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**Toxic RISKAT version 3.1 - The Inclusion of
the Site Risk Methodology**

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EXECUTIVE SUMMARY

The Risk Assessment Section (RAS) of the Health and Safety Laboratory were asked by the Methodology and Standards Development Unit (MSDU) of the Hazardous Installations Directorate (HID) of the Health and Safety Executive to develop a Site Risk extension to the Toxic RISKAT code. This extension allows for the spreading of the risk over a specified area or areas, rather than having it concentrated at one particular point, as in the previous versions of RISKAT. The version of Toxic RISKAT with this functionality is known as Toxic RISKAT 3.1.

Objectives

The objective of this work was to develop an extension to the Toxic RISKAT code to enable risk to be spread or ‘smeared’ over an area rather than being concentrated at one point. On major hazard sites with large vessel areas or moveable container areas, very different risk grid values will be obtained with point and area source risks. This has consequences for the off-site risk contours. The area risk capability is required in the Toxic RISKAT code as a result of a hazardous substance consent holder’s entitlement to specify an area for the storage of moveable containers and bulk vessels.

Main findings

The main new features of Toxic RISKAT 3.1 are:

- The ability to define a site area on RISKAT Grid and create a *.sit* file to represent vessel areas.
- The site vessel areas file can be read and used to perform the grid smearing process allowing the risk grid file, *.ttc*, associated with a Toxic RISKAT run to be calculated.
- The original calculated risk file, *.ttc*, can be saved as a *.tto* file, for reference, and the new grid smeared risk file can be saved as the *.ttc* file. This enables the grid smeared file to be used by other tools, e.g. Combine, Contour, etc..
- A Risk Map file can be created in a comma separated values format, *.csv*, that lists the risk calculated at each grid square on the RISKAT grid.

1 INTRODUCTION

1.1 BACKGROUND

The Site Risk extension to the Toxic RISKAT model to develop Toxic RISKAT version 3.1 is detailed in this report. The extension, requested by Methodology and Standards Development Unit (MSDU) of the Health and Safety Executive (HSE), allows for the scenario where hazardous substances can be stored in movable containers (or a number of bulk tanks), that can be placed anywhere within a predefined area on a site. This is a result of a hazardous substance consent holder's entitlement to specify an area for storage of moveable containers when applying for consent for their site. A new methodology had to be developed to allow for the 'smearing' of the risk from a point source to an area and this is detailed in this report. The implementation of this methodology into Toxic RISKAT and full specification details of the new code are also fully documented.

The new code has been developed in accordance with the Risk Assessment Section (RAS) software quality assurance procedures. Whilst this software was being developed RAS was in the process of developing its software quality assurance procedures in line with those for software developers producing software to Safety Integrity Level (SIL) 2, as specified in the International Standard on function safety of safety related systems IEC61508. The majority of the site risk module has, therefore, been produced to this standard. However, it was not possible to assure the entire code to SIL 2 due to its interaction with the non assured RISKAT code.

1.2 OVERVIEW

A full description of the software product is detailed in this document. This includes, in section 2, a description of the site risk methodology, the functional requirements and the factors which affect these requirements. This is followed in section 3, by a detailed description of the coding of the site risk module and the specific functional requirements of the software. Details of the user interface requirements and the general software and hardware requirements are also presented here. In addition, specific performance requirements and design constraints are detailed, as well as other required attributes of the software product. Section 4 discusses details of the software quality assurance development and procedures and section 5 presents a brief summary of the work.

2 THE SITE RISK METHODOLOGY

2.1 BACKGROUND

HSL has developed a suite of computerised QRA tools, known as RISKAT, for the assessment of risks to population in the vicinity of plants processing and storing toxic and flammable materials (Pape and Nussey, 1985). The development of these tools first began in 1981 following the Pheasant Wood Public Inquiry. The RISKAT suite has two component parts: Toxic RISKAT, and Flammable RISKAT, which calculate individual risk levels for toxic and flammable releases respectively.

Several versions of RISKAT have been developed, the current released version being RISKAT version 3.0. The Site Risk extension implements a procedure for creating a risk grid for an area source from a risk grid for a point source and forms Toxic RISKAT version 3.1. Initially the extension has been applied only to the Toxic RISKAT code and allows for the scenario where hazardous substances can be stored in movable containers (or a number of bulk tanks), which can be placed anywhere within a predefined area on a site. On major hazard sites with large vessel areas or moveable container areas, very different risk grid values will be obtained with point and area source risks. This has consequences for the off-site risk contours. The area risk source is the natural consequence of a hazardous substance consent holder's entitlement to specify an area for storage of moveable containers and is therefore being implemented in the Toxic RISKAT code. All risks are calculated initially as arising from one or more point sources, including risks to be smeared over an area. The risks to be 'smeared' are then spread over the specified area using the new module within the Toxic RISKAT code. Smeared and point source risks may then be combined as required.

2.2 THE SITE RISK METHODOLOGY

The methodology used to implement the Site Risk Source code is that developed by Martin Goose of MSDU and agreed by the MSDU panel meeting system. A worked example of the site risk smearing technique is presented in Appendix A.2, however the methodology is also outlined here for completeness. The method uses the risk grid for a point source, and details of the site outline to create a risk grid for an area source and initially requires the hazardous site vessel area (or areas) outline details to be input into the code. To do this the '*grid edit*' graphical user interface (GUI) is modified to contain additional functions. This allows a user to input the vessel area details in a similar manner to that presently used to specify the land type around a site. The vessel area details are then stored in a new *.sit* file. This will be used with the point source risk grid, *.ttc* file, calculated for any moveable containers present on site.

The point source risk grid is overlaid on the vessel area outline grid as illustrated in figure A2.3 of Appendix A.2. The maximum value of risk is stored for each grid square. The risk grid is then moved to the next grid square in the vessel area outline grid, as shown in figure A2.4 of Appendix A.2. The risk value at each square is compared with the previous value and the maximum is again recorded. This process is repeated for the whole of the vessel area outline grid, as illustrated in figure A2.2. Once the entire site grid has been covered square by square, the final vessel area risk values, as illustrated in figure A2.19, will be stored in a new *.ttc* file. This file can then be combined with any other compatible *.ttc* file for the site using the existing COMBINE code associated with RISKAT.

Briefly, the general software requirement is the development of the Site Risk Source module to be used with the Toxic RISKAT software. The new module functionality is implemented in two ways, firstly via changes to the GUI to record the details of the major hazard site and secondly via a modular piece of code which performs the manipulation of the risk grid values to ‘smear’ the risk over the specified area. The implementation of the Site Risk methodology into the code is discussed in detail in section 3 of this document.

2.3 MODULE FUNCTION

The overall function of the new module is to allow a user to estimate the risk over an area, when appropriate, instead of having the risk centred at one particular point on the site. The general functions that the software will perform are to:

- allow a user to add site details via new functions on the ‘*grid edit*’ GUI;
- store the area details in a new *.sit* file;
- spread the risk over the area using the Site Risk methodology;
- combine the area risk results with any other risk results;
- output the results from the Site Risk Source in the form of a *.ttc* file.

3 THE SITE RISK MODULE

This section describes in detail the implementation of the Site Risk methodology into the Site Risk module (smear routine) and how this integrates into the Toxic RISKAT code.

3.1 REQUIRED TASKS

The tasks required of the Site Risk software are:

- **Define the Site Area on RISKAT Grid.**

To allow the user to create a file, *.sit*, to represent the Site vessel areas on the RISKAT grid.

- **Determine the Grid Smeared Risk.**

To read in the Site vessel areas file, *.sit*, and the calculated Risk grid file, *.ttc*, associated with a Toxic RISKAT run, and use this information to perform the grid smearing process.

- **Create the Grid Smeared *.ttc* file.**

To save the original calculated risk file, *.ttc*, as a *.tto* file for Toxic RISKAT files. To save the grid smeared risk file as the *.ttc* file to allow the grid smeared file to be used by other tools associated with RISKAT, e.g. Combine, Contour, etc.

- **Create a Risk Map file.**

To produce a new file in a comma separated values format, *.csv*, that lists the risk calculated at each grid square on the RISKAT grid.

Detailed descriptions of these tasks are given in sections 3.1.1 to 3.1.4.

3.1.1 Task 1 : Define the Site or Vessel Areas on the RISKAT Grid

Purpose

To allow the user to select the grid squares on the RISKAT grid representative of the Site vessel areas in which the hazardous substances could be stored.

Preconditions

The user will have specified a RISKAT grid, and will have selected an origin for the release to allow the existing RISKAT code to calculate the risks. It is recommended that in cases where grid smearing is to occur that the centre grid square should be taken as the origin. This reduces the chances of having a zero contribution to a grid square during the smearing process than if an origin near to the RISKAT grid boundary were to be chosen.

Post conditions

Modifications to be made to the existing RISKAT GUI in the '*grid edit*' dialog. The functionality to allow the user to select the grid squares representative of the site shall be incorporated. Upon saving the Toxic RISKAT file a Site vessel areas file (*.sit*) will be created in the Toxic RISKAT data directory (see Appendix A.3 for proposed *.sit* file format). If a user edits an existing Toxic RISKAT file for which a *.sit* file exists, and removes all vessel areas in the grid edit dialog, then upon saving the existing *.sit* file would be deleted in such a case.

Processing

The output from this phase towards the grid smearing process will be the Site vessel areas *.sit* file. The smeared risk grid *.ttc* file will be obtained by selecting the RISKAT file in the RISKAT Runner application.

3.1.2 Task 2 : Determine the Grid Smeared Risk

Purpose

To read in the vessel areas *.sit* file and the calculated Risk grid *.ttc* file. The information from these files can then be used to perform the grid smearing process to calculate the risk.

Preconditions

A Risk Grid file (*.ttc*) and a Site Area (*.sit*) file will both have to be available to carry out the grid smearing process.

Processing

The co-ordinates of the release grid square, and the dimensions of the RISKAT grid, will be read in from the *.ttc* file and the array of risk values will be read in and stored in a two-dimensional Risk Grid array. The values of the *.sit* file will be read in and allocated to a two-dimensional Site Area array. A two-dimensional Calculation array with the same dimensions as the Risk Grid and Site grid arrays will be created to store the “grid smeared” risk values. Each element in the Site Area array will be considered. If a null value is returned then the program will proceed to the next element in the array. If a positive value is returned, thereby indicating that the current element represents part of the site vessel areas specified by the user in Task 1, then the grid smearing process is undertaken. The co-ordinates of the current site area element are stored and, by using the release origin co-ordinates read in from the *.ttc* file, the Risk Grid array release point is mapped onto the Calculation array at the co-ordinates indicated by the Site Area array. No manipulation of either the Risk Grid or Site Area arrays is carried out. All working takes place in the Calculation array. By looping through each element of the Calculation array consideration is given to the current value of the Calculation array element and the value of the current element mapped from the Risk Grid array. The larger of the two values is stored in the Calculation array. The program then proceeds to the next Calculation array element. Once all the elements in the Calculation array have been considered, the program proceeds to the next element of the Site Area array, and this process continues until all the elements of the Site Area array have been considered. An example of this process is given in Appendix A.2.

Post conditions

The original *.ttc* file read in will be copied as a *.tto* file. The contents of the Calculation array will be used to create a replacement “smeared” *.ttc* file. The proposed format of the “smeared” *.ttc* file is shown in Appendix A.4.

3.1.3 Task 3 : Creating the Grid Smeared Risk .ttc file

Purpose

To save the original Risk Grid *.ttc* file with an alternative file extension (*.tto*) to allow a copy of the original file calculated by RISKAT to be kept. To save the elements of the Calculation array in the appropriate format to provide a Grid Smeared Risk *.ttc* file.

Preconditions

Task 2 will need to be completed successfully before the manipulation of the *.ttc* files takes place.

Processing

Upon the completion of the grid smearing process the original *.ttc* file will be copied to the RISKAT\DATA directory as a file with extension *.tto*. The contents of the file will remain unaltered. The *.ttc* file will then be deleted. A replacement file with extension *.ttc* will be created in the RISKAT\DATA directory using the contents of the Calculation array.

Post conditions

The new *.ttc* file can be used with the Contour application to provide risk contours that can be plotted on the RISKAT GUI, and can be used by other tools associated with RISKAT such as Combine, Values, etc.

3.1.4 Task 4 : Creating a Risk Map file

Purpose

An additional requirement is for the creation of a Risk Map, that is, a list of the risk values at each grid square on the RISKAT grid.

Preconditions

A RISKAT .ttc file is required.

Processing

The risk values for the RISKAT grid listed in the .ttc file will be read in and entered into a two-dimensional array. A new file with a comma separated values (.csv) format will be created showing the x and y axes on the RISKAT grid and listing the risk values at each grid square as it would appear on the RISKAT grid. The proposed format for the Risk Map .csv file is illustrated in Appendix A.5.

Post conditions

The .csv file could be opened using a spreadsheet package (e.g. Microsoft ® Excel) to view the risk values at each grid square on the RISKAT grid.

3.2 THE CODE DESIGN

The operation of the code can be illustrated by a top-down design. The descriptions in bold font are the additions to the use and operation of the existing RISKAT suite of programs.

User opens RISKAT GUI

User creates RISKAT scenario using GUI, or sets up dummy .tox file for imported .ttc file

User edits RISKAT grid to include Site Area

User saves RISKAT file

Site Area file (.sit) is saved at same time

User opens RISKAT Runner Application

Under “File Type” user selects the ‘Toxic’, or the ‘Imported Toxic Risk Values’ option

User opens RISKAT file

RISKAT runner executes the Toxic Batch file - this is TOXMOD.BAT for the ‘Toxic’ option, and TOXMOD2.BAT for the ‘Imported Toxic Risk Values’ option

For TOXMOD.BAT RISKIN, DENZ, CRUNCH, and RISKAT are run and calculated risk on grid is saved to a .ttc file

For TOXMOD2.BAT, the .ttc file has already been created by another application

If a .sit file is found then the Toxic Batch file runs the SMEAR.EXE grid smearing program, otherwise skip the grid smearing and execute the Contouring routine.

SMEAR.EXE operation

Site Area file (.sit) and calculated risk file (.ttc) opened and read

Save grid values in .sit file to a two-dimensional array with M by N elements

Save grid values in .ttc file to a two-dimensional array with M by N elements

Save (x,y) co-ordinates of origin of release from .ttc file

Consider each grid cell (i,j) in Site Area array

If the grid cell (i,j) is not part of the Site Area

Move to next grid cell

If the grid cell (i,j) is part of the Site Area

Map the Risk release origin (x,y) to the current Site Area cell (i,j)

Set I = x-i, and J = y-j

**Consider each grid cell (k,l) in a two-dimensional Calculation array
 with M by N elements**
If I+k or J+l are outside the appropriate grid dimensions
 No contribution to grid cell (k,l) from mapped risk array
 Calculation grid cell (k,l) value remains unchanged
If I+k and J+l are within appropriate grid dimensions
 Compare current value in Calculation Array grid cell (k,l) with
 value in mapped risk array grid cell (I+k,J+l)
 Larger of the two values is saved to Calculation cell (k,l)
Once each grid cell (i,j) has been considered in Site Area array
 Save original .ttc Risk file as a .tto file
 Write Calculation Array in the format of a .ttc file
End SMEAR.EXE and return control to the Toxic batch file

The Toxic Batch file calls the RISKAT contouring routine - **this uses the grid smeared .ttc file if the grid smearing process has been carried out. If no .sit file had been found then the original .ttc file is used for the contouring.**

The Toxic Batch file calls RISKMAP.EXE

RISKMAP.EXE operation

The .ttc Risk file is opened and read
The grid values in .ttc file are saved to a two-dimensional array with M by N elements
The array elements are saved in a comma separated values format, .csv, as the values
would appear on the RISKAT grid with the x and y axes displayed
End RISKMAP.EXE and return control to the Toxic Batch file

The Toxic Batch file ends and control is returned to the RISKAT runner dialog.

The contours can be viewed using the RISKAT GUI.

The grid smeared .ttc file can be used by other tools associated with RISKAT such as Combine, Values, etc.

The Risk Map .csv file can be opened and viewed/manipulated using a spreadsheet package.

3.3 EXTERNAL INTERFACE REQUIREMENTS

3.3.1. User Interfaces

There are two instances in which the user will interface directly with the software:

- To select the grid squares on the Toxic RISKAT grid representative of the Site vessel areas over which the grid smearing process is to take place, and to save this information to a file.
- To select the Toxic RISKAT file for which the Grid Smeared Risk is to be calculated, to perform the grid smearing process, and to save the calculated risk values to a file.

The first interface is provided for by modifying the 'grid edit' dialog within the Toxic RISKAT GUI to allow the selection of the Site vessel areas. The second interface can be provided by the RISKAT Runner application where the grid smearing process, and the creation of the Risk Map file, can be included as part of the Toxic Batch file execution. A modification to the Toxic RISKAT Runner dialog will also allow grid smearing and Risk Maps to be undertaken on .ttc

files that have been created from other applications, e.g. SANDRA and POLECAT, PASKER and POLECAT, etc. Figure 1 illustrates the modified 'grid edit' dialog within the RISKAT GUI. Figure 2 illustrates the modified RISKAT Runner application dialog.

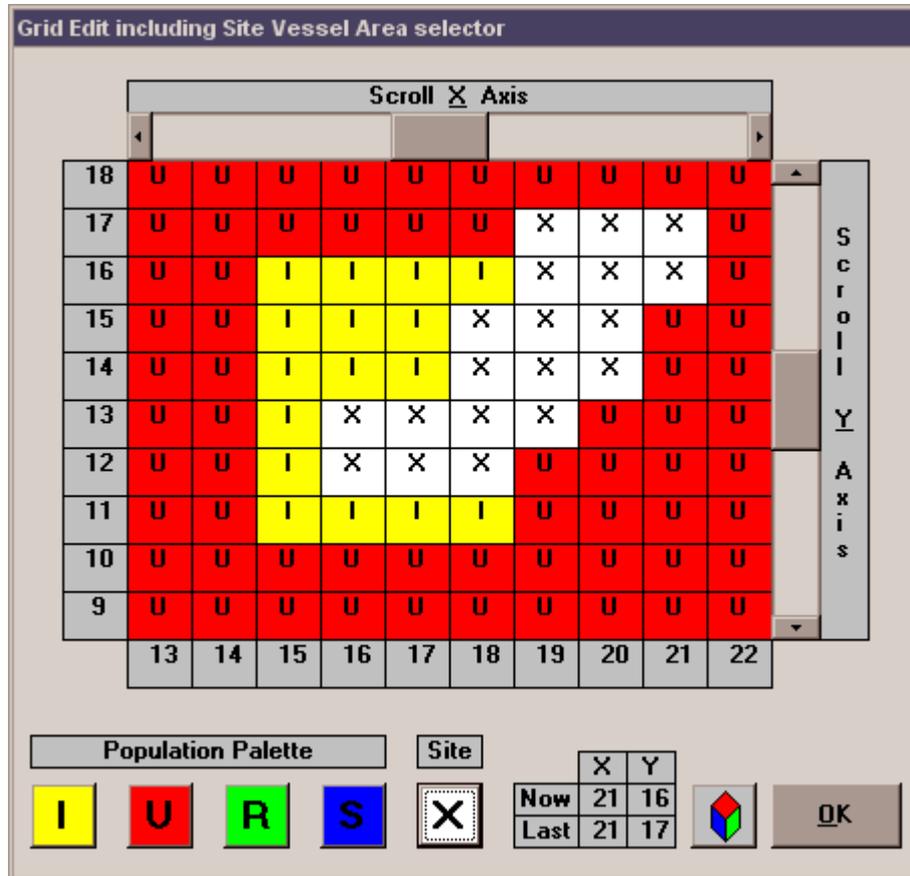


Figure 1. Grid Edit dialog box within RISKAT GUI

The user opens the RISKAT GUI and creates a RISKAT file. On selection of the 'Grid/Edit' menu item in the RISKAT GUI menu, the 'grid edit' dialog is displayed. Figure 1 shows the modified 'grid edit' dialog box. This dialog box can be used to create the RISKAT population grid in the same manner as in the current version of Toxic RISKAT. There is the additional choice in this dialog to select a Site button and from this select the area on the Toxic RISKAT grid to represent the Site vessel areas over which the grid smearing process will take place. In Figure 1, the selection of the Site Area is represented by white grid boxes and an "X" mark.

Once the user has selected the Site vessel areas and clicked 'OK' on the 'grid edit' dialog, the RISKAT file can be saved using the 'File/Save' on the RISKAT GUI menu. When the RISKAT file is saved, a Site vessel areas file with the same filestem and the extension .sit will also be saved to the format shown in Appendix A.3.

If a user opens an existing RISKAT file for which a .sit file exists and proceeds to remove all of the Site vessel areas from the grid, upon saving the RISKAT file the associated .sit file will be deleted.

Figure 2 shows the modified RISKAT Runner application dialog box. The user can select the 'Toxic' option under 'File Type' to run a Toxic RISKAT file as normal by executing the Toxic Batch file TOXMOD.BAT. In this case if a .sit file is associated with the Toxic RISKAT .tox file then the Grid Smearing process will take place, using the methods described in Sections 3.1.2 and 3.1.3, after Toxic RISKAT has calculated the point source .ttc file. Once the Grid Smearred .ttc file has been created the Contouring program is called by the Batch file followed by the Risk Map program, which creates the Risk Map .csv file as described in Section 3.1.4.

The new feature on the RISKAT Runner dialog is the inclusion of the 'Imported Toxic Risk Values' option. The user can select this option if a .ttc file has been created using an application other than RISKAT, e.g. PASKER, SANDRA, FIREPEST are examples of tools from which .ttc files can be obtained through running their outputs through the Polar to Cartesian program POLECAT. In this case an alternative Toxic Batch file, TOXMOD2.BAT, is called that does not run the risk calculation process programs present in the TOXMOD.BAT file. The TOXMOD2.BAT file immediately checks for a .sit file and if this file is found the Grid Smearing process is executed using the imported .ttc file. The Contouring program is then run, followed by the Risk Map program. An outline of the operation of the TOXMOD.BAT and the TOXMOD2.BAT files are shown in Appendices A.6 and A.7 respectively.

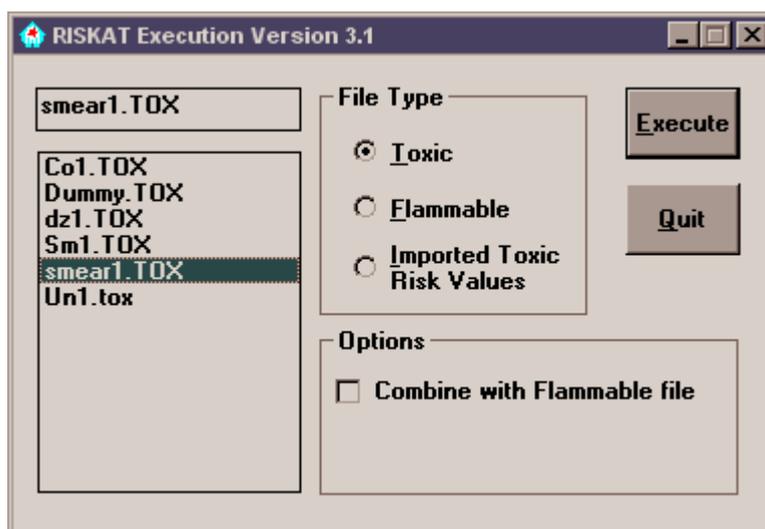


Figure 2. RISKAT Runner application dialog box including 'Imported Toxic Risk Values' option

3.3.2. Hardware Interfaces

The PC monitor is the main display.

3.3.3. Software Interfaces

All software is contained on the network drive on the MSDU server in the appropriate folder. Data files generated (.sit, .tto, .ttc, .csv) will be stored in the appropriate RISKAT data directory as indicated in the RISKAT.INI file.

3.2.4. Communications Interfaces

The program is able to be run as a “stand-alone” application (e.g. on a laptop computer) and as an application on the MSDU network.

3.4 PERFORMANCE REQUIREMENTS

The software has been designed so that it can be used simultaneously by a number of users on the MSDU network. The operation of the program should not disrupt other network operations, overuse network resources, or block transfer protocols.

3.5 DESIGN CONSTRAINTS

3.5.1. General Constraints

The Windows application has been developed as standard Windows application and adheres to published Windows programming guidelines (e.g. The Windows Interface: An Application Design Guide, published by Microsoft). The application has been developed using Visual Basic version 5 to conform with the existing RISKAT version 3.0 code. The code has been written in such a way to provide portability to future versions of the development environment.

3.5.2. Standards Compliance

The software has been written in accordance with the RAS Software Quality procedures, which is being brought into conformance to SIL2 as defined in the IEC65108 standard. See section 4 for more details.

3.4.2. Hardware Limitations

The software is required to operate on the MSDU minimum specification PC. It is assumed that Windows NT 4 (service pack 6) or higher will be available on the users machine. The installation of the new software will be undertaken by the HSE REFIT team; HSL will manage and monitor this process and advise MSDU of progress.

3.6 ATTRIBUTES

3.6.1. Security

No security issues were to be addressed in the program.

3.6.2. Maintainability

Software support will be provided under the RISKAT Helpdesk service. The software will be described as part of the RISKAT QRA tool entry in PCAG and PCAS.

3.7 USER CHARACTERISTICS

It is intended that the users of the Site Risk source software will be the general users of the RISKAT version 3.0 software. These are 'specialised users' at MSDU or HSL. Users should have a thorough understanding of the QRA methodology used in RISKAT and of the assumptions used within the model. Users should also be familiar with running applications in the Windows environment.

4 SOFTWARE QUALITY ASSURANCE PROCEDURES

The new Site Risk code has been developed in accordance with the RAS software quality assurance procedures. In addition, whilst the Site Risk software was being developed RAS was in the process of bringing its software quality assurance procedures in line with those for software developers producing software to Safety Integrity Level (SIL) 2, as specified in the International Standard on function safety of safety related systems IEC61508.

An initial User Requirement Specification (URS) document was agreed beforehand with the MSDU customers. The URS is an agreed set of requirements between the developer and the client and is intended to identify the broad vision and outline of the proposed software product. It was agreed that as the Toxic RISKAT code had been classified as requiring SIL2, then any additional module must be developed in accordance with the regulations of SIL2. These requirements are described in the document by Ed Fergus of TD1 (*Contract Research Report 336/2001*). It was acknowledged that while RAS was in the process of attaining these software QA levels, this particular piece of software may not always be fully compliant with the full SIL2 requirements, as this project was the first development and implementation of these new procedures.

As required by the SIL 2 standards, the RAS software QA procedures now include comprehensive software specification, design details, testing plans, maintenance plans and pre and post installation support. Full details of the QA system are available from RAS on request.

5 SUMMARY

This report provide details of the Site Risk extension to the Toxic RISKAT code. This includes a description of the methodology and how this has been implemented into the RISKAT code to form RISKAT version 3.1.

The Site Risk extension arose from a requirement to be able to determine an area of risk from a point source of risk, as a result of a duty holders right to specify an area of storage for hazardous materials rather than a single point.

The main new features of RISKAT 3.1, as a result of the Site Risk extension are:

- A user can define the site area on RISKAT Grid and create a *.sit* file to represent the vessel areas.
- The site vessel areas file, *.sit*, can be read and the risk grid file, *.ttc*, associated with a Toxic RISKAT run calculated to perform the grid smearing process.
- The original calculated risk file, *.ttc*, is saved as a *.tto* file for Toxic RISKAT files and reference. The grid smeared risk file is then saved as the *.ttc* file which allows the grid smeared file to be used by other RISKAT tools, e.g. Combine, Contour, etc.
- A Risk Map file can be created in a comma separated values format, *.csv*, that lists the risk calculated at each grid square on the RISKAT grid.

6 REFERENCES

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APPENDIX

A.1 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

HSE: Health and Safety Executive

HSL: Health and Safety Laboratory

MSDU: Methodology and Standards Development Unit

PCAG: Planning Case Assessment Guide

PCAS: Planning Case Assessment Support

QRA: Quantified Risk Assessment

RAM: Random Access Memory

RAS: Risk Assessment Section

RISKAT: Risk Assessment Tool

A.2 EXAMPLE OF GRID SMEARING PROCESS

A worked example of the grid smearing process is illustrated here. This follows the method described in Section 3.1.

The dimensions of the RISKAT grid and the release origin for the RISKAT run are read in from the RISKAT *.ttc* file. A Risk Grid array is created with the dimensions of the RISKAT grid. The risk values are then read in from the *.ttc* file and assigned to the RISK Grid array as illustrated in Figure A2.1. The release origin is identified as the grey box at (4,4) on the grid shown.

7	2	3	4	5	4	3	2
6	3	5	6	7	6	5	3
5	4	6	8	9	8	6	4
4	5	7	9	10	9	7	5
3	4	6	8	9	8	6	4
2	3	5	6	7	6	5	3
1	2	3	4	5	4	3	2
y/x	1	2	3	4	5	6	7

Figure A2.1. Risk Grid

The *.sit* file is opened and the dimensions of the Site vessel area grid are read in and stored. A Site vessel areas array is created with these dimensions and the values of the grid read in and assigned to the array as illustrated in Figure A2.2.

It should be noted that the risk grid as displayed in Figure A2.1 will appear to be upside down when compared to the way the values are stored in the *.ttc* file. In the *.ttc* file the values are stored beginning with (1,1) and end with (M,N), where M is the maximum dimension in the x-direction, and N is the maximum dimension in the y-direction. As can be seen the top left value displayed on the RISKAT grid is (1,N) rather than (1,1). The *.sit* file is stored in the same way as displayed in Figure A2.2, as it would appear on the RISKAT grid.

7	0	0	0	0	1	1	0
6	0	0	0	1	1	1	0
5	0	0	1	1	1	0	0
4	0	0	1	1	0	0	0
3	0	0	1	1	1	0	0
2	0	0	0	1	1	0	0
1	0	0	0	0	1	0	0
y/x	1	2	3	4	5	6	7

Figure A2.2. Site vessel areas Grid

A Calculation array is created with the same dimensions, (M,N), as the Risk Grid and Site vessel areas arrays. By looping through the Site vessel areas array, at each co-ordinate where a 1 indicates part of the site, the value of the Calculation array is set equal to the value for the release origin in the Risk Grid array. If a co-ordinate in the Site vessel areas array is equal to 0, then the value for that co-ordinate in the Calculation array remains 0.

In this example the release origin of the Risk Grid array is at (4,4) and has a value of 10. Therefore each value from the Site vessel areas array becomes equal to 10 in the Calculation array. The contents of the calculation array after this step is shown in Figure A2.3.

7	0	0	0	0	10	10	0
6	0	0	0	10	10	10	0
5	0	0	10	10	10	0	0
4	0	0	10	10	0	0	0
3	0	0	10	10	10	0	0
2	0	0	0	10	10	0	0
1	0	0	0	0	10	0	0
y/x	1	2	3	4	5	6	7

Figure A2.3. Calculation Grid after setting risk at Site

Starting from (1,1) each co-ordinate in the Site vessel areas array is considered until part of the Site vessel area is found as designated by a 1. In this example, the first co-ordinate where the

grid smearing process would occur is at (5,1). Once this has been identified the Risk Grid array is mapped onto the Calculation array where the current co-ordinate is set at the release Origin.

By setting $I = x-i$ and $J = y-j$ the mapping can be carried out.

In this case $(x,y) = (4,4)$, and $(i,j) = (5,1)$.

Therefore $I = -1$ and $J = 3$.

Beginning at (1,1) on the Calculation array the corresponding co-ordinate is identified on the Risk Grid array by adding the I and J values to the current Calculation co-ordinate. Therefore for (1,1) on the calculation array a corresponding co-ordinate of (0,4) is identified for the Risk Grid array. However this falls outside the range of the Risk Grid array and subsequently there is no contribution to (1,1) of the Calculation array, which remains at its current value (in this case, equal to 0).

Moving to (2,1) on the Calculation array, the corresponding co-ordinate for the Risk Grid array is found to be (1,4). As this falls within the range of the Risk Grid array then this co-ordinate can be mapped to the Calculation array. The value in (2,1) of the Calculation array (equal to 0 as shown in Figure A2.3) is compared to the value in (1,4) of the Risk Grid array (equal to 5 as illustrated in Figure A2.1). The larger of these two values is assigned to the Calculation array. Therefore (2,1) in the Calculation array is set equal to 5. This mapping is carried out for each co-ordinate in the Calculation array. Figure A3.4 shows the Calculation array after this process has been completed for the first mapping. The site area is shown as a dark shade of grey. The current release origin on the site area is in bold font. Those co-ordinates on the Site for which a mapping has already been calculated are indicated by an underline to the value. The co-ordinates in the Calculation array for which the value has been altered in the mapping are indicated by a light grey shading.

7	0	0	0	0	10	10	0
6	0	0	0	10	10	10	0
5	0	0	10	10	10	0	0
4	0	2	10	10	5	4	3
3	0	3	10	10	10	6	5
2	0	4	6	10	10	8	6
1	0	5	7	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.4. Calculation Grid after 1st mapping

Looping through the elements of the Site vessel areas array continues until another grid square-representative of the Site vessel area is identified. In this case the next co-ordinate identified is (4,2). Therefore $I = 0$, and $J = 2$. For (1,1) on the Calculation array the risk value is 0 (as shown in Figure A2.4), and the corresponding co-ordinate of the Risk Grid array is (1,3), which has a risk value equal to 4 (as shown in Figure A2.1). Subsequently the risk value for (1,1) on the Calculation grid is set to 4.

For (2,1) on the Calculation array, the risk value is equal to 5. For the corresponding mapped Risk Grid co-ordinate (2,3), the risk value is equal to 6. Subsequently the risk value at (2,1) on the Calculation array is set equal to 6. If (6,1) on the Calculation array is considered, however, then the risk value is found to be equal to 9 for the Calculation array and equal to 6

for the corresponding co-ordinate (6,3) of the Risk Grid array. In this instance the risk value in the Calculation array remains the same. Figure A2.5 illustrates how the Calculation array has changed after the 2nd mapping.

7	0	0	0	0	10	10	0
6	0	0	0	10	10	10	0
5	2	3	10	10	10	3	2
4	3	5	10	10	6	5	3
3	4	6	10	10	10	6	5
2	5	7	9	<u>10</u>	10	8	6
1	4	6	8	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.5. Calculation Grid after 2nd mapping

This process continues for each co-ordinate identified as part of the Site vessel area from the Site vessel areas array. The changes made to the Calculation array after each mapping using the grid smearing process are shown in Figures A2.6 through to A2.19.

7	0	0	0	0	10	10	0
6	0	0	0	10	10	10	0
5	2	3	10	10	10	4	3
4	3	5	10	10	7	6	5
3	4	6	10	10	10	8	6
2	5	7	9	<u>10</u>	<u>10</u>	9	7
1	4	6	8	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.6. Calculation Grid after 3rd mapping

7	0	0	0	0	10	10	0
6	3	4	5	10	10	10	0
5	5	6	10	10	10	4	3
4	6	8	10	10	7	6	5
3	7	9	<u>10</u>	10	10	8	6
2	6	8	9	<u>10</u>	<u>10</u>	9	7
1	5	6	8	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.7. Calculation Grid after 4th mapping

7	0	0	0	0	10	10	0
6	3	4	5	10	10	10	2
5	5	6	10	10	10	5	3
4	6	8	10	10	8	6	5
3	7	9	<u>10</u>	<u>10</u>	10	8	6
2	6	8	9	<u>10</u>	<u>10</u>	9	7
1	5	6	8	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.8. Calculation Grid after 5th mapping

7	0	0	0	0	10	10	0
6	3	4	5	10	10	10	3
5	5	6	10	10	10	6	5
4	6	8	10	10	9	8	6
3	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	7
2	6	8	9	<u>10</u>	<u>10</u>	9	7
1	5	6	8	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.9. Calculation Grid after 6th mapping

7	3	4	5	4	10	10	0
6	5	6	7	10	10	10	3
5	6	8	10	10	10	6	5
4	7	9	<u>10</u>	10	9	8	6
3	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	7
2	6	8	9	<u>10</u>	<u>10</u>	9	7
1	5	6	8	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.10. Calculation Grid after 7th mapping

7	3	4	5	5	10	10	2
6	5	6	7	10	10	10	3
5	6	8	10	10	10	6	5
4	7	9	<u>10</u>	<u>10</u>	9	8	6
3	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	7
2	6	8	9	<u>10</u>	<u>10</u>	9	7
1	5	6	8	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.11. Calculation Grid after 8th mapping

7	5	6	7	6	10	10	2
6	6	8	9	10	10	10	3
5	7	9	<u>10</u>	10	10	6	5
4	7	9	<u>10</u>	<u>10</u>	9	8	6
3	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	7
2	6	8	9	<u>10</u>	<u>10</u>	9	7
1	5	6	8	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.12. Calculation Grid after 9th mapping

7	5	6	7	7	10	10	3
6	6	8	9	10	10	10	4
5	7	9	<u>10</u>	<u>10</u>	10	7	5
4	7	9	<u>10</u>	<u>10</u>	9	8	6
3	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	7
2	6	8	9	<u>10</u>	<u>10</u>	9	7
1	5	6	8	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.13. Calculation Grid after 10th mapping

7	5	6	7	7	10	10	5
6	6	8	9	10	10	10	6
5	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	7
4	7	9	<u>10</u>	<u>10</u>	9	8	6
3	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	7
2	6	8	9	<u>10</u>	<u>10</u>	9	7
1	5	6	8	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.14. Calculation Grid after 11th mapping

7	5	6	8	9	10	10	5
6	6	8	9	<u>10</u>	10	10	6
5	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	7
4	7	9	<u>10</u>	<u>10</u>	9	8	6
3	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	7
2	6	8	9	<u>10</u>	<u>10</u>	9	7
1	5	6	8	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.15. Calculation Grid after 12th mapping

7	5	6	8	9	10	10	6
6	6	8	9	<u>10</u>	<u>10</u>	10	7
5	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	7
4	7	9	<u>10</u>	<u>10</u>	9	8	6
3	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	7
2	6	8	9	<u>10</u>	<u>10</u>	9	7
1	5	6	8	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.16. Calculation Grid after 13th mapping

7	5	6	8	9	10	10	8
6	6	8	9	<u>10</u>	<u>10</u>	<u>10</u>	9
5	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	8
4	7	9	<u>10</u>	<u>10</u>	9	8	6
3	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	7
2	6	8	9	<u>10</u>	<u>10</u>	9	7
1	5	6	8	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.17. Calculation Grid after 14th mapping

7	5	6	8	9	<u>10</u>	10	8
6	6	8	9	<u>10</u>	<u>10</u>	<u>10</u>	9
5	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	8
4	7	9	<u>10</u>	<u>10</u>	9	8	6
3	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	7
2	6	8	9	<u>10</u>	<u>10</u>	9	7
1	5	6	8	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.18. Calculation Grid after 15th mapping

7	5	6	8	9	<u>10</u>	<u>10</u>	9
6	6	8	9	<u>10</u>	<u>10</u>	<u>10</u>	9
5	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	8
4	7	9	<u>10</u>	<u>10</u>	9	8	6
3	7	9	<u>10</u>	<u>10</u>	<u>10</u>	9	7
2	6	8	9	<u>10</u>	<u>10</u>	9	7
1	5	6	8	9	<u>10</u>	9	7
y/x	1	2	3	4	5	6	7

Figure A2.19. Final Calculation Grid after 16th mapping

Figure A2.19 shows the Calculation grid after the final mapping has taken place for this example. This grid is now the 'grid smeared' Risk grid and would be saved as the new *.ttc* file. The grid shown in Figure A2.1 would be copied to the *.tto* file.

A.3 SITE VESSEL AREAS *.SIT* FILE FORMAT

RISKAT GUI version 3.1

X = 7

Y = 7

0,0,0,0,1,1,0

0,0,0,1,1,1,0

0,0,1,1,1,0,0

0,0,1,1,0,0,0

0,0,1,1,1,0,0

0,0,0,1,1,0,0

0,0,0,0,1,0,0

A.4 SAMPLE SMEARED *.TTC* FILE FORMAT

5

1 100

1 7 1 7 4 4

1 3

.30000 1.0000 10.000 SMEARV1.0

100.00

5.000 6.000 8.000 9.000 10.000 9.000 7.000

6.000 8.000 9.000 10.000 10.000 9.000 7.000

7.000 9.000 10.000 10.000 10.000 9.000 7.000

7.000 9.000 10.000 10.000 9.000 8.000 6.000

7.000 9.000 10.000 10.000 10.000 9.000 8.000

6.000 8.000 9.000 10.000 10.000 10.000 9.000

5.000 6.000 8.000 9.000 10.000 10.000 9.000

A.5 RISK MAP *.CSV* FILE FORMAT

RISKMAP V1.0 Risk of Dangerous Dose (or greater) in Chances per million per year

Y\X,1,2,3,4,5,6,7

7,0.50000,0.60000,0.80000,0.90000,1,1,0.90000

6,0.60000,0.80000,0.90000,1,1,1,0.90000

5,0.70000,0.90000,1,1,1,0.90000,0.80000

4,0.70000,0.90000,1,1,0.90000,0.80000,0.60000

3,0.70000,0.90000,1,1,1,0.90000,0.70000

2,0.60000,0.80000,0.90000,1,1,0.90000,0.70000

1,0.50000,0.60000,0.80000,0.90000,1,0.90000,0.70000

A.6 TOXMOD.BAT OPERATION

Call TTITLE.EXE
Call RISKIN.EXE
Call DENZ.EXE
Call CRUNCH.EXE
Call RISKAT.EXE
If *.sit* file is found - Call SMEAR.EXE
Call CNNS.EXE
Call RISKMAP.EXE
End TOXMOD

A.7 TOXMOD2.BAT OPERATION

If *.sit* file is found - Call SMEAR.EXE
Call CNNS.EXE
Call RISKMAP.EXE
End TOXMOD2