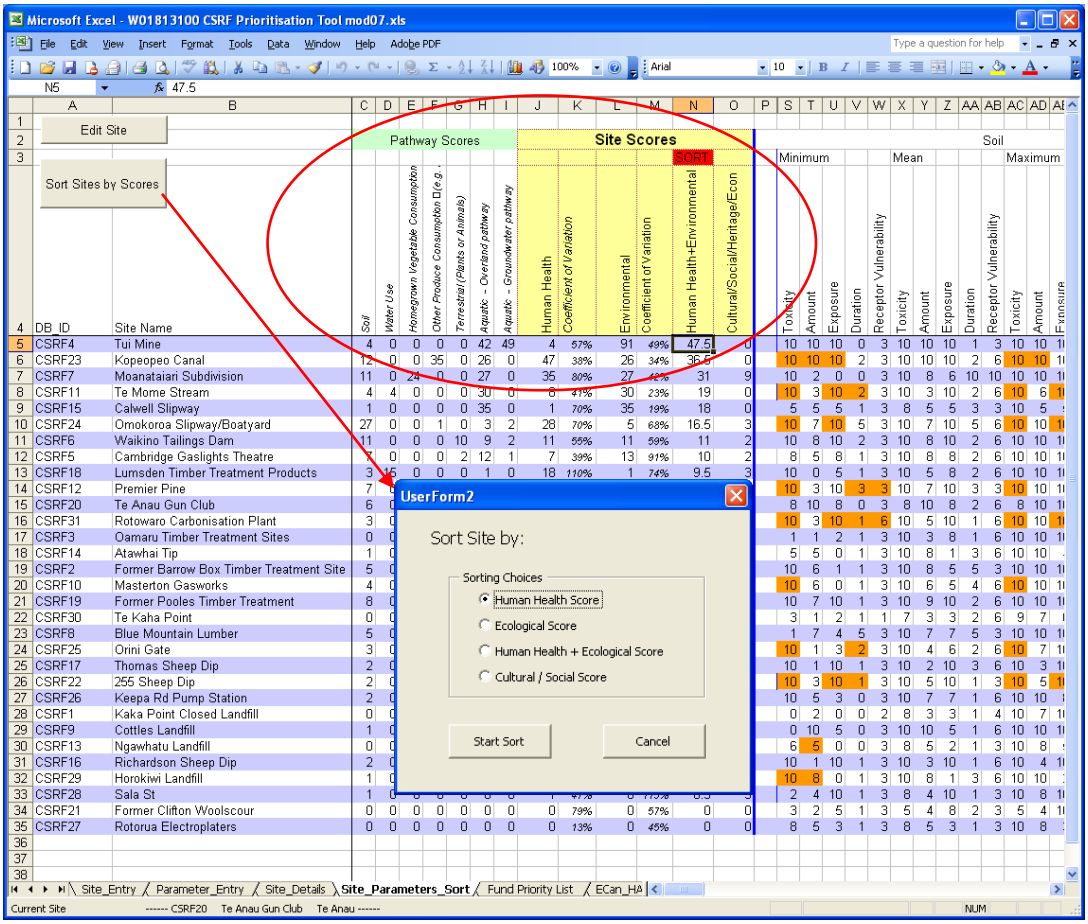


Data_Parameters_Sort Worksheet

The **Site_Parameters_Sort** worksheet stores all the details from the **Parameter_Entry** worksheet, including all the individual parameter scores for each exposure pathway, the calculated scores for each pathway and the overall scores for Human Health, Ecological receptors and Human Health and Ecological combined.

As its name suggests, there is also a sort function to sort the sites into priority order. In addition, a site may be selected for editing in a similar manner to the **Site_Details** worksheet as described in the previous section. No attempt should be made to edit the data in the **Site_Parameters_Sort** worksheet (the worksheet is protected to prevent this).

A portion of the worksheet is shown on the next page. The columns below the highlighted headings show each of the pathway scores and the overall scores for the sites as currently sorted. Clicking on the **Sort Sites by Scores** button will bring up a dialogue box that allows the sites to be sorted by one of four different ways – human health, ecological, human health and ecological combined, and cultural/social. The example below is sorted on human health and ecological combined.

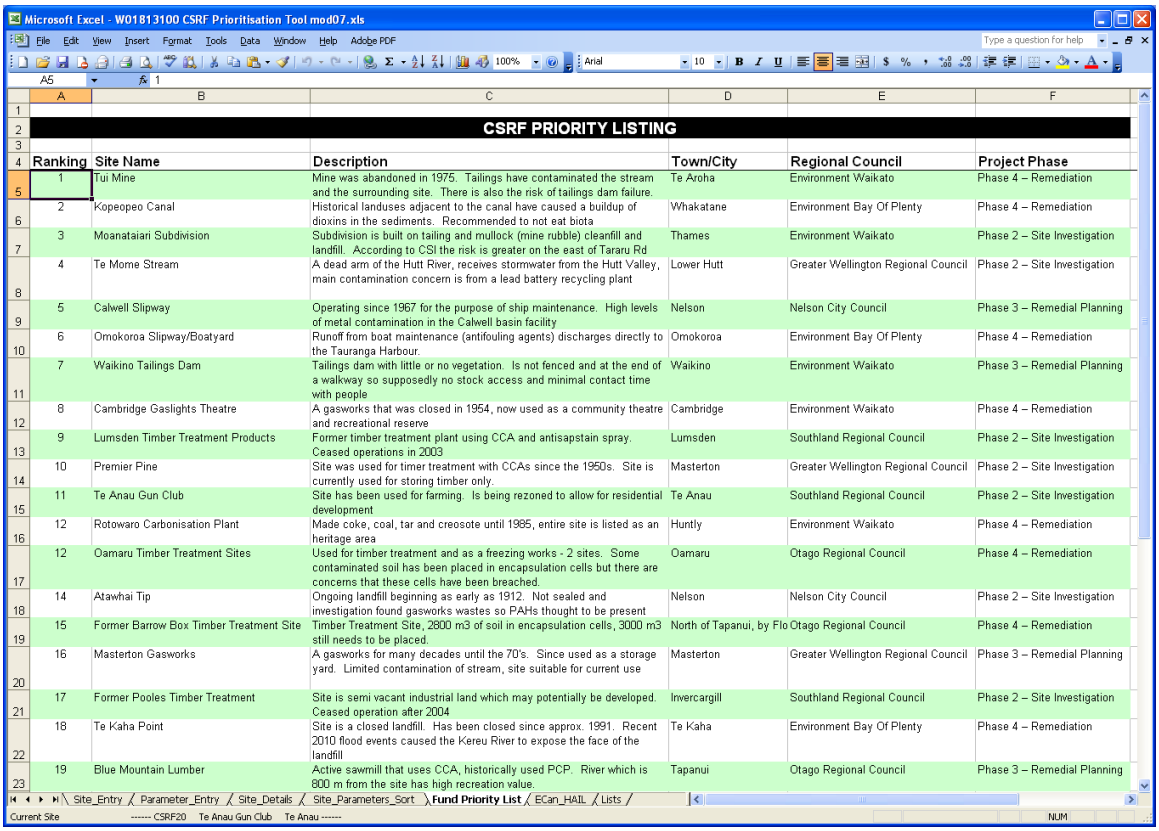


3.5 Fund Priority List Worksheet

The **Fund Priority List** worksheet is a summary list of site names, description, location and project phase in order of last sorting. Numerical scores are not shown in the list; the only numbers being the order of the site in the list (1 being top ranking, 2 being second ranking, etc).

Changing the sorting choice in the **Site_Parameters_Sort** worksheet will generally change the order of the priority list and therefore the apparent ranking of a site.

An example of the Fund Priority List, sorted in the same order as the example given above for the **Site_Parameters_Sort** worksheet, is shown on the next page.



Microsoft Excel - W01813100 CSRF Prioritisation Tool mod07.xls

CSRF PRIORITY LISTING

Ranking	Site Name	Description	Town/City	Regional Council	Project Phase
1	Tui Mine	Mine was abandoned in 1975. Tailings have contaminated the stream and the surrounding site. There is also the risk of tailings dam failure.	Te Aroha	Environment Waikato	Phase 4 – Remediation
2	Kopeopeo Canal	Historical landuses adjacent to the canal have caused a buildup of dioxins in the sediments. Recommended to not eat biota	Whakatane	Environment Bay Of Plenty	Phase 4 – Remediation
3	Moanataiari Subdivision	Subdivision is built on tailing and mullock (mine rubble) cleanfill and landfill. According to CSI the risk is greater on the east of Tararu Rd	Thames	Environment Waikato	Phase 2 – Site Investigation
4	Te Mome Stream	A dead arm of the Hutt River, receives stormwater from the Hutt Valley, main contamination concern is from a lead battery recycling plant	Lower Hutt	Greater Wellington Regional Council	Phase 2 – Site Investigation
5	Calwell Slipway	Operating since 1967 for the purpose of ship maintenance. High levels of metal contamination in the Calwell basin facility	Nelson	Nelson City Council	Phase 3 – Remedial Planning
6	Omokoroa Slipway/Boatyard	Runoff from boat maintenance (antifouling agents) discharges directly to the Tauranga Harbour.	Omokoroa	Environment Bay Of Plenty	Phase 4 – Remediation
7	Waikino Tailings Dam	Tailings dam with little or no vegetation. Is not fenced and at the end of a walkway so supposedly no stock access and minimal contact time with people	Waikino	Environment Waikato	Phase 3 – Remedial Planning
8	Cambridge Gaslights Theatre	A gasworks that was closed in 1954, now used as a community theatre and recreational reserve	Cambridge	Environment Waikato	Phase 4 – Remediation
9	Lumsden Timber Treatment Products	Former timber treatment plant using CCA and antisapstain spray. Ceased operations in 2003	Lumsden	Southland Regional Council	Phase 2 – Site Investigation
10	Premier Pine	Site was used for timer treatment with CCAs since the 1950s. Site is currently used for storing timber only.	Masterton	Greater Wellington Regional Council	Phase 2 – Site Investigation
11	Te Anau Gun Club	Site has been used for farming. Is being rezoned to allow for residential development	Te Anau	Southland Regional Council	Phase 2 – Site Investigation
12	Rotowaro Carbonisation Plant	Made coke, coal, tar and creosote until 1985, entire site is listed as an heritage area	Huntly	Environment Waikato	Phase 4 – Remediation
12	Oamaru Timber Treatment Sites	Used for timber treatment and as a freezing works - 2 sites. Some contaminated soil has been placed in encapsulation cells but there are concerns that these cells have been breached.	Oamaru	Otago Regional Council	Phase 4 – Remediation
14	Atawhai Tip	Ongoing landfill beginning as early as 1912. Not sealed and investigation found gasworks wastes so PAHs thought to be present	Nelson	Nelson City Council	Phase 2 – Site Investigation
15	Former Barrow Box Timber Treatment Site	Timber Treatment Site, 2800 m3 of soil in encapsulation cells, 3000 m3 still needs to be placed.	North of Tapanui, by Flo	Otago Regional Council	Phase 4 – Remediation
16	Masterton Gasworks	A gasworks for many decades until the 70's. Since used as a storage yard. Limited contamination of stream, site suitable for current use	Masterton	Greater Wellington Regional Council	Phase 3 – Remedial Planning
17	Former Pooles Timber Treatment	Site is semi vacant industrial land which may potentially be developed. Ceased operation after 2004	Invercargill	Southland Regional Council	Phase 2 – Site Investigation
18	Te Kaha Point	Site is a closed landfill. Has been closed since approx. 1991. Recent 2010 flood events caused the Kereu River to expose the face of the landfill	Te Kaha	Environment Bay Of Plenty	Phase 4 – Remediation
19	Blue Mountain Lumber	Active sawmill that uses CCA, historically used PCP. River which is 800 m from the site has high recreation value.	Tapanui	Otago Regional Council	Phase 3 – Remedial Planning

4.0 Assessment strategies

4.1 Human Health

It is assumed that all priority sites will have some degree of human exposure and therefore human health will need assessment in all cases. While the Pathway is not the first factor encountered using the Source – Pathway – Receptor model in the spreadsheet, a pragmatic strategy is to look at the Pathway and consider the Exposure parameters first. Determining whether particular exposure routes can be eliminated at the outset can save considerable time. A zero in the Exposure box for one or more exposure routes will mean the score for that exposure route(s) is zero and therefore no risk to the particular receptor for that route. Further parameters do not need to be considered for that route(s).

For example, an industrial site will very seldom need consideration of home-grown vegetables and unless there is a likelihood of home-raised chickens or pigs browsing on contaminated land, or a nearby fishable waterway, consumption of other contaminated produce is unlikely. Zeroes should therefore be entered into the Exposure boxes for both the vegetable and the other produce pathways.

Once the initial decision is made on which exposure pathways are complete; working through the parameters in a systematic fashion from top to bottom is recommended.

4.2 Ecological

It is not a given that ecological receptors will be present for all sites. This very much depends on site use and the proximity of a sensitive receiving environment to the site.

A pragmatic strategy to undertake when assessing Ecological risk is to firstly consider whether a receptor exists. Are there any sensitive receptors that could potentially be affected by the contaminated site? On the actual site this should be obvious, but for indirect pathways, consideration will need to be given to such things as distance from the site. For example, if there are no watercourses within influencing distance of the contaminated site, then there will be no risk to aquatic environments and a zero score should be entered into the Receptor Vulnerability box for the two aquatic pathways.

4.3 Recording Zero Decisions

In all cases of incomplete exposure pathways, a comment should be entered into the appropriate box to record why the pathway is incomplete or a receptor is absent.

5.0 Human Health Parameters

5.1 General

In the descriptions and examples that follow, the following nomenclature is used:

Min The minimum box for a particular parameter on the spreadsheet

Likely The box for the most likely score on the spreadsheet

Max The maximum boxes on the spreadsheet

1 – 5 – 10 A score of 1, 5 and 10 in the **Min**, **Likely**, and **Max** boxes respectively.

5.2 Hazard

The Hazard consists of two components, the Toxicity of the contaminants of concern and the Amount of the contaminant.

5.2.1 Toxicity

The toxicity score will be similar regardless of which human health pathway is being considered. In general, the toxicity score will be towards the high end of the 0 – 10 range as a site with low toxicity substances is not likely to be considered for the CSRF priority list. However, given a site may have a variety of contaminants, the less toxic contaminants may be given low scores in the **Min** box, with the more toxic compounds scored more highly in the **Likely** or **Max** boxes. Where there is certainty that particular contaminants are present, the most toxic may be scored in all three boxes.

Where there is uncertainty about whether a highly toxic contaminant is present (e.g. arsenic) but greater certainty that a slightly less toxic substance (e.g. lead), the lead toxicity would be scored in the **Likely** box with arsenic in the **Max** box.

The toxicity scores have been based on published values of chronic toxicity. Rough guidance may be found in the list of toxicities based on HAIL classifications within the "List" tab of the spreadsheet. Specific guidance is provided for commonly encountered contaminant below, and examples follow. In general, human health toxicity will be irrespective of the particular human health pathway being considered, that is, toxicity is not affected by mode of exposure. However, in some instances, dermal absorption for some organic compounds is a significant exposure route and the user will need to consider whether higher toxicity should be assigned to the soil pathway relative to the other three human health pathways.

The user may also need to consider whether the contaminants have the potential to bioaccumulate directly in the human body and/or in foods that are grown or gathered on the site.

Some soil guideline values (SGV) and Soil Contaminant Standards include the potential for contaminants to be present in food and/or produce from contaminated land. When undertaking the assessment of a contaminated site, the user should be aware of particular exposure routes considered during the development of the SGV/SCSs.

It is anticipated that the potential for bioaccumulation of contaminants will most frequently need to be considered when assessing the Homegrown Vegetable Consumption and the Other Produce Consumption exposure pathways. Where bioaccumulation of contaminants has not already been accounted for and is considered to pose a risk, the toxicity scores may be increased.

Contaminant	Score
Arsenic, benzene, benzo(a)pyrene, dieldrin/aldrin, dioxins, benzene, polychlorinated biphenyls	10
DDT, cadmium, tributyl tin	9
Chromium VI, Lead, mercury (inorganic)	8
Lindane	6
Cresol (methyl phenol), naphthalene, nickel, potassium cyanide, toluene	4
Heavy end petroleum distillates (lube oil)	2
Boron, copper, chromium III, ferro- and ferri-cyanide complexes (spent oxide),phenol, zinc,	1

Examples:

(a) Lead and zinc at significant concentrations are known to be on the site: Toxicity Score **1 – 8 – 8**. The **Likely** and **Max** values are

given the same score as a greater toxicity substance is not expected on the site.

(b) If, in the above example, there is also suspicion that arsenic may be present, the score would be: **1 – 8 – 10**

(c) A timber treatment site has confirmed copper, chromium and arsenic contamination, with the possibility of PCP contamination. Scored **1 – 10 – 10**, but for simplicity it makes very little difference if just the most significant contaminant was scored, i.e. **10 – 10 – 10**. The additional possible presence of PCP would not change the score.

5.2.2 Amount

The other component of the Hazard is the amount of contaminated media that could be contacted by a receptor or creates the source for remote exposure. A large amount of a particular contaminant is clearly a greater hazard than a small amount. Amount combines the concepts of contaminant concentration and quantity of soil (or groundwater) affected. User judgement is required in determining appropriate scores.

The starting point is considering the size of the site and the quantity (area/volume) within the site that could be contaminated. Knowledge of the pattern of contamination expected on different types of site will assist the user. The areas of contamination should be considered rather than the overall site size. For example, a large sawmill and timber treatment site is likely to have concentrated hotspots near the treatment plant and perhaps sawmill, more diffuse contamination in treated timber storage areas but perhaps little contamination elsewhere.

Once the area (or combination of areas) has been decided on, the likely degree of contamination has to be decided, modifying as appropriate the initial area judgements. This has to be either knowledge of the typical concentrations on various site types or, preferably, actual concentrations from investigation of the site. Where investigation information exists on contamination pattern and concentrations, greater certainty will result in a narrower range of scores. However, where no or only limited sampling has been carried out the uncertainty will mean a larger range in the scores. For industrial sites, knowledge of whether housekeeping practices were poor or good will assist in deciding the extent and degree of contamination.

Examples follow for pathways other than water use follow. Water use is discussed further below:

Site type	Typical Amount scores with explanation – Soil and Vegetable	
	No samples	Samples taken
CCA timber treatment site – large, more than five hectares, much unsealed ground, drip pad known to have been uncovered in past.	**5 – 9 – 10** Large site, could be high concentrations, but probably limited areas. Uncertain	**6 – 8 – 8** Large site but sampling shows soil concentrations are not extreme (100s but not 1000s ppm) so reduce Likely and Max score, reduced uncertainty increase Min score.
Large, old, closed municipal landfill – several hectares	**6 – 8 – 10** Large site therefore start high, however landfill typically limited concentrations in general, reducing score. Old landfill therefore lower risk of VOCs. Some uncertainty	**8 – 8 – 10** As per left but samples confirm concentrations, reducing Min uncertainty. Still allow high Max for inevitable unknown past dumping.
Small to moderate size landfill, 2 – 5 hectares	**4 – 6 – 8** As above, but smaller size.	**6 – 6 – 8** As above, but smaller size.
Former small-town gasworks – 3 hectares	**4 – 10 – 10** Moderate to large site but likely highly variable concentrations, with possibility of waste having been dumped anywhere on site. Uncertain	**6 – 10 – 10** Sampling confirmed widespread contamination in excess of guidelines values. Uncertainty reduced.
Sheep dip, old style disused 30+ years. Area of actual dip and surrounds - tens of square metres. Holding pen at dip exit a few hundred square metres.	**1 – 3 – 5** Small area of unknown but possibly high concentrations. Small size plus high concentration gives moderate Max of 5. Range because of uncertainty.	**1 – 3 – 4** A few samples at most likely places confirmed moderate concentrations of dieldrin (10s ppm) and arsenic low 100s ppm). Overall low with greater certainty.

Water Use

A variety of possible scenarios for determining the amount or quantity for the indirect water use pathway exist, as the water use or contact may be either

on the site and remote from the site. The most straightforward scenarios are where contact or use is on or immediately adjacent to the site and water concentrations have been measured. Considerably less straightforward are situations where little is known about site concentrations, whether in soil or water, and the potential point of contact is remote from the site.

The Amount parameter is not intended to deal with attenuation that is likely to occur between the site and some remote point of contact. The Exposure parameter of the Pathway (see Section 5.3.1) should be used for this.

The following sequence demonstrates the scoring process as the amount of information reduces:

(a) Water concentrations measured at the point of use/contact (which may be on site) exceed appropriate guidelines (drinking-water standards or contact recreation as the case may be). Default score **10 – 10 – 10**. Score for the Exposure parameter of the Pathway (see Section 5.3.1) would also be **10 – 10 – 10**.

(b) As above, but multiple monitoring rounds show guidelines are not always exceeded and/or in the case of recreational waters, are only exceeded within a proportion of the likely contact area: reduce **Likely** and **Min** scores in proportion. The **Max** score may or may not reduce depending on the confidence of the monitoring; more monitoring points (in the case of recreational water) and many rounds giving greater confidence than fewer samples. A precautionary approach should be adopted, erring on the side of higher scores.

(c) Water concentrations measured at the point of use/contact are always some fraction of the relevant guideline. Score **0 – 0 – 0** if concentration <50% of the relevant guideline, otherwise between 0 and 10 in proportion. For example, concentrations are consistently 70% of the drinking-water guideline, i.e. 20% over the 50% cutoff. Score 20% of 10: **4 – 4 – 4** as the starting point, with further reductions for **Likely** and **Min** if concentrations are not consistent over time as in (b) above.

(d) Water concentrations have not been measured at the point of use/contact but have been measured in either groundwater or surface water on site (preferably at the site boundary) in excess of relevant guidelines, and the site is not a point of contact/use. Score up to a maximum of **10 – 10 – 10**, but reduce values in proportion to the site coverage of the plume in the case of groundwater, and/or if concentrations do not consistently exceed guidelines over repeated monitoring as in (b). Note: remoteness of the site relative to the point of use/contact is dealt with using the Exposure parameter.

(e) As in (d) but concentrations are some fractions of relevant guidelines. Score **0 – 0 – 0** if concentration <50% of relevant guideline. Otherwise reduce score in proportion, as per (c) above.

(f) Water concentrations have not been measured but soil concentrations are known. A judgement has to be arrived at as to whether groundwater exceedances as in (d) or (e) above are possible, based on knowledge of soil concentrations, contaminant properties, relationship of contamination to the watertable, likely infiltration and local soil properties. There would necessarily be a large degree of uncertainty, and therefore potentially a large range between **Min** and **Max**. High **Likely** and **Max** scores will only occur for situations where several of the following occur; high concentrations, large areas of contamination, high mobility contaminant, close proximity of the contamination to the watertable.

(g) As in (f) above but soil concentrations have also not been measured. A judgement has to be made about likely contaminant concentrations and distribution based on site type. A large degree of uncertainty will exist.

Some examples follow:

Site type	Typical Amount scores with explanation – Water Use Pathway	
	No samples	Samples taken
CCA timber treatment site – large, more than five hectares, much unsealed ground, drip pad known to have been uncovered in past. Groundwater at 1 – 2m, silty gravel soil.	Large site, could be high soil concentrations, but probably limited areas. Groundwater shallow in places. Silt will tend to absorb CCA but probably inconsistent. Err on high side, but large range. **0 – 8 – 10**	Arsenic in well in adjacent property consistently exceeds drinking-water standard. **10 – 10 – 10**
Corner service station in urban area, old style with steel tanks. Suspected leaks. Groundwater at 2 – 3 m. Gravels	Small site. Unknown but possibly large volume of petroleum product has leaked – a few hundred up to thousands of litres. Tanks in contact with groundwater. Probable dissolved plume. Unknown free product plume. Err on	Four wells installed on downgradient boundary. Benzene non-detect in one, in excess of drinking-water standard in central well and 50 – 60 % of drinking-water standard in other two. No free product measured, but suspected in tank pit,

	high side, large range because of uncertainty **3 – 8 – 10**	therefore on-going source. Max must be 10, but most likely and min taken as average of measured concentrations (average of 0, 0, 2 ,10). **3 – 3 – 10**
Large, old, closed municipal landfill – several hectares. Leachate known to be discharging to stream. Children swim in pool immediately downstream of discharge	Direct discharge, therefore start at 10. Waste is mature, therefore contaminant concentrations in leachate probably low to moderate, but unknown – score 1 – 5 – 10. Estimated leachate discharge makes up less than 25% of stream, reduce score accordingly, but could still exceed guidelines - uncertain. **0 – 2 – 10**	Wide range of analytes shows concentrations generally well below contact recreation guidelines. Occasional excursion up to 60% of guideline. **0 – 0 – 2** Note: Exposure parameter set at 10 – 10 – 10 as exposure pathway complete.

5.3 Pathway

The Pathway consists of two components, the likelihood of the exposure occurring, e.g. contact being made, and the duration and frequency of that exposure. As the mode of exposure is different for soil exposure, groundwater exposure and produce exposure, the same scores will generally not be appropriate for the various human health pathways.

As noted is Section 5.1, whether the pathway is complete should be considered at the outset to avoid unnecessary decisions on other parameters if the pathway is, in fact, not complete.

5.3.1 Exposure Parameter

The Exposure parameter is a measure of the likelihood of receptor making contact with, or consuming, the media containing the contaminant, whether soil, water or produce. In the case of off-site water use, the Exposure parameter must include how likely it is for the contaminant to travel to the site of water use.

Scoring of the Exposure parameter will depend on site use; vegetable and produce exposure are highly unlikely for some site uses.

Soil pathway

For the soil pathway the Exposure parameter is a direct measure of how likely it is that the receptor will come into contact with the soil that contains the contaminant, in the case of non- and semi-volatile substances, while for volatile substances it is also how likely vapours will travel through the ground to a point of exposure. For volatiles, consideration of accumulating at sufficient concentrations to be a risk at the point of exposure (typically an enclosed space) has also to be considered.

The following scores are typical:

Exposure Situation	Typical Exposure Scores – Soil Pathway	
	Non- & Semi-volatile	Volatile
Contaminant in bare surface soil defined as 0 – 150 mm.	**10 – 10 – 10**	
Contaminant in surface soil with grass cover or other vegetation that reduces likelihood of contact (e.g. scrub, particularly plants such as blackberry. Reduce score up to 3 units depending on perception of thickness of cover, then increase **Likely** and **Max** if cover is patchy.	**6 – 7 – 8** to **7 – 9 – 9** Depending on perception of thickness of cover and barrier it provides. If cover is sparse or particularly patchy score **Max** as **10**	**6 – 7 – 8** to **7 – 9 – 9** Similar to non-volatiles but if possibility of vapours collecting increase **Likely** and **Max** scores.
Contaminant below the surface 150 – 300 mm, less likely to be routinely contacted. Some uncertainty. Vegetation will increase barrier. For volatiles, need to consider whether enclosed space provides opportunity for vapour collection and distance of enclosed space from contamination > 30m vapour unlikely.	**3 – 5 – 5** to **5 – 6 – 7** Lower range covers soil & vegetation cover. Higher range for less certain situation, less vegetation or patchy cover	**3 – 5 – 5** to **7 – 9 – 9** Same as non-volatile if no possibility of vapours collecting in enclosed space. Otherwise same as above as small soil thickness an insignificant barrier. Reduce scores as source distance increases.
Contaminant below the surface 300 – 500 mm. Vegetation cover increases barrier. For volatiles, need to consider whether enclosed space provides opportunity for vapour collection and distance of enclosed space from contamination > 30m vapour unlikely.	**1 – 2 – 3** to **3 – 5 – 5**	**1 – 2 – 3** to **7 – 9 – 9** Same as non-volatile if no possibility of vapours collecting in enclosed space. Otherwise same as above as small soil thickness an insignificant barrier. Reduce as source distance increases.
Contaminant below the surface >500 mm	**0 – 0 – 0** to **1 – 2 – 2** Depending on depth and other barriers	**0 – 0 – 0** to **7 – 8 – 8** As above but decreasing likelihood of volatile pathway as depth increases.
Hydrocarbon contaminant on watertable at 2 m	**0 – 0 – 0**	**3 – 5 – 5** to **0 – 1 – 1** Sand to clay soil
Contaminant below concrete or other surface seal. Increased depth of source will reduce likelihood of contact.	**0 – 0 – 0** to **0 – 1 – 2** Higher scores for poor condition seal	**0 – 0 – 2** to **1 – 2 – 3** Need to consider condition of barrier, if known. If not known choose higher scores if volatile collection possible.

Homegrown vegetable pathway

The Pathway parameter for the homegrown vegetable pathway is a combination of land use, contaminant depth and whether the particular contaminant(s) is taken up into plants and potentially biomagnified contributing to the likelihood of the pathway.

Scoring should start with the land use. Home-grown vegetables are most likely in a residential situation, with rural residential having a higher likelihood of home gardens than standard residential, but the highest score is reserved for those who have adopted a self-sufficiency lifestyle. Central city or other high density residential will have a low likelihood of vegetable gardens, depending on whether land exists for gardens. Farmland remote from a house will also score zero or a low score (1s or 2s).

Generally, industrial and commercial will score zero. Educational facilities will also generally score zero but on rare occasions may score highly if vegetable gardens exist as teaching aids. Given this may not be known, a large **Min** to **Max** range may be appropriate.

Typical scores for **Likely** and **Max** will be:

- Self-sufficient lifestyle 9 – 10
- Rural residential 6 – 6
- Urban residential 3 – 3
- Rural land remote from house 0 – 1
- High density residential 0 – 1
- Industrial/commercial 0 – 0

The depth of contaminant should be considered next. If the contaminant is not within the top 300 mm, then the likelihood of contaminant uptake into the vegetable is considerably reduced. The starting point should be no higher than 5. If the contaminant is not within the top 500 mm, the score will be zero, i.e. no pathway. The land use and depth considerations should be mentally combined at this point before continuing.

For example, a few samples show a standard residential site generally does not have contamination within the top 300 mm but does have some contamination within the top 500 mm. The small number of samples creates uncertainty about whether there is more shallow contamination. Start at a score of 3 for residential, but allow a range to cover a range of possible vegetable growing behaviour, i.e. **1 – 3 – 6**. Reduce for the majority of contamination being below 300 but less than 500, but because of the uncertainty of depth and vegetable growing behaviour, reduce by only one unit and leave **Max** as existing value, i.e. **0 – 2 – 6**.

Finally, the potential for contaminant uptake should be considered in reducing the score and/or broadening the **Min** to **Max** range. The table below gives a broad uptake ranking for some common contaminants. The score should not be adjusted for a high uptake ranking but the score should be reduced by one or two units for moderate or low uptake, respectively.

Contaminant	Uptake
Cadmium (low pH), boron, dieldrin	High
Copper – variable, can be high but kills plant at moderate to high soil concentrations so crop cannot be harvested	
BaP, DDT, lindane, petroleum hydrocarbons	Moderate to high
Lead, mercury (inorganic), chromium VI	Moderate
Arsenic	Moderate to low
Dioxins, PCBs (except cucurbits)	Very low
PCP - taken up but metabolised, therefore zero	

For the previous example:

If the contaminant was cadmium, the score is not adjusted because cadmium has a high uptake potential (for acidic soils) **0 – 2 – 6**.

If the contaminant was lead the score becomes **0 – 1 – 5**.

If the contaminant was PCB the score becomes **0 – 0 – 3**.

Water Use Pathway

Consideration of the Exposure pathway for water use should start with whether water is used or contacted either on or off site. If shallow groundwater is used on the site for drinking-water, or there is a stream on site used as a potable water supply or for recreation, then the Exposure score should be **10 – 10 – 10**. The on-site concentrations of the water being used or contacted are dealt with in the Amount parameter of the Hazard - see Section 5.2.2.

For water use or contact off site, the Exposure score reflects a combination of the various things that will cause a barrier to transport and/or attenuation/dilution between the site and the point of use/contact. For groundwater this will included the direction of flow, the distance to the point of exposure, the mobility of the contaminant and the aquifer properties. For

surface water, this will reflect dilution or attenuation between the site and point of use or contact.

The following scores should be used as starting points for distance, before considering contaminant mobility properties:

Well location from source	Gravel aquifer	Silty or clayey aquifer
< 30 m	10	10
100 m	10	5
200 m	5	3
300 m	3	0
500 m	0	0

Then to allow for the variable mobility of contaminants, for every 100 m greater than 100 m from the site, subtract:

Contaminant	Gravel aquifer	Silty or clayey aquifer
High mobility, e.g. boron, ammonia	0	0
Moderate mobility, e.g. BTEX	0	1
Limited mobility, e.g. SVOCs such as PAHs, DDT, and dieldrin. Metals such as lead, arsenic and copper	1	2
Low mobility such as PCBs and dioxins	5	5

For surface water exposure, a judgement must be made as to the amount of dilution between the site and point of contact. If the waterbody of concern is a larger river or the sea, then the amount of dilution relative to the stream passing through or close by the site must be estimated. In general, discharges from a stream to a large water body will be insignificant in the larger water body, and scores of 0 to 2 would be expected.

If the waterbody of concern is a stream that passes through or adjacent to a site, then it is necessary to consider the drainage pattern and determine to what degree tributaries will dilute the flow between the site and point of potential contact or use. For every tributary of similar size the score should be reduced in proportion, i.e. one tributary score 5 for **Likely**, two tributaries score 3, etc, with uncertainty in the amount of dilution (size of tributaries) allowed for in the **Min** and **Max** scores.

If the contaminant is volatile, subtract 3 units for every 200 m of travel distance from the site.

For surface water bodies at risk from groundwater discharges, apply the reduction factors as set out above with an additional factor to allow for dilution within the waterbody. In general, even small streams will be receiving only a small proportion of their flow from groundwater flowing under a site. Except in the case of a landfill which fills the head of a gully, and is therefore may be the source of a stream, dilution factors of at least 10 and often several orders of magnitude can be assumed, depending on the size of the waterbody.

Other Produce Pathway

Whether other produce pathways exist will need to be considered on a case-by-case basis using site-specific evidence. In general this pathway will not be considered without good evidence that the pathway is complete for contaminants that accumulate sufficiently in produce, particularly accumulation up through the food chain. Examples of contaminants that may accumulate include chlorinated organic compounds and methyl mercury.

Situations where other produce consumption could be considered are:

- Known or a strong possibility of fish contamination with fish known to be caught for regular consumption as a food source close to a sawmill site that used PCP, the issue being dioxin. Occasional consumption through recreational fishing would not be sufficient.
- Known or strong possibility of keeping of hens for eggs on a former sawmill site known or suspected to have used PCP.

5.3.2 Duration Parameter

The Duration parameter combines the concepts of exposure frequency, i.e. proportion of the time exposed, and the duration of exposure. Duration of exposure (proportion of years in a lifetime) is relevant only for non-threshold substances.

The duration is directly related to the type of land use at the point of exposure. Residential use will have the highest score (default of 10) and unoccupied land with no or difficult access will have a zero score (no pathway). Other land uses fall between, depending on the number of days per year relative to residential that contact may occur. For a block of land with a variety of uses, the **Likely** score should be the predominant use and **Max** should be the most sensitive use. Where the most sensitive use (e.g. residential is also the predominant use then **Likely** and **Max** will be the same.

Default scores: Residential **10 – 10 – 10**

Industrial	**6 – 6 – 6**
Active Recreation	**3 – 3 – 3**
Passive recreation	**1 – 1 – 1**

Duration for the Water Use pathway is scored at the point of exposure. If water is taken for human consumption on residential or industrial premises, then the scores above should be used, i.e. **10 – 10 – 10** and **6 – 6 – 6**, respectively.

For the contact recreation scenario, an estimate of the frequency of recreational contact relative to residential use will have to be. In general, recreational contact will be only a fraction of residential exposure. For example, swimming once a week for few hours would be less than a seventh of the drinking-water exposure assumed for a residential site. A typical contact recreational score would therefore be no greater than **1 – 1 – 1.** Swimming several times a week might go as high as **3 – 3 – 3**.

5.4 Receptor Vulnerability

The human health receptor vulnerability score is based on age-related likelihood that the allowable dose of the contaminant will be exceeded. This is based on the weight of the particular receptor and the amount of contaminated soil, groundwater or produce likely to be exposed to. For simplicity, three scores are used:

Small child (i.e. toddler) – 10

School age child – 6

Adult – 3

For a residential situation the default is 10, i.e. **10 – 10 – 10**.

For an industrial situation the default would normally be **3 – 3 – 3**, but consideration should be given to whether older children might play on the site at times, resulting in **3 – 3 – 6**.

Other situations will have to be judged on a case-by-case basis. Many situations that are neither residential nor industrial will probably have the older child as the **Likely** vulnerable receptor (score 6) on the basis that older children could be exposed during unsupervised play activities. A decision will then have to be made whether the **Max** value for that situation should be scored as a small child/toddler. In most non-residential situations a small child would be supervised and therefore unlikely to be significantly exposed.

An example is a disused closed landfill. The most likely visitors are adults and school-age children. The score would be **3 – 6 – 6**. However, if the

landfill has been converted to an urban playing field, the score would be **6 – 10 – 10**. Whether actual exposure occurs will be scored on the Pathway parameter.

6.0 Ecological Receptor Parameters

6.1 Hazard

6.1.1 Toxicity

The toxicity score will vary depending on whether terrestrial or aquatic receptors are being considered.

Terrestrial

For terrestrial animals, assume toxicity is similar to that of human toxicity – see 5.2.1.

For plants, there is a wide range of phytotoxicity for particular contaminants, given that toxicity will depend on the tolerance of particular plant species and uptake will vary depending on soil type. In general, effects on human health will be of greater significance than plant health for most contaminants, and therefore plants as a receptor will seldom need to be assessed. However, there are some common contaminants which have high plant toxicity relative to human toxicity which should be considered in situations where plant health may be of importance, e.g. some residential situations and land of high ecological value such as bush reserves or parks. Industrial land will rarely require assessment for plant toxicity.

Common contaminants that may be phytotoxic, particularly for sandy soils, for soil concentrations in the range of several hundred to low thousands of ppm are copper, boron, chromium and zinc. It is not possible to be definitive about such metals, given their variable effects on different plant types, but the following range of scores is suggested as **Likely** scores, with a range either side for uncertainty of soil type and plant sensitivity:

Copper, boron: 5 – 8

Zinc, chromium: 3 – 6

Aquatic

The toxicity scores for the aquatic pathways are based on published guideline values, e.g. the ANZECC 2000 Australian and New Zealand Guidelines for Fresh and Marine Water Quality. When undertaking an assessment of aquatic environments the ability of a contaminant to bioaccumulate within an organism and/or to biomagnifiy up through the food chain should be considered when scoring toxicity.

Some soil guideline values (SGV) and Soil Contaminant Standards include the potential for contaminants to bioaccumulate. When undertaking the assessment of a contaminated site, the user should be aware of particular exposure routes considered during the development of the SGV/SCSs. Where

bioaccumulation of contaminants has not already been accounted for and is considered to pose a risk to receptors, the toxicity score may be increased.

Contaminant	Score
Cadmium, chromium VI, mercury, tributyl tin, dioxins, OC and OP pesticides,	10
Arsenic, chlorine, heavier PAHs e.g. benzo(a)pyrene, dioxin-like PCBs	9
Copper, lead, non-dioxin like PCBs,	8
Cyanide, zinc, lighter PAHs (e.g. naphthalene), higher chlorinated phenols (e.g. PCP)	6
Boron, phenol, chlorobenzenes	5
Ammonia, lower chlorinated phenols, mono-aromatic hydrocarbons (BTEX)	4
Aliphatic hydrocarbons, phthalates	2
Heavy end petroleum distillates (lube oil)	1

The most toxic known contaminant should be scored as **Likely**. If there is an unconfirmed possibility of a more toxic chemical then this should be scored as **Max**, otherwise **Likely** and **Max** will take the same score. Other less toxic contaminants should be scored as **Min**.

Examples:

(a) A CCA plant has contaminated an adjacent stream: Score **8 – 9 – 9**. The **Likely** and **Max** values are given the same score as a greater toxicity substance is not expected on the site.

(b) PCP is also suspected on the site, with sediments suspected to be contaminated with dioxins: Score **8 – 9 – 10**.

6.1.2 Amount

Terrestrial pathway

The Amount/Quantity for terrestrial pathway is the same as that for the human health soil pathway – see 5.2.2.

Aquatic pathways

The most straightforward scoring for the two aquatic pathways is when samples of either sediment or surface water have been taken.

Otherwise, a judgement has to be made as to the likelihood of the contaminants being transported from the site to the point of contact. This will be simpler if the surface water is close to the site and at least soil concentrations and hopefully groundwater concentrations have been measured. Otherwise judgements will need to be made based on site size, likely concentrations, distance of the water body from the site, and the like. Score uncertainty will be much greater for the latter situations.

The Amount parameter is not intended to deal with attenuation that is likely to occur between the site and some remote point of contact. The Exposure parameter of the Pathway (see Section 6.1.3.1) should be used for this.

The following sequence demonstrates the scoring process as the amount of information for the waterbody reduces:

(a) Sediment or water concentrations measured within the waterbody exceed relevant guidelines (e.g. ANZECC 2000 aquatic ecosystem guidelines). Default score **10 – 10 – 10** in either or both of the Aquatic Overland and Aquatic Groundwater pathway, as the case may be. Also score **10 – 10 – 10** for the Exposure parameter as the pathway is complete.

(b) As above, but multiple monitoring rounds show guidelines are not always exceeded or, in the case of sediment, the exceedances are patchy over the area of interest: reduce **Likely** and **Min** scores in proportion. The **Max** score may or may not reduce depending on the confidence of the monitoring; more monitoring points and many rounds giving greater confidence than fewer samples. A precautionary approach should be adopted, erring on the side of higher scores.

(c) Sediment or water concentrations measured within the water body are always some fraction of the relevant guideline. Score **0 – 0 – 0** if concentration <50% of the relevant guideline, otherwise between 0 and 10 in proportion. For example, concentrations are consistently 70% of the relevant aquatic guideline, i.e. 20% over the 50% cutoff. Score 20% of 10: **4 – 4 – 4** as the starting point, with further reductions for **Likely** and **Min** if concentrations are not consistent over time as in (b) above. Score the Exposure parameter as **10 – 10 – 10**.

(d) Sediment or water concentrations have not been measured within the water body but soil and/or groundwater concentrations have

been measured (preferably at the site boundary nearest to the water body) in excess of relevant aquatic guidelines. Score up to a maximum of **10 – 10 – 10**, but reduce values in proportion to the site coverage of the plume in the case of groundwater, and/or if concentrations do not consistently exceed guidelines over repeated monitoring as in (b). In the case of soil concentrations, reduce the score in proportion to the size of the site and the likelihood of soil being transported as sediment over the site boundary in the direction of the water body. This will include considerations of site topography (slope) and site surface covering. Note: the remoteness of the site relative to the waterbody, and the attenuation that may occur between the site and the waterbody is dealt with using the Exposure parameter. The Amount is a measure of potential at the site.

(e) As in (d) but concentrations are some fractions of relevant guidelines. Score **0 – 0 – 0** if concentration <50% of relevant guideline. Otherwise reduce score in proportion, as per (c) above.

Example scores are:

Site type	Typical scores for Amount with on-site samples – Aquatic pathways	
	Overland	Groundwater
CCA timber treatment site – large, more than five hectares, much unsealed ground, drip pad known to have been uncovered in past. Groundwater at 1 – 2m, silty gravel soil.	Large site, with arsenic at concentrations in excess of sediment guidelines at the surface along length of site boundary closest to waterbody. **10 – 10 – 10** Same as above but site has variable grass cover. Reduce potential for erosion, but keep high **Max** score. **8 – 8 – 10** As above but contamination is 50 m from nearest boundary with flat slopes. Reduce score to reflect much less potential for sediment to leave site – large range for uncertainty.	Arsenic measured in three wells along downgradient boundary in excess of aquatic guidelines. **10 – 10 – 10** As above, but only a single well. Soil concentrations generally high over the site, therefore assume groundwater contaminated over wide area, but allow for uncertainty. **5 – 10 – 10** Several wells in excess of aquatic guidelines close to treatment plant which is 75 m from downgradient boundary. Will get significant attenuation by time groundwater travels to site boundary. Silt in

Site type	Typical scores for Amount with on-site samples – Aquatic pathways	
	Overland	Groundwater
	2 – 5 – 8	aquifer will limit travel; reduce score applying similar considerations to that for groundwater use. Large uncertainty **0 – 4 – 6**
Corner service station in urban area, old style with steel tanks of thousands of litres capacity. Suspected leaks. Groundwater at 2 – 3 m. Gravels	Contamination is below the surface and the ground is fully paved. No potential for sediment transport. **0 – 0 – 0**	Four wells installed on downgradient boundary. Benzene non-detect in one, in excess of aquatic guidelines in central well and 50 – 60 % of guideline in other two. On-going soil source. Max must be 10, but most likely and min taken as average of measured concentrations (average of 0, 0, 2, 10). **3 – 3 – 10**
Disused sheep dip about 30 m from small stream. Dieldrin and arsenic. Site flat and well grassed. Groundwater at 2 m, silt loam over silty gravels.	Dieldrin and arsenic both well above aquatic sediment guidelines at surface, but highest concentrations over a small area – several tens of m^2. Small site, start at 3, but increase for high concentrations 5. Grass cover and small site reduces potential for erosion, back to 3. Allow for uncertainty – could be no erosion. **0 – 3 – 4**	A single well has been installed which shows arsenic at about 60% of guideline on one occasion and non-detect on another. Dieldrin not detected on either occasion. Starting point 2 for one occasion but 0 for another – average 1. Allow for uncertainty on high side. **1 – 1 – 2**

(f) Water concentrations have not been measured but soil concentrations are known. A judgement has to be arrived at as to whether groundwater exceedances as in (d) or (e) above are possible, based on knowledge of probable soil concentrations, contaminant properties, relationship of contamination to the watertable, likely infiltration and local soil properties. There would necessarily be a large degree of uncertainty, and therefore potentially a large range between **Min** and **Max**. High **Likely** and **Max** scores will only occur for situations where several of the

following occur; high concentrations, large areas of contamination, high mobility contaminant, and close proximity of the contamination to the watertable.

(g) As in (f) above but soil concentrations have also not been measured. A judgement has to be made about likely contaminant concentrations and distribution based on site type. A large degree of uncertainty will exist.

Some examples follow:

Site type	Typical scores for Amount with no samples – Aquatic pathways	
	Overland	Groundwater
CCA timber treatment site – large, more than five hectares, much unsealed ground, drip pad known to have been uncovered in past. Groundwater at 1 – 2m, silty gravel soil.	Large site, probably concentration in excess of aquatic sediment guidelines over large areas, but some uncertainty. Large potential for off-site transport. **8 – 8 – 10**	Large site, could be high soil concentrations contributing to leaching, but probably limited areas. Groundwater shallow in places. Silt will tend to bind CCA but probably inconsistent. Err on high side, but large range. **0 – 7 – 10**
Corner service station in urban area, old style with steel tanks. Suspected leaks. Groundwater at 2 – 3 m. Gravels	Most of contamination likely to be below surface, plus surface is paved. No potential for sediment transport. **0 – 0 – 0**	Possibility of hydrocarbons in the ground, including free phase at watertable. Probable groundwater plume with on-going source. BTEX and TPH. Quite possibly above aquatic guidelines. Max must be 10. Allow for uncertainty in **Min** score. **5 – 10 – 10**
Large, old, closed municipal landfill – several hectares – well capped and grassed. Leachate known to be discharging to stream.	Unlikely to be contaminated sediment discharging to stream from capped and grassed landfill. Might be effects of historic discharges. Allow moderate **Max**. **0 – 0 – 5**	Direct discharge, therefore start at 10. Waste is mature, therefore contaminant concentrations in leachate probably low to moderate, but unknown relative to aquatic guidelines. Large range erring on high side.

Site type	Typical scores for Amount with no samples – Aquatic pathways	
	Overland	Groundwater
		1 – 7 – 10 Note: Exposure parameter set at 10 – 10 – 10 as exposure pathway complete.
Disused sheep dip about 30 m from small stream. Site flat and well grassed. Depth to groundwater and sub-surface geology not known.	Possible dieldrin and arsenic above aquatic sediment guidelines, but probably small area. Small site, start at 3, but increase for high concentrations 5. Grass cover and small site reduces potential for erosion, back to 3. Allow for greater uncertainty than if had samples. **0 – 3 – 5**	Possible dieldrin and arsenic have limited mobility – tend to bind to soil, particularly dieldrin which is seldom seen in groundwater. Small site therefore limited potential for leaching. Assume zero to low potential, but allow uncertainty. **0 – 2 – 4**

6.1.3 Pathway

The Pathway consists of two components, the likelihood of the exposure occurring, e.g. contact being made, and the degree of that exposure. For the terrestrial the degree of exposure is the duration. For the two aquatic pathways the degree of exposure is moderated by the dilution available between the source and point of exposure.

For both the overland and groundwater aquatic pathways, if either sediment or water concentration measurements have been made in the receiving environment then for the particular aquatic pathway:

- For concentrations above relevant guidelines, score both Exposure and Dilution as **10 – 10 – 10**.
- For concentrations <50% of the relevant guidelines, score both Exposure and Dilution as **1 – 1 – 1**. If concentrations are only marginally below 50%, allow higher **Max** if only a few samples taken or only a short period of monitoring.
- For between relevant guidelines and 50% of relevant guideline values, score **10 – 10 – 10** in Exposure and pro rata between 0 and 10 for Dilution, that is a reduction of 1 unit for every 5% below the guideline. Allow higher **Max** for uncertain results or a small number of results.

The remainder of the discussion in this section relates to situations where there have not been any concentration measurements. For the aquatic pathways, the Exposure parameter relates to whether the pathway is complete, and if so, to what degree barriers to transport will reduce the amount of contaminant reaching the receiving water. In this sense it is similar to dilution, however, the Dilution parameter is to account for dilution at the actual receiving waters, i.e. the amount of dilution the sediment or water discharge receives in the receiving environment.

6.1.3.1 Exposure Parameter

The Exposure parameter is a measure of the likelihood of receptor making contact with, or ingesting, the media containing the contaminant, whether soil or water. In the case of off-site aquatic environments, the Exposure parameter must include how likely it is for the contaminant to travel to the site of exposure.

Terrestrial pathway

The terrestrial pathway is intended for land where plant or animal protection is of particular importance, e.g. national parks. It is not intended to be used for industrial sites, for which it is highly unlikely that sensitive plants or animals require protection. Similarly, it is unlikely that the pathway would be used for residential sites. Human health will always be a larger issue for a residential site.

For high value terrestrial environments the score would be similar to that used for the soil pathway for human health, for terrestrial animals, and the vegetable pathway for terrestrial plants, although each situation would be site-specific. The starting position would be **10 – 10 – 10** for surface contamination, reducing to zero for sub-surface contamination for animals and zero for sub-surface contamination below the root zone for plants. The depth of root zone would vary depending on what sort of plants were to be protected.

Aquatic Overland Pathway

Where there have been are no sediment concentration measurements within the aquatic environment, a judgement has to be made as to whether there is a pathway for sediment to be transported to an aquatic pathway, the barriers along this pathway (ground cover at the source, and between the source and receiving environment, ground slopes, distance and the efficiency/directness of the pathway). Attenuation/dilution along the way should be considered, but not dilution within the final receiving environment.

If there is potential for a contaminant to enter a receiving water, irrespective of the attenuation within the aquifer and dilution in the receiving water, a

minimum score of 1 should be entered for exposure. This recognises that although the effect on the receiving water may be negligible, an effect however small remains.

Typical scores are:

- Receiving waters within a site: 8 - 10
- Site close (<100m) to a waterbody: 5 - 8
- Site 500 m from waterbody: 2 - 5
- A significant pathway is unlikely to exist for distances >1000 m: 1

What could be considerable uncertainty should be allowed for by assigning lower and higher scores against **Min** and **Max** either side of the **Likely** score. This uncertainty would largely revolve around efficiency of sediment transport to the receiving water.

Groundwater Aquatic pathway

Where contaminated groundwater discharge to a receiving water is possible, the Exposure score reflects a combination of the various things that will cause a barrier to transport and/or attenuation/dilution between the site and the point of discharge. This will included the direction of flow, the distance to the point of exposure, the mobility of the contaminant and the aquifer properties.

Dilution within the receiving water is considered separately.

If there is potential for a contaminant to enter a receiving water, irrespective of the attenuation within the aquifer and dilution in the receiving water, a minimum score of 1 should be entered for exposure. This recognises that although the effect on the receiving water may be negligible, an effect however small remains.

Where there is a possibility that there is complete pathway and there have been no receiving water concentration measurements, similar considerations to that for the human health water use for groundwater use explained under the human health Exposure parameter (see Section 5.3.1) should be used.

6.1.4 Duration/Dilution Parameter

Terrestrial pathway

For plants, the Duration pathway will be **10 – 10 – 10**, as plants will always be exposed. For animals, the score will depend on the browsing behaviour and range of the animals relative to the size of the site. If the animals are likely to have a small range and be always on the site, then the score will be high. If the animals have a wide range then the score will be low. Uncertainty on animal behaviour will be reflected in the range of scores

Aquatic Overland Pathway

Where there are no sediment concentration measurements within the aquatic environment, a judgement has to be made as to the likely dilution that will occur at the point that sediment discharges to the aquatic environment, principally from transport downstream within a stream and/or mixing with other sediment in the stream. This will largely depend on the size of the stream relative to the amount of sediment likely to have been transported (which will be influenced by the site size) and the amount of energy in the receiving environment.

The score is smaller the larger the dilution.

Typical scores are:

- Small stream and a large site (several hectares): 9 - 10
- Small stream and a moderate size site (up to a few hectares): 6 - 8
- Small stream and a small site (few hundred square meters): 2 - 4
- Large river or the sea and a small site: 1
- Large River or the sea and a moderate size site: 2 – 5
- Large River or the sea: 1 - 3

Aquatic Groundwater Pathway

In general, the dilution available in even a small stream will be considerable relative to groundwater discharges from a site. The exception could be leachate from a landfill discharging directly to a small stream, where dilution from nothing to a few-fold might occur. In that case the score out of ten should be inversely proportional to the amount of dilution. Otherwise, groundwater discharging to even a small stream is likely to undergo dilution of at least 10 times (score no less than 1) and possibly hundreds of times, and dilution in larger rivers or the sea will be orders of magnitude (score no greater than 1).

6.2 Ecological Receptor Vulnerability

The ecological receptor vulnerability score will depend on the pathway and type of receptor at risks – plant, animal or aquatic life.

6.2.1 Terrestrial Environment

The following scores would apply to plants:

- Pristine natural environments and wetlands: 10
- Modified rural environments, farmland: 5
- Highly modified urban environments: 0 – 3.

A similar philosophy and range of score can be applied to terrestrial animals, e.g. native fauna in a bush setting would be 10, ranging down to pest animals being zero.

6.2.2 Aquatic Environments

For an aquatic environment, the Receptor Vulnerability parameter should be scored on the waterbody considered to be within range of effects, as considered under the Pathway parameters. For example, a small modified stream may be discharging to a high value river several hundred metres away. If it has been determined that there is unlikely to be a significant pathway because the river is too far away or the dilution is too great, then it is the vulnerability of the small modified stream that is considered, not the remote river, no matter that the river may have very high ecological value.

In marginal cases, two Pathway/Receptor combinations may have to be trialled to see whether it is the nearby stream rather than the more remote ultimate receiving water that is more vulnerable.

Examples of aquatic vulnerability scores are:

- A high quality stream or river with a fishery or significant native fish population, or a marine environment with a fishery (including filter-feeding shellfish): 10
- A smaller stream without a fishery or a significant native fish population. The score will depend on the surrounding environment. A highly modified surrounding environment (e.g. intensively farmed) will have lower scores than a bush environment. Score range: 5 – 9
- A degraded stream or marine environment (e.g. an urban stream used to carry stormwater) will have a lower vulnerability: 5
- A modified stream channel used as a drainage channel will be scored lower again. Score on the perceived degree of modification: 1 – 5
- An ephemeral stream - no permanent aquatic environment: 1
- Wastewater treatment ponds (regardless of incidental aquatic life): 1

Wetlands will score depending on their size, perceived significance and degree of modification.

- Large and/or nationally significant wetland: 10
- Locally or regionally significant wetland: 7 – 9
- Small, partially drained wetlands and/or wetlands accessible to farm animals. Score range 3 – 5
- Artificial wetlands intended for water treatment (aquatic life incidental): 1

7.0 Cultural, Social, Heritage and Economic Benefit

Scores for cultural, social, heritage or economic benefit factors are scored as high, medium, low of none. Drop down list on each of the boxes facilitates scoring.

7.1 Cultural

The Cultural score will depend on the site being listed on a council, iwi or Historic Places Trust register as a site of cultural interest. If listed, the score will depend on whether it is if significant interest (high), of some interest (medium), indentified/unknown (low) or not listed (none).

7.2 Social

Scoring the Social parameter will be subjective. The assessor will need to consider whether investigation/remediation of the site will likely result in an increase in the social wellbeing of the community and if so how much and how widely will this be felt.

Issue that could be considered are:

- Whether the site in its current state is creating general concern in the community, or would create concern in the community if the information was known.
- Whether the site is currently unsightly.
- Whether such things as recreational opportunities could be improved
- Whether the site is of importance to particular community groups
- Whether the site has particular landscape values that have been degraded, e.g. a site with reserve status.

7.3 Heritage

The Heritage score will depend on the site being listed on any council or Historic Places Trust register as a site with heritage value; e.g. Category I - high, Category II – medium, places not on the register but of local historical interest – low.

7.4 Economic Benefit

Coring Economic Benefit will also be subjective as it is not intended that a cost-benefit analysis be carried out. The assessor will need to consider whether investigation/remediation of the site result will increase financial opportunities or mitigate expenditure to address detrimental effects resulting from the site contamination.

- Significant and identified financial opportunities or cost savings – High
- Potentially large financial opportunities or cost savings – Medium
- Potential for financial opportunities or cost savings – Low
- No identified economic benefit – None