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Framework and tools for local flood risk
assessment: software user guide

SC070059/R4

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Miranda Kavanagh
Director of Evidence

Contents

1	Introduction	1
2	Software overview	2
3	System requirements	3
4	LFRA Calculator	4
4.1	Installation	4
4.2	Overview	5
4.3	Getting started	5
4.4	Additional functionality and frequently asked questions	18
5	LFRA Viewer	30
5.1	Installation	30
5.2	Overview	32
5.3	Getting started	32
5.4	Additional functionality and frequently asked questions	38
References		43
List of abbreviations		44
Table 4.1 Summary of the damage calculation process		25
Figure 2.1	Structure and work flow of prototype software tools	2
Figure 4.1	Location of the installed LFRA Calculator software in Windows Explorer	4
Figure 4.2	LFRA Calculator main form	6
Figure 4.3	LFRA Calculator Set Project Name form	7
Figure 4.4	LFRA Calculator Set Working Geo-database form	8
Figure 4.5	LFRA Calculator Set Area of Interest form	9
Figure 4.6	LFRA Calculator Set Reporting Units form	10
Figure 4.7	LFRA Calculator Select Flooding Datasets form	12
Figure 4.8	LFRA Calculator Select Receptor Datasets form	13
Figure 4.9	LFRA Calculator Define Basic Metrics form	15
Figure 4.10	LFRA Calculator Define Extended Metrics form	16
Figure 4.11	Running the LFRA Calculator	17
Figure 4.12	Using building footprint polygons to count affected properties in the LFRA Calculator software. Properties A and C fall entirely within reporting units (RUs) 1 and 4 respectively and are therefore easy to attribute to a particular reporting unit. However, property B overlaps RUs 1 and 3 and could potentially be counted in both reporting units which, if occurring frequently, would lead to exaggerated counts of affected properties. Yet because the corresponding "centroid" point (red dot) is within RU 3, property B is only counted with this reporting unit by the software.	19
Figure 4.13	LFRA Calculator settings for using building footprint polygons to count affected properties	20
Figure 4.14	Using Environment Agency Flood Map for Surface Water data to count affected properties	20
Figure 4.15	LFRA Calculator settings for extracting flood depth information at individual properties (Option 1)	21
Figure 4.16	Property level depth analysis with buildings (a, b) included or (c) removed from the computational mesh. Building footprint polygons and property points are shown as black outlines and red points respectively. The "analysis buffer" of user-defined width is displayed using a red hatching pattern.	22
Figure 4.17	LFRA Calculator settings for extracting flood depth information at individual properties (Option 2)	23
Figure 4.18	LFRA Calculator settings for extracting flood depth information at individual properties (Option 3)	24
Figure 4.19	LFRA Calculator settings for calculating economic damage to properties	27
Figure 4.20	Approximation of annual average risk based on a limited number of system simulations. The vertical axis is a flood risk metric (such as economic damage, number of residential properties flooded). The AEP refers to the probability weight attached to the system simulation used to calculate the flood risk metric.	28

Figure 4.21 LFRA Calculator settings for calculating annual average quantities	29
Figure 5.1 Location of the installed LFRA Viewer software in Windows Explorer	30
Figure 5.2 Running the “Register LFRAViewer.bat” file	31
Figure 5.3 Installing the LFRA Viewer in ArcMap 9.3 (Step 1 – Using the Customize form)	31
Figure 5.4 Installing the LFRA Viewer in ArcMap 9.3 (Step 2 – Adding the software icon to a Toolbar)	32
Figure 5.5 LFRA Viewer main user interface	34
Figure 5.6 LFRA Viewer map layout	34
Figure 5.7 LFRA Viewer settings for identifying flood risk hotspots	36
Figure 5.8 LFRA Viewer settings for prioritising flood risk hotspots	37
Figure 5.9 Select a reporting unit (shown with a blue border) from the map layout in order to view depth information extracted at individual receptors within that reporting unit	39
Figure 5.10 Depth of flooding at individual receptors within a selected reporting unit	39
Figure 5.11 Viewing annual average damages within the LFRA Viewer	40
Figure 5.12 ArcCatalog view of the base mapping geo-database “OS_OpenData.gdb”	41

1 Introduction

This project, *Framework and Tools for Local Flood Risk Assessment*, falls under the Modelling and Risk Theme within the Department for Environment, Food and Rural Affairs (Defra) and Environment Agency joint Flood and Coastal Risk Management (FCRM) research and development programme. The project aimed to produce a framework, methods, and prototype software tools to help local authorities better understand and manage flood risk in their area.

The prototype software tools were developed to demonstrate the functional implementation of the risk assessment methods set out in the final project report (SC070059/R3). These “proof of concepts” are not intended to be business-ready software applications, which would require more precise specification of how they would be used and by whom. Instead, they are designed to be useable by third parties for evaluation and demonstration purposes, provided they meet certain operating system and software dependency criteria (see Section 3) and comply with licensing arrangements. In Section 6 of the final project report, the tools have been demonstrated using case study data for two hypothetical cases but, as prototypes, have not undergone formal testing and acceptance procedures as set out in Defra/Environment Agency (2007).

This report is a “quick start” user guide to the prototype software tools developed in Phases 2 and 3 of the project.

2 Software overview

In terms of software, this project has created two tools:

1. A **Calculator** for deriving flood risk indicator and undertaking property-level depth-damage analysis
2. A **Viewer** for efficient interrogation and presentation of the calculator outputs.

These two tools can be used to implement the risk assessment methods set out in Section 4 of the final project report (SC070059/R3). The structure and work flow of the software is shown in Figure 2.1.

It is necessary to calculate and analyse the flood risk indicators and depth-damage results using separate software tools as these can be time-consuming to compute, particularly for large, geometrically complex datasets such as national flood maps or very high resolution raster depth maps. Performing these calculations together within a single software tool is therefore not practicable for large areas and/or detailed inputs.

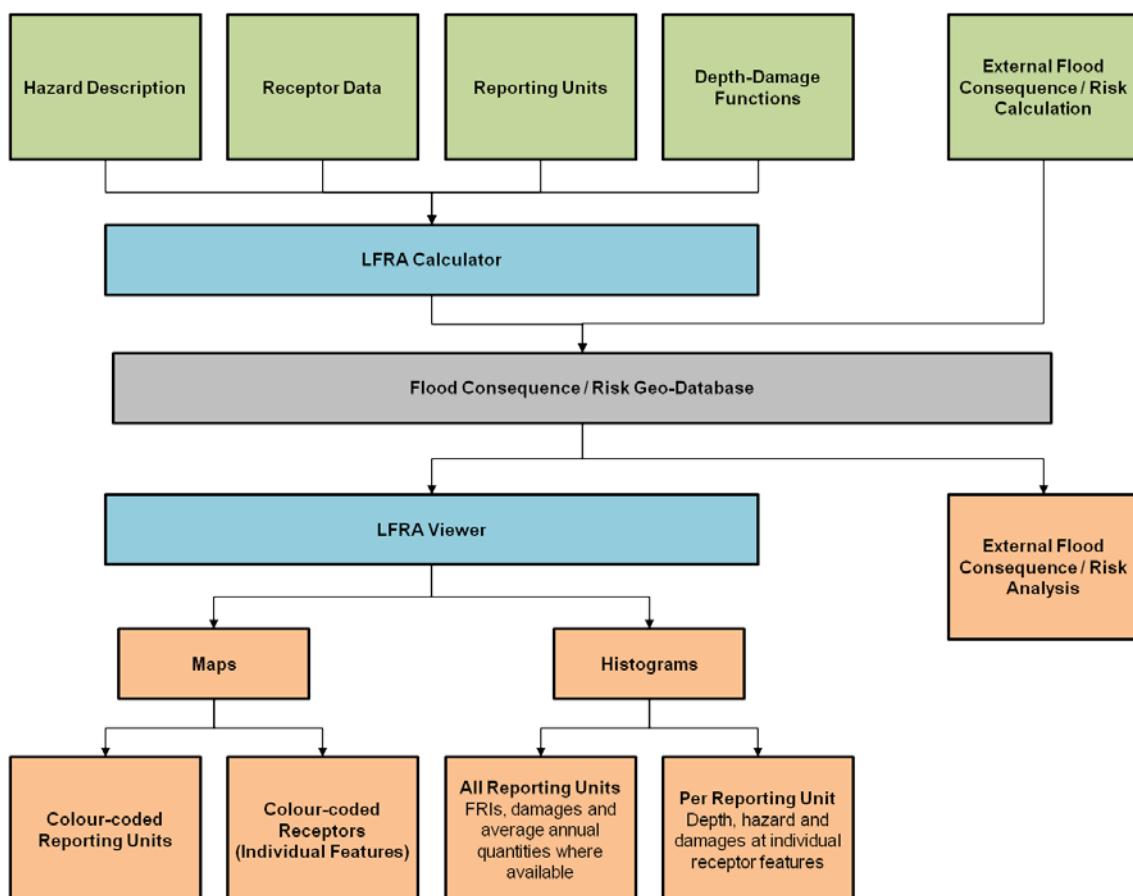


Figure 2.1 Structure and work flow of prototype software tools

3 System requirements

The prototype software tools have been developed as “add-ins” for ArcGIS 9.3 only. Certain depth map processing functionality within the software tools also requires the ArcGIS Spatial Analyst extension. Development and testing has been done on a 32-bit Windows XP operating system.

Not all users will have access to ArcGIS and this will need to be considered in any further development of the prototypes into operational products. However, outputs from the calculator and viewer software can be exported to other Geographical Information Systems (such as MapInfo) or drafting (such as AutoCAD) software using built-in format conversion tools, such as ArcToolbox or Universal Translator.

4 LFRA Calculator

4.1 Installation

Installation of the Local Flood Risk Assessment (LFRA) Calculator is straightforward. Create a new folder on the **C: drive** of the user's PC called "LFRA Calculator" (ensuring that there is a space between the two words). Copy the "LFRAcalculator.zip" file from the installation disk to the "C:LFRA Calculator" folder and extract the contents as shown in Figure 4.1.

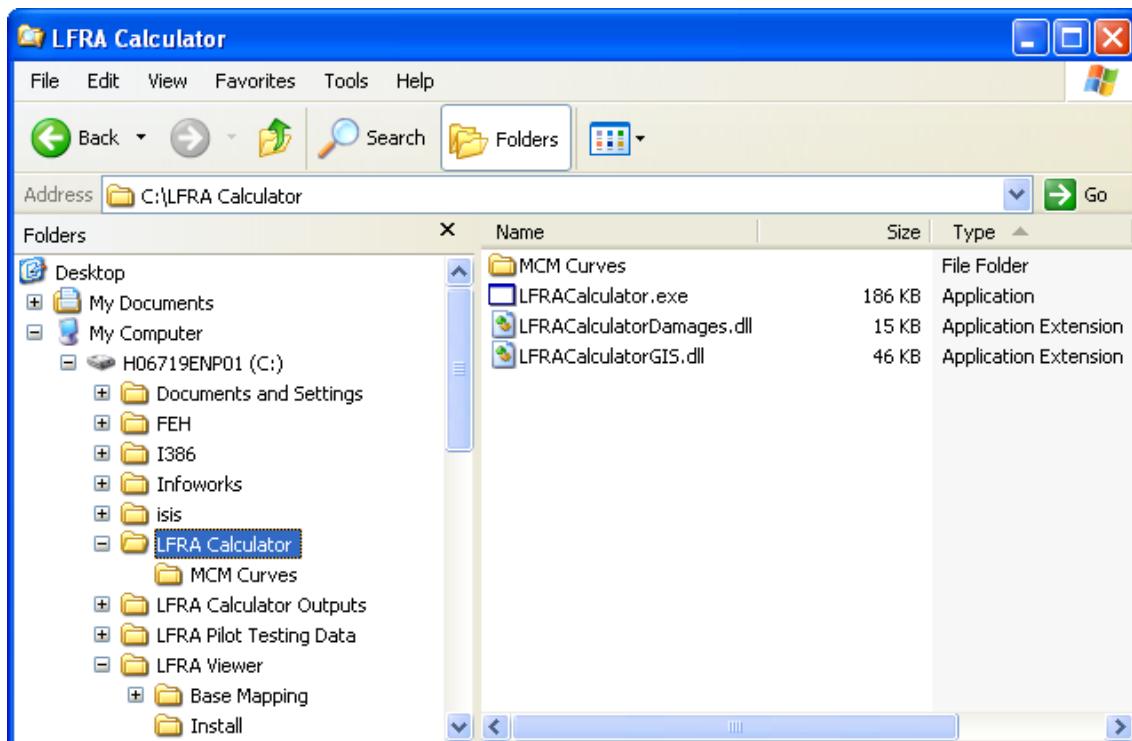


Figure 4.1 Location of the installed LFRA Calculator software in Windows Explorer

It is assumed that ArcGIS 9.3 has been installed previously.

4.2 Overview

The LFRA Calculator software provides a functional implementation of the methods described in Sections 4.3.1-4.3.4 and 4.4.1-4.4.4 of SC070059/R3. Therefore it can:

- spatially query flood extent outlines against receptor data to determine counts, lengths and areas of affected receptors within a set of reporting units;
- attribute representative depth and hazard rating information to individual properties and assets and calculate economic damages where suitable functions exist or have been defined by the user;
- evaluate annual average quantities of flood risk metrics and damages where multiple, probability-weighted scenarios are available.

The LFRA Calculator also offers users total flexibility to apply this software to whatever flood risk information has been agreed by local FCRM partners and report the outputs on locally chosen spatial units. Inputs, which can be supplied in any ArcGIS-supported format, consist of:

- a description of the hazard, provided by national flood maps from the Environment Agency or locally-available modelling;
- point, polyline or polygon receptor data provided, for example, by locally-validated/augmented subsets of the National Receptor Dataset;
- a set of reporting unit polygons (such as regular grids or irregular catchments/administrative units) that are subsequently attributed with the flood risk indicators calculated for each unit;
- Flood Hazard Research Centre (FHRC) Multi-Coloured Manual (MCM) or user-defined depth-damage functions (optional unless depth information is provided and damage estimates are required).

As such, the LFRA Calculator, even in prototype form, provides a powerful, flexible means of implementing the risk assessment methods outlined in SC070059/R3. However the software has no knowledge of, or means of capturing, the quality of the input data or modelling approaches/data collection strategies used to derive it. Therefore, the adage “garbage in, garbage out” is appropriate here.

4.3 Getting started

Section 4.3 provides step-by-step instructions for calculating flood risk metrics across a study area using national flood risk datasets available to all, such as the Environment Agency flood maps and National Receptor Dataset. At the end of Step 9, the LFRA Calculator produces an ArcGIS-compatible geo-database that can be read directly into the LFRA Viewer software (Section 5).

Browse to the “C:\LFRA Calculator” folder and double click on the file “LFRACalculator.exe” to launch the software. You should see the following display:

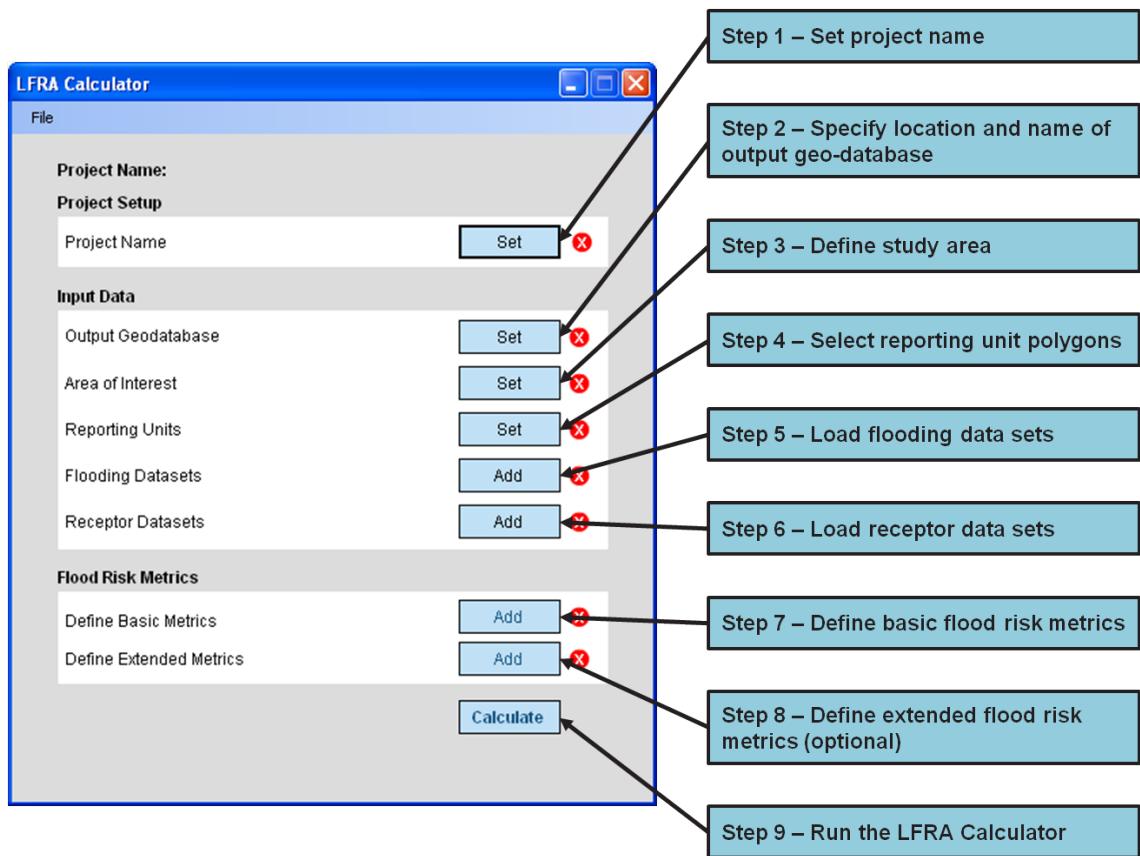


Figure 4.2 LFRA Calculator main form

As shown in Figure 4.2, the main form of the LFRA Calculator is designed to be worked through sequentially. Each of the nine steps is described in more detail below, while additional functionality and frequently asked questions are covered in Section 4.4.

4.3.1 Step 1 – Set project name

Click on the “Set” button, highlighted red in Figure 4.3, and enter a *Project Name* (mandatory) and *Project Description* (optional) into the corresponding text boxes. Project names can include uppercase and lowercase letters, numbers, spaces, hyphens and underscores. Click “OK” and the *Project Name* text should appear at the top of the LFRA Calculator main form.

Once Step 1 has been completed successfully, a green “tick” icon will appear alongside the “Set” button (see Figure 4.4). If you wish to edit either text entries at any time during the project set-up, click “Set”, make the necessary changes and click “OK” to accept.

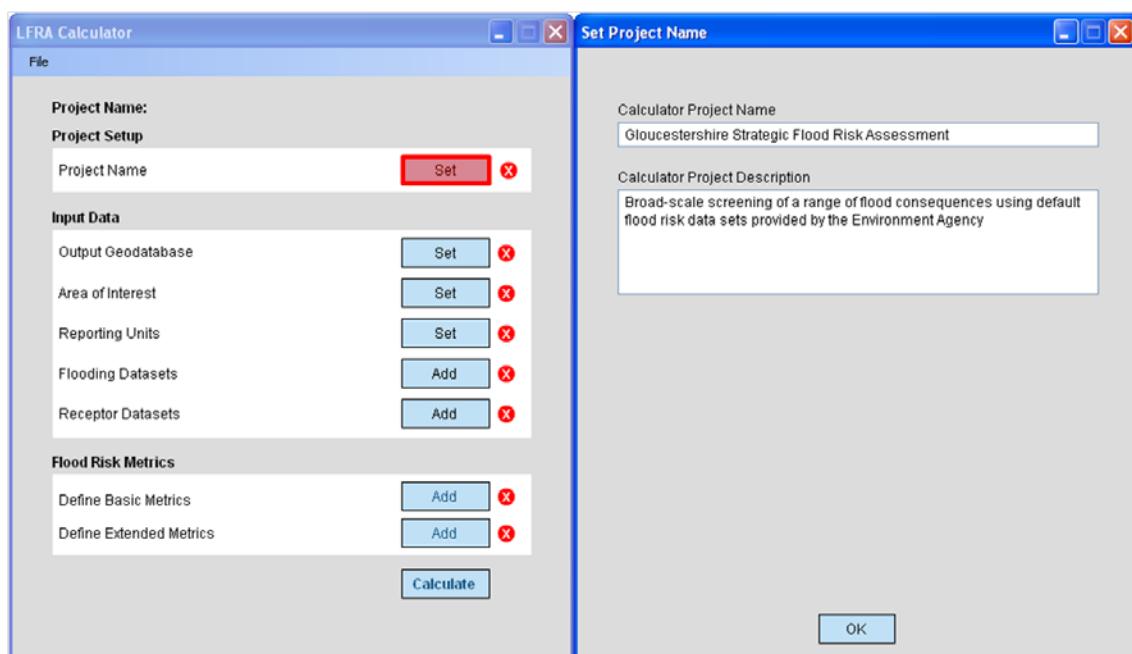


Figure 4.3 LFRA Calculator Set Project Name form

4.3.2 Step 2 – Specify location and name of output geo-database

Click on the “Set” button, highlighted red in Figure 4.4, and either type or use the “...” browse button to select the location where the geo-database will be created. Enter the name of the geo-database (with or without the .gdb extension) in the *Geodatabase Name* text box and click “OK”. Uppercase and lowercase letters, numbers, spaces, hyphens and underscores can all be used in the name. A green “tick” icon will appear alongside the “Set” button once Step 2 has been completed successfully.

In the example shown in Figure 4.4, a geo-database called “Gloucestershire_SFRA.gdb” will be created in the “C:\LFRA Calculator Outputs” folder.

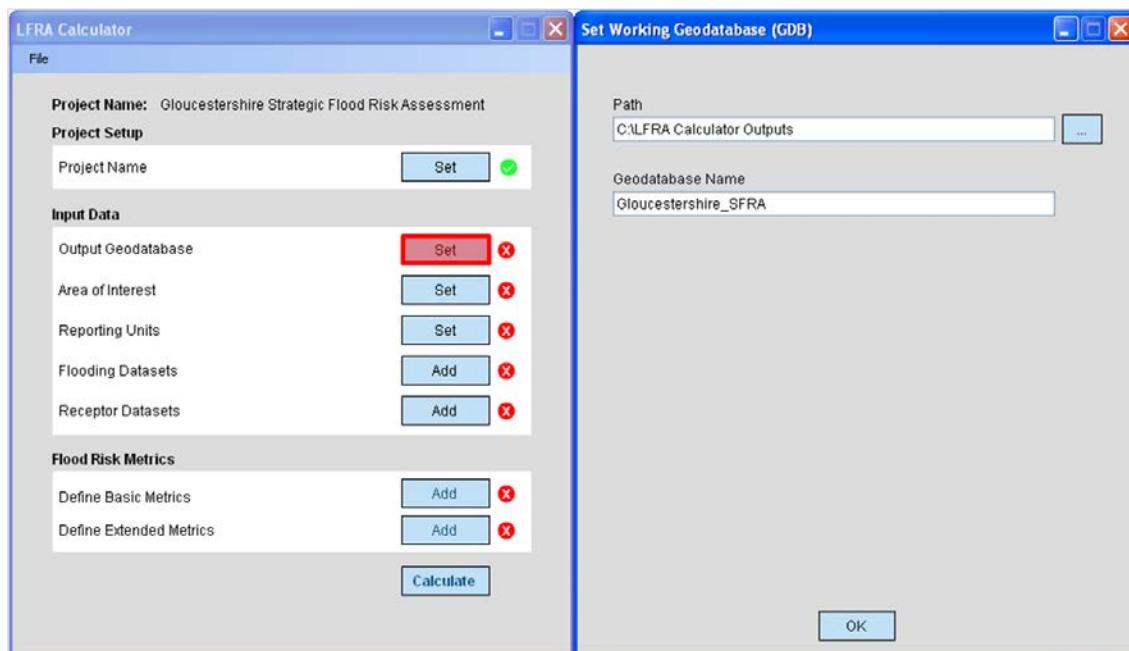


Figure 4.4 LFRA Calculator Set Working Geo-database form

4.3.3 Step 3 – Define study area

Click on the “Set” button, highlighted red in Figure 4.5, and use the “...” browse button to select an ArcGIS-compatible polygon data set (either a .shp file or geo-database feature class) that contains the study area boundary.

If the projection of polygon dataset is already defined as British National Grid, the *Spatial Reference* text box will populate automatically as shown in Figure 4.5. If the projection of the dataset has not been defined (*Spatial Reference* = “Unknown”), use the “...” browse button to select the predefined projection file “British National Grid.prj” from the library (typically) found in “C:\Program Files\ArcGIS\Coordinate Systems\Projected Coordinate Systems\National Grids”. Click “Next >” on the *New Spatial Reference* form and then “Finish” to accept the default parameters. “British_National_Grid” should now appear in the *Spatial Reference* text box.

Alternatively, check the *Extent of Interest* radio button and enter British National Grid coordinates in the *X Min*, *Y Min*, *X Max*, *Y Max* text boxes to define a rectangular window of interest. Use the “...” browse button next to the *Spatial Reference* text box to set the coordinate system to British National Grid as above.

Click “OK” and a green “tick” icon will appear alongside the “Set” button once Step 3 has been completed successfully.

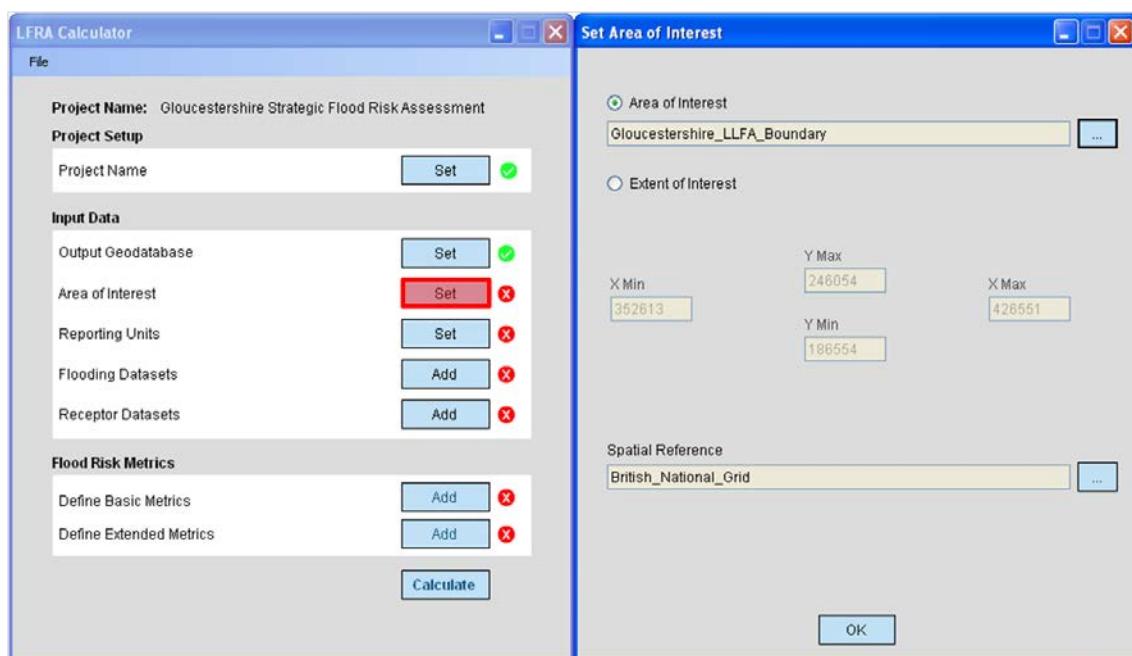


Figure 4.5 LFRA Calculator Set Area of Interest form

4.3.4 Step 4 – Select reporting unit polygons

Reporting units are a set of polygons for which counts, lengths and areas of affected receptors will be calculated and reported for each polygon feature. Reporting units can be regular grids, such as that used to support the identification of indicative Flood Risk Areas as part of the England and Wales Preliminary Flood Risk Assessments (PFRA), or they can be irregular drainage catchments or administrative units (such as districts, wards or parishes). Regardless of their shape, each reporting unit is required to be a separate polygon object.

Click on the “Set” button, highlighted red in Figure 4.6, to open the *Set Reporting Units* form. The default reporting units are one-km regular grid squares, although the option to use a 100-m resolution grid is available from the drop-down menu. The LFRA Calculator will use the study boundary defined in Step 3 to automatically create a fitted grid of regular one-km/100-m reporting units that also aligns with, and snaps to, the British National Grid.

Alternatively, check the *User-Defined Reporting Units* radio button and use the “...” browse button to select a suitable polygon dataset. There are no restrictions on the number, size or shape of user-defined reporting unit polygons but they must cover the whole study area.

Click “OK” and a green “tick” icon will appear alongside the “Set” button once Step 4 has been completed successfully.

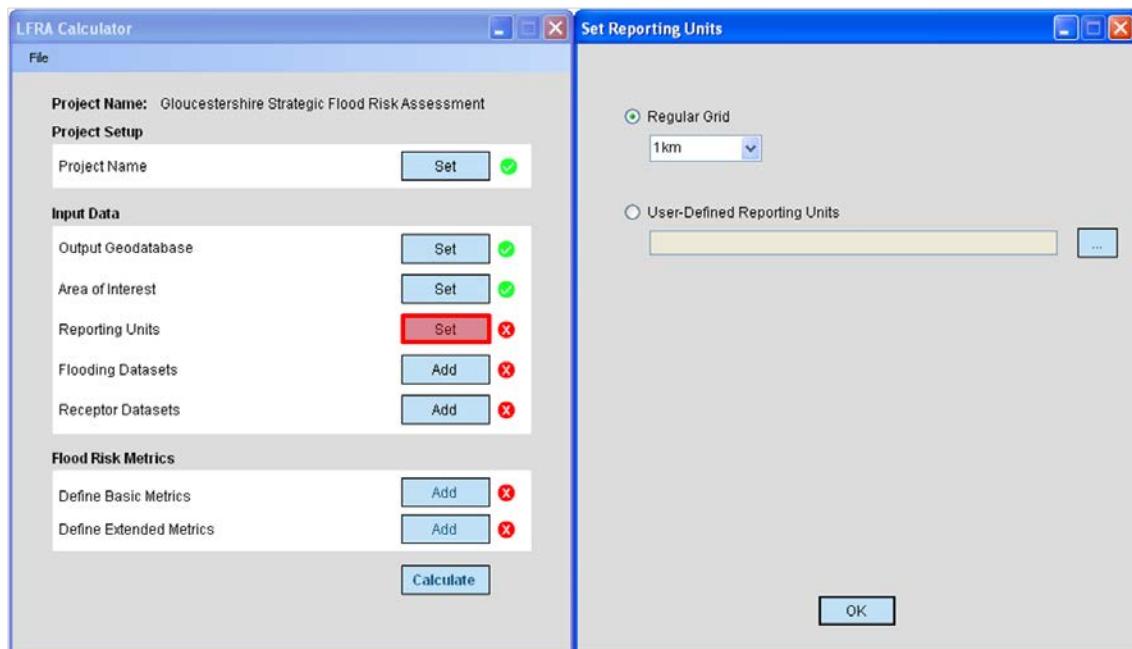


Figure 4.6 LFRA Calculator Set Reporting Units form

4.3.5 Step 5 – Load flooding datasets

In the example shown in Figure 4.7, a set of flood risk metrics (defined in Steps 7 and 8 below) will be calculated for two flood map datasets:

1. “Intermediate” susceptibility band of the Areas Susceptible to Surface Water Flooding (AStSWF) map.
2. Flood Zone 3 of the fluvial and coastal Flood Map.

As a result, each reporting unit will have counts/lengths/areas of affected receptors associated with each flood map dataset. There is no restriction on the number of flood maps that can be processed in a single project, but obviously more maps will take longer to process.

Click on the “Add” button, highlighted red in Figure 4.7, to open the *Select Flooding Datasets* form.

Enter a short description of the common theme that links the flood map datasets to be analysed in the *Flood Map/Model Group* text box (in this case, “Environment Agency Flood Maps”).

From the *Flood Map Type* drop-down menu, select the most appropriate description of the flood map data structure and information content (in this case, “Polygon Outlines”).

Click on the “Add” button and select the flood map datasets to be analysed. These can be added one at a time or as a batch from the same location by holding down either the Shift or Control key and selecting items with a left mouse click. A label can be attached to each flood map by editing the corresponding text in the *Scenario* column (defaults to S1, S2, ...). It is this label which is used to identify flood risk metrics associated with a particular flood map in the *Scenario/Event* drop-down menu in the LFRA Viewer software (see Section 5.3.2). Scenario labels can include uppercase and lowercase letters, numbers, spaces, hyphens and underscores. Added flood map data sets can also be removed from the project using the “Remove” button.

In this simple example, leave the *Assign Event Probability (EP)?* and *Buildings Modelled As Voids?* check boxes unchecked. Their functionality is explained later in Sections 4.4.5 and 4.4.2 respectively.

Click “OK” and a green “tick” icon will appear alongside the “Add” button once Step 5 has been completed successfully.

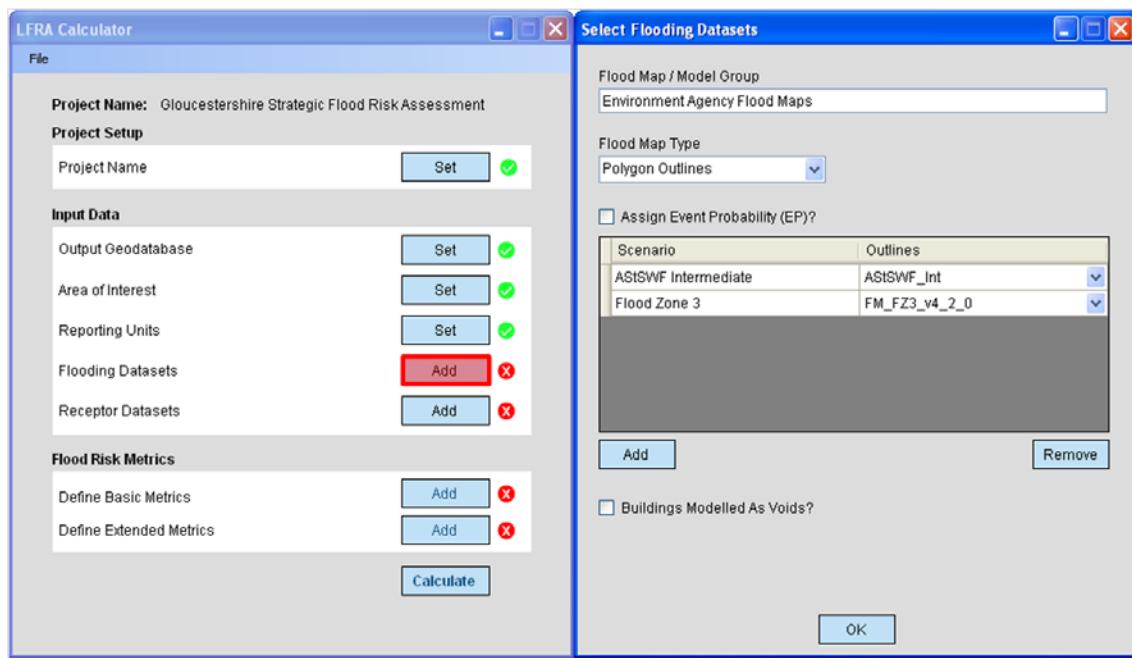


Figure 4.7 LFRA Calculator Select Flooding Datasets form

4.3.6 Step 6 – Load receptor datasets

Click on the “Add” button, highlighted red in Figure 4.8, to open the *Select Receptor Datasets* form.

Use the “Add” browse button to select ArcGIS-compatible point, polyline and/or polygon datasets (either .shp files or geo-database feature classes) that contain the receptor information to be analysed. These can be added one at a time or as a batch from the same location by holding down either the Shift or Control key and selecting items with a left mouse click. Added receptor datasets can also be removed from the project using the “Remove” button.

As datasets are added, the *Receptors* and *Geometry Type* columns will populate automatically for each item as shown in Figure 4.8. Once all the receptor data that you may wish to analyse are loaded, click “OK” and a green “tick” icon will appear alongside the “Add” button.

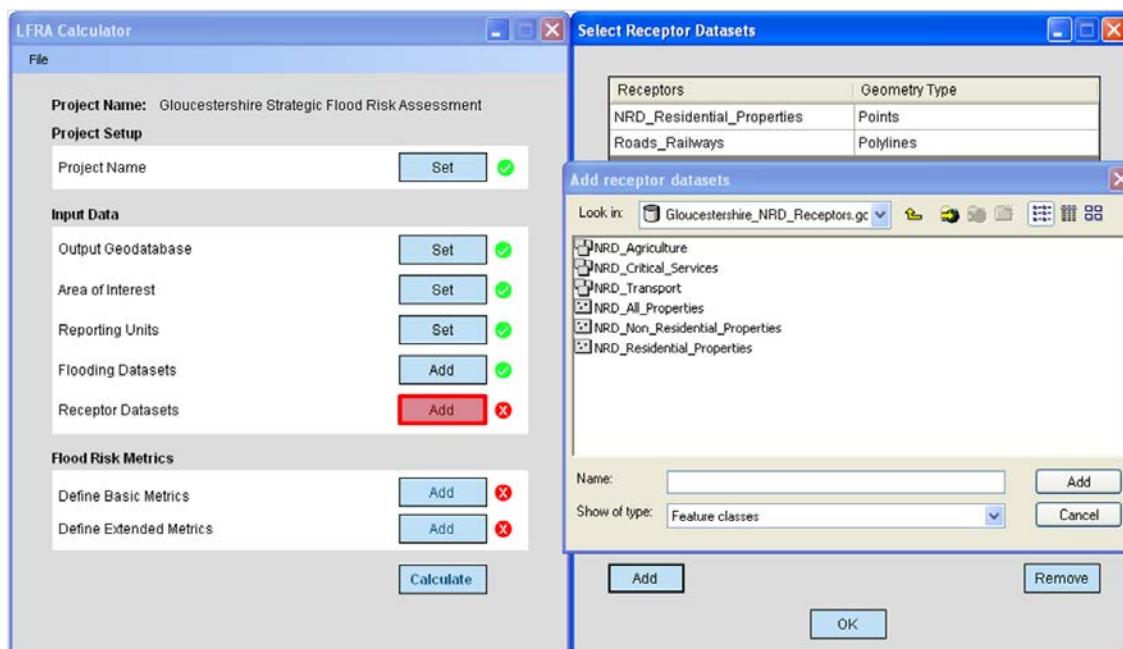


Figure 4.8 LFRA Calculator Select Receptor Datasets form

4.3.7 Step 7 – Define basic flood risk metrics

In Step 7, flood risk metrics are defined using some or all of the data loaded in the previous step. For flood extent polygons, there are three principal types of flood risk metric that can be calculated depending on the geometry type of the receptor data. These are:

- a simple **count** of property or asset points in an outline (note that properties can also be identified by their footprint which is discussed in Section 4.4.2);
- the **length** of key infrastructure within an outline;
- the **area** of a special designation within an outline.

Click on the “Add” button, highlighted red in Figure 4.9, to open the *Define Basic Metrics* form. Each flood risk metric (count, length or area of affected receptors) is then defined individually using the *Define Basic Metrics* sub-form (click “Add” to open).

First, chose a receptor dataset loaded in Step 6 from the *Receptor Dataset* drop-down menu. The *Receptor Geometry Type* field will populate automatically and, if it is a polyline or polygon dataset, a SI unit of measurement should also be selected from the *Metric Units* drop-down menu.

Second, assign the metric to one of four “impact categories” using the *Metric Category* drop-down menu. These categories are used to group metrics within the LFRA Viewer software (see Section 5.3.2) and can help to provide evidence of a balanced assessment of the economic, social and environmental consequences of flooding.

Finally, an appropriate *Metric Name* should be entered in the corresponding text box. It is this label which is used to identify particular flood risk metrics in the *Flood Risk Metric* drop-down menu in the LFRA Viewer software. Metric names can include uppercase and lowercase letters, numbers, spaces, hyphens and underscores. Where appropriate, the metric name will also be automatically appended with a symbol describing the chosen metric unit (e.g. “[m]” for the example shown in Figure 4.9).

Click “OK” and summary details of the flood risk metric will be added to the two-column table in the main *Define Basic Metrics* form. Additional metrics can be defined as required following the same process, while existing metrics can be reviewed, modified or removed using the “View” and “Remove” buttons respectively.

Once all the metrics that you wish to calculate have been defined, click “OK” and a green “tick” icon will appear alongside the “Add” button on LFRA Calculator main form.

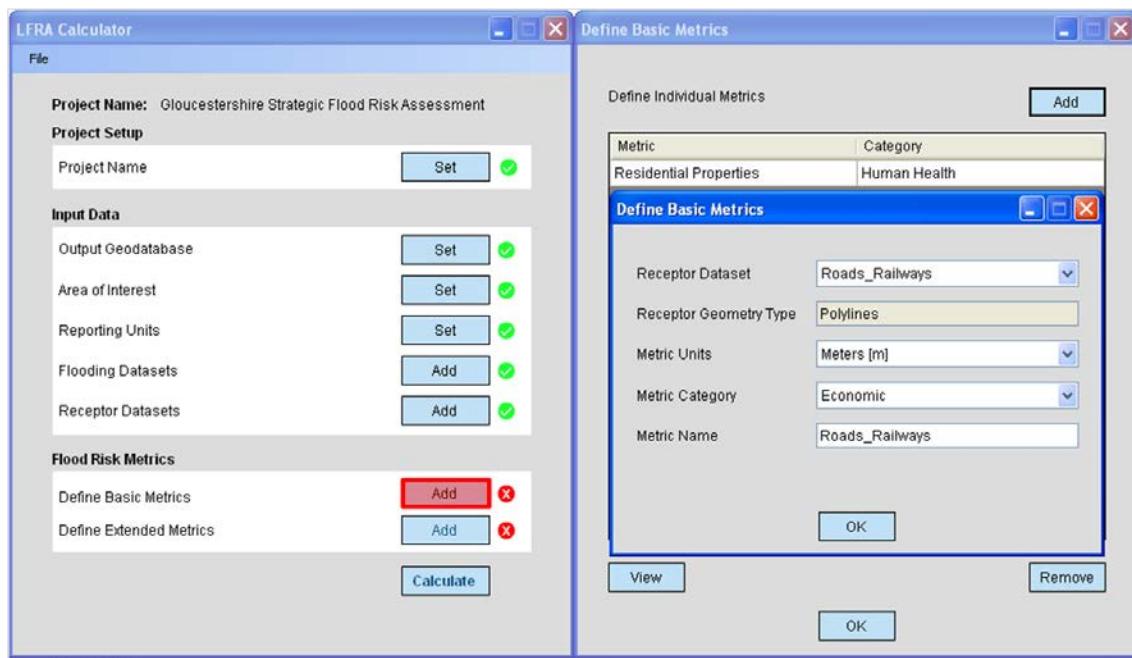


Figure 4.9 LFRA Calculator Define Basic Metrics form

4.3.8 Step 8 – Define extended flood risk metrics (optional)

Flood risk metrics can simply be counts, lengths or areas of the various geometries that fall within each of the reporting units, or may require additional processing (or “extending”) to produce the final indicator value. For example, for the England and Wales PFRA, the number of people at risk of flooding within each one-km square reporting unit was calculated by multiplying the count of residential properties flooded by 2.34.

Click on the “Add” button, highlighted red in Figure 4.10, to open the *Define Extended Metrics* form. Each extended flood risk metric is then defined using the “calculator” tool in the *Define Extended Metrics* sub-form (click “Add” to open) and assigned a *Metric Category* and *Metric Name*. Metric names can include uppercase and lowercase letters, numbers, spaces, hyphens and underscores.

Once all the extended metrics that you wish to calculate have been defined, click “OK” and a green “tick” icon will appear alongside the “Add” button on LFRA Calculator main form.

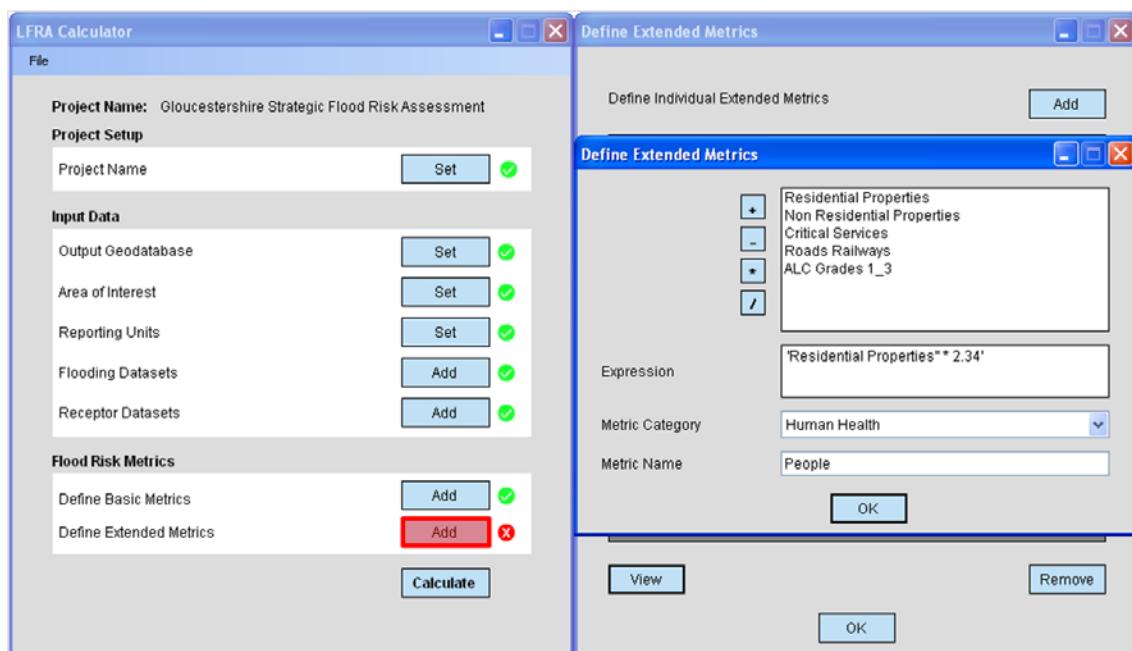


Figure 4.10 LFRA Calculator Define Extended Metrics form

4.3.9 Step 9 – Run the LFRA Calculator

Once you have completed Steps 1-7 (mandatory) and Step 8 (optional), the LFRA Calculator project is ready to run.

Click on the “Calculate” button, highlighted red in Figure 4.11, and the read-only *Log File/Calculation Progress* window and “Calculating...” progress bar will appear. Once the geo-processing has started, a record of all activity is written to the *Log File/Calculation Progress* window and a Calculator Log File (in this case, “Gloucestershire_SFRA_CLF.txt”). This log file is written to a “Project Files” sub-folder that will be created automatically in the same location as the output geo-database (defined in Step 2 as “C:\LFRA Calculator Outputs”).

A separate Calculator Project File (Gloucestershire_SFRA_CPF.txt) is also written to the “Project Files” folder that contains details of all the input datasets and flood risk metrics to be calculated. As well as providing an important audit record, this file can be used to re-run a previous analysis (see Section 4.4.6 for more details).

LFRA Calculator run times can vary from minutes to days and depend primarily on:

- computer hardware specification (processor speed and memory);
- number, size and topological complexity of flood map and receptor datasets to be processed.

Once the calculation has finished, the LFRA Calculator produces an ArcGIS-compatible geo-database that can be read directly into the LFRA Viewer software (Section 5.3.1). To stop the software mid-calculation, click on the cross in the top right corner of the *LFRA Calculator* main form and accept the resulting warning messages. **Note that the results of any geo-processing up to that point will be lost.**

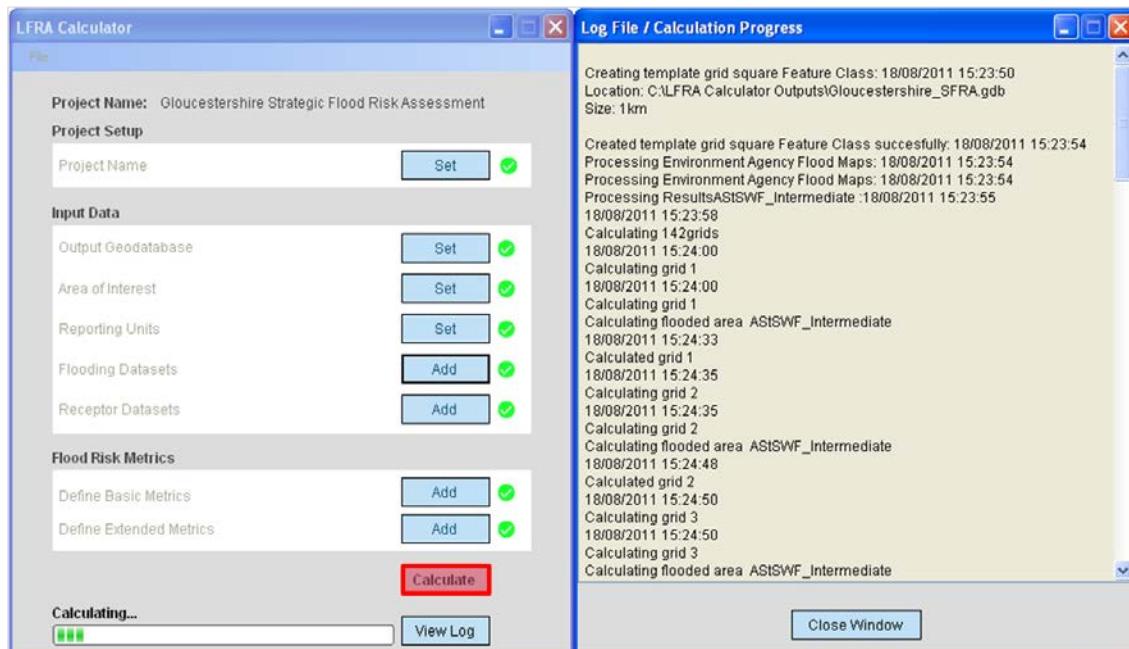


Figure 4.11 Running the LFRA Calculator

4.4 Additional functionality and frequently asked questions

Section 4.4 provides answers to the following common questions regarding the functionality of the LFRA Calculator software:

- Can I use outlines from historical flood events?
- Can I use building footprint polygons to count affected properties?
- Can I extract flood depth information at individual properties?
- Can I calculate economic damage to properties?
- Can I calculate annual average damages?
- Can I use flood extent polygons and raster depth maps in the same LFRA Calculator project?
- Can I save work in progress or modify and re-run a previous analysis?
- What should I do if the software crashes?

4.4.1 Can I use outlines from historical flood events?

Yes, the software can help to quantify the impacts of historical flood events provided their extent is satisfactorily described by an ArcGIS-compatible polygon dataset.

Each historical flood map should be saved as a separate polygon dataset but multiple events can be analysed simultaneously within the same LFRA Calculator and Viewer projects.

4.4.2 Can I use building footprint polygons to count affected properties?

Yes. The LFRA Calculator requires two ArcGIS-compatible datasets to count properties as per the “Detailed GIS” method set out in the Environment Agency (2010) guidance.

1. A **polygon** dataset containing the building footprints, which can be obtained from Ordnance Survey mapping products (such as MasterMap) or extracted from the simulation model geometry depending on how buildings have been represented in the calculation mesh.
2. A **point** dataset containing a “centroid” for each building polygon. The point data is required to ensure that affected properties are only attributed to one reporting unit in cases where the building footprints overlap more than one reporting unit (see Figure 4.12). Each point must lie somewhere within a building footprint and can be extracted from national or locally-available property point datasets or be calculated automatically at the centroid of each polygon within ArcMap. **Building footprints without a corresponding “centroid” point will not be counted by the LFRA Calculator.**

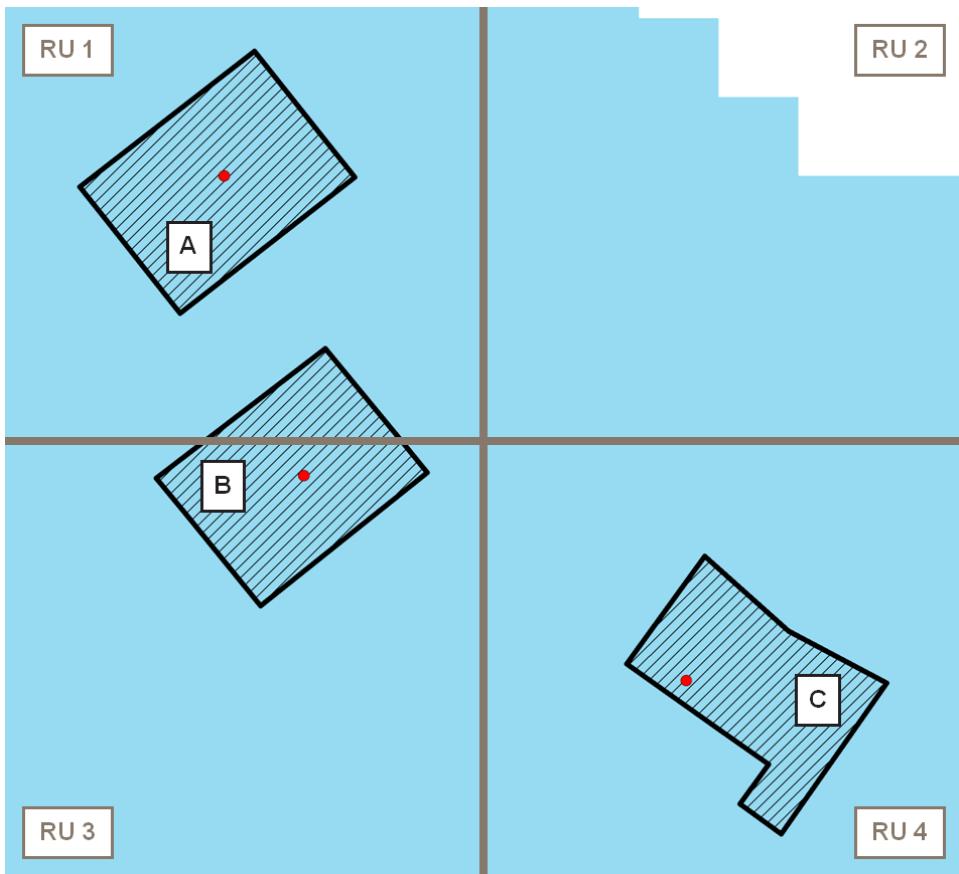


Figure 4.12 Using building footprint polygons to count affected properties in the LFRA Calculator software. Properties A and C fall entirely within reporting units (RUs) 1 and 4 respectively and are therefore easy to attribute to a particular reporting unit. However, property B overlaps RUs 1 and 3 and could potentially be counted in both reporting units which, if occurring frequently, would lead to exaggerated counts of affected properties. Yet because the corresponding “centroid” point (red dot) is within RU 3, property B is only counted with this reporting unit by the software.

The polygon dataset containing the building footprints is referenced in the *Select Flooding Datasets* form (see Figure 4.13). Check the *Buildings Modelled As Voids?* check box and use the “...” browse button to select a suitable polygon dataset. Set the *Buffer Distance (m)* to zero.

The point dataset containing the centroid for each building polygon is referenced in the *Define Basic Metrics* form as per Step 7 above. The LFRA Calculator will automatically link the polygon and point datasets based on their spatial relationship and there is no need to manually develop a common “join” field for the two datasets.

The same approach can also be used to count properties using the Environment Agency’s Flood Map for Surface Water data in which buildings have been explicitly modelled as unfloodable objects (see Figure 4.14). The building “mask” used in the national modelling is not (currently) available to professional partners and so an additional post processing procedure was developed to enable property counts using this mapping. The resulting arc-shaped artefacts that extend the flood outline into the building footprints are clearly visible in Figure 4.14.

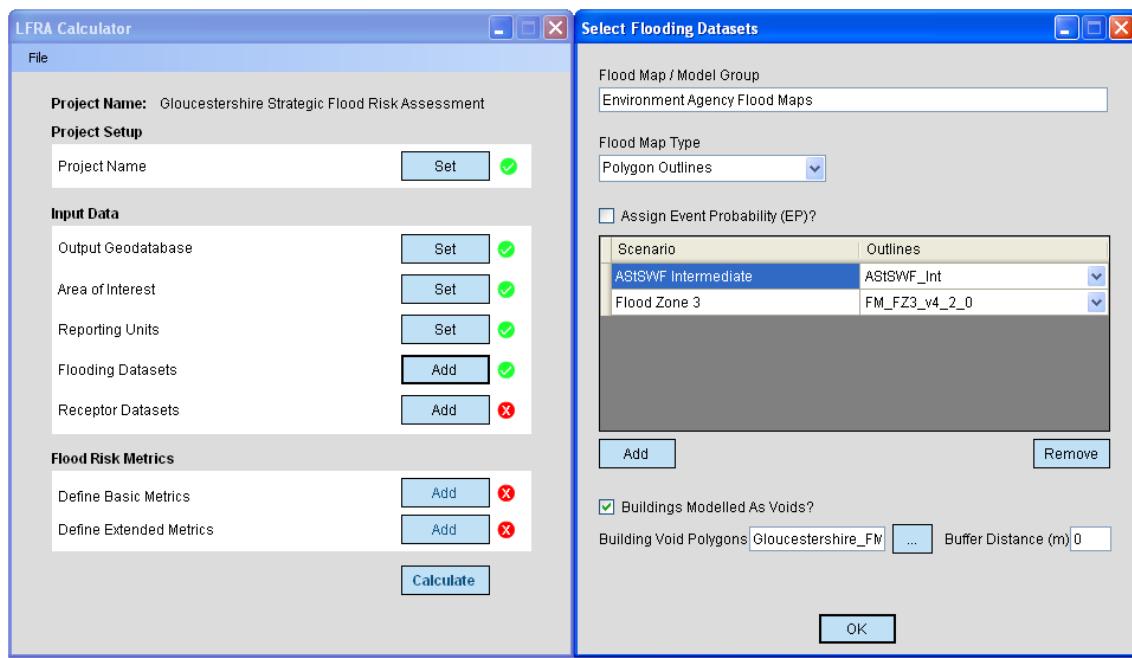


Figure 4.13 LFRA Calculator settings for using building footprint polygons to count affected properties

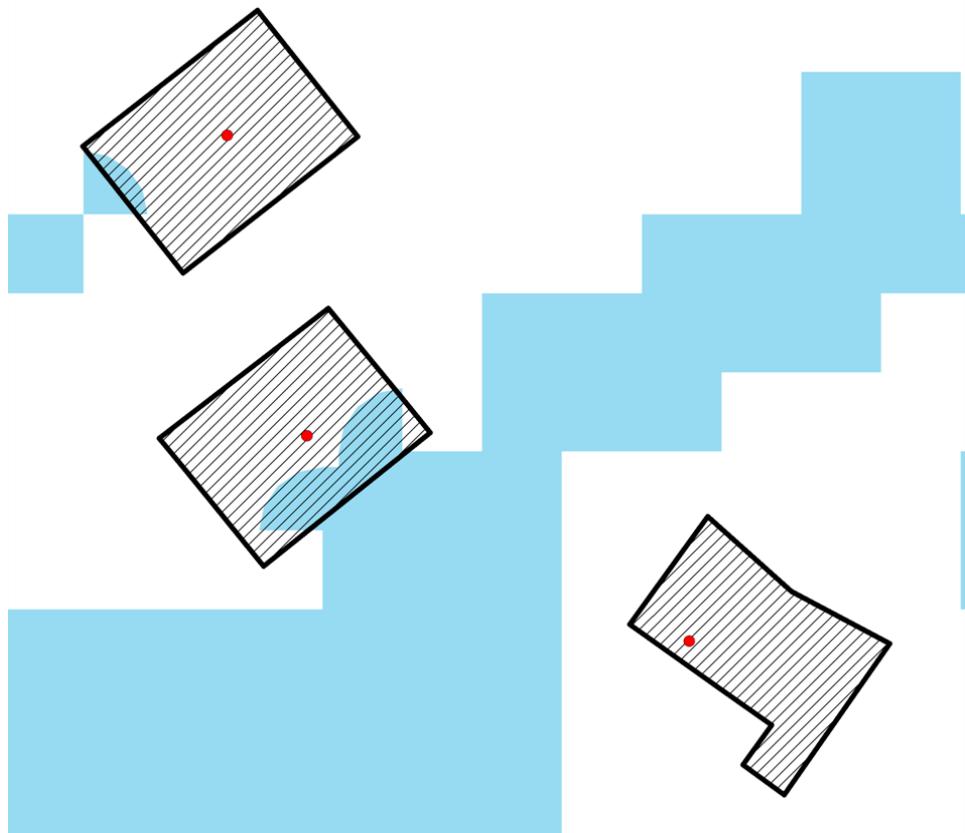


Figure 4.14 Using Environment Agency Flood Map for Surface Water data to count affected properties

4.4.3 Can I extract flood depth information at individual properties?

Yes, provided depth information is available in either ESRI Grid or ASCII raster format for the area of interest.

There are **three** ways in which depth can be determined at individual properties and the choice of method will depend on how the receptor features are described, both in the model itself (for example, as voids or unfloodable objects in the computational mesh) and the subsequent receptor analysis (as single address points or polygon footprints). The options for extracting depth information are shown in Figure 4.16.

1. **Option 1** where depth information is available within the building footprint and property locations are described by point data (see Figure 4.16a). Option 1 can be considered analogous to a “point inspection” of the raster data.

From the *Flood Map Type* drop-down menu, select the “Depth (Raster)” option. Once selected, the *Flood Depth/Hazard Descriptor* drop-down menu will appear on the form. For Option 1, selection of either the “Mean” or “Maximum” options is immaterial because only one depth value can be returned for this type of analysis (that which corresponds to each point location).

Click on the “Add” button and select the flood depth datasets to be analysed as per Step 5 above.

A *Depth Threshold (m)* can also be applied by entering an appropriate value in the corresponding text box. Raster values less than the specified threshold will be converted to “no data”, which can be useful for removing areas of very shallow flooding that may be an artefact of the modelling process rather than real flooding.

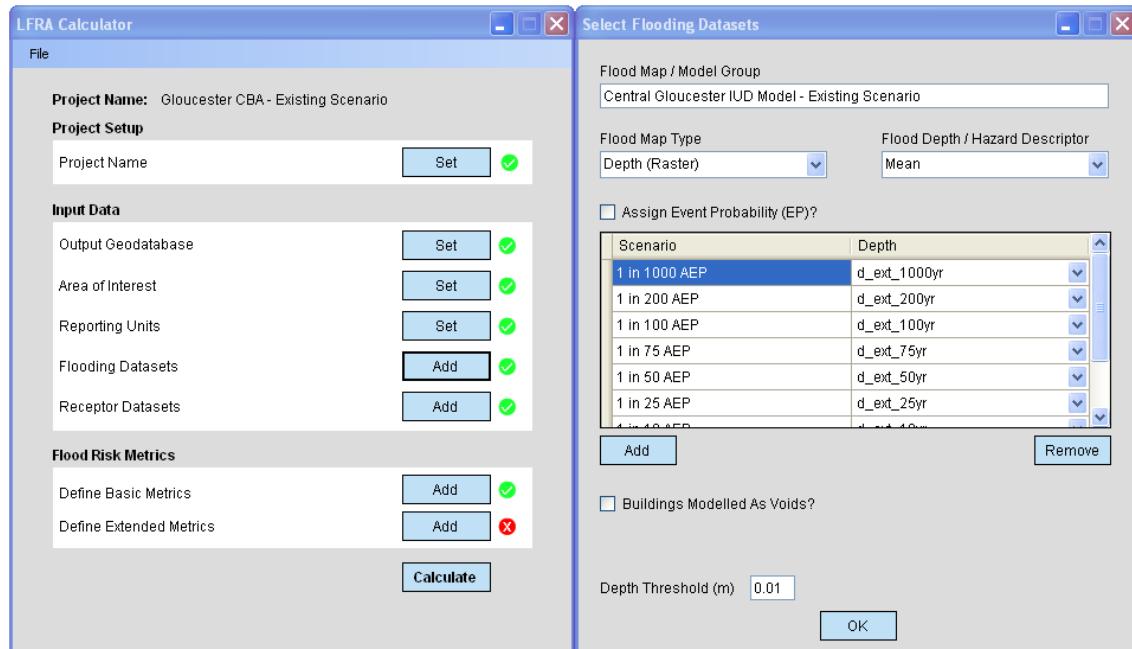


Figure 4.15 LFRA Calculator settings for extracting flood depth information at individual properties (Option 1)

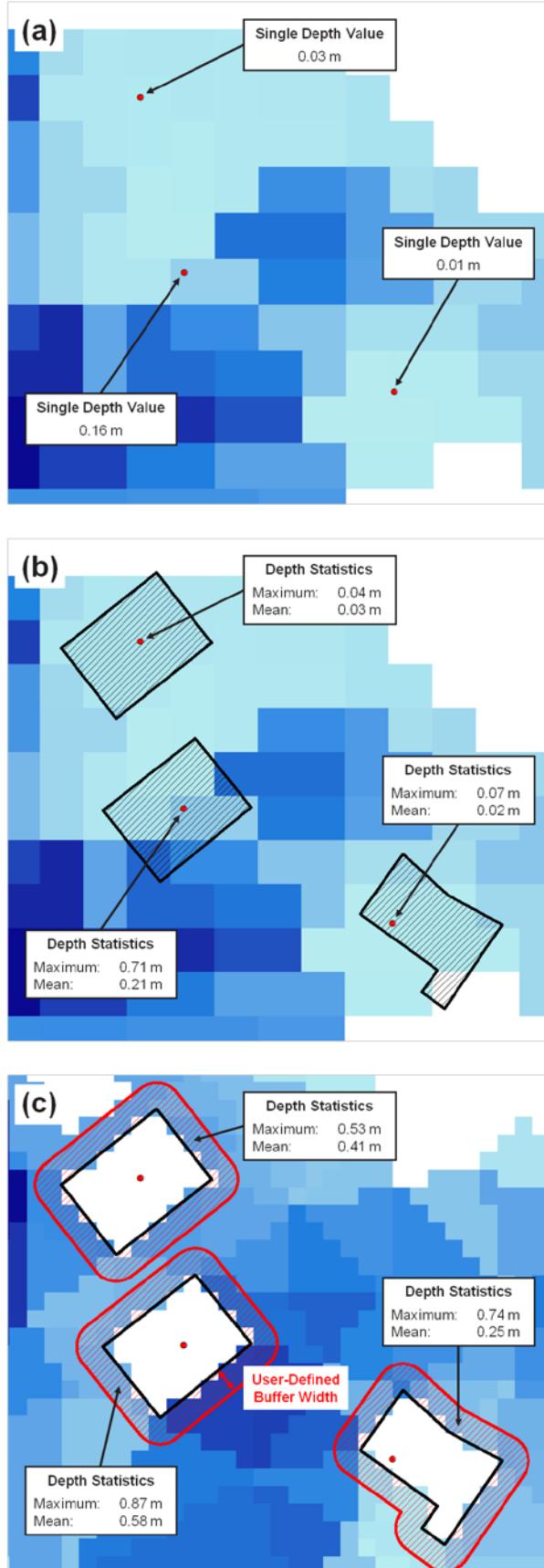


Figure 4.16 Property level depth analysis with buildings (a, b) included or (c) removed from the computational mesh. Building footprint polygons and property points are shown as black outlines and red points respectively. The “analysis buffer” of user-defined width is displayed using a red hatching pattern.

2. **Option 2** where depth information is available within the building footprint and property locations are described by polygon data (see Figure 4.16b).

Option 2 can be considered analogous to a “region inspection” of the raster data which returns either the mean or maximum of raster values lying within each building footprint polygon (the black hatched areas in Figure 4.16b).

From the *Flood Map Type* drop-down menu, select the “Depth (Raster)” option.

Select either the “Mean” or “Maximum” option from the *Flood Depth/Hazard Descriptor* drop-down menu. As shown in Figure 4.16b, this may have significant implications for the magnitude of flood depth values returned from the analysis.

Click on the “Add” button and select the flood depth datasets to be analysed as per Step 5 above.

Check the *Buildings Modelled As Voids?* check box and use the “...” browse button to select the polygon dataset containing the building footprints. Set the *Buffer Distance (m)* to zero.

Enter an appropriate *Depth Threshold (m)* in the corresponding text box.

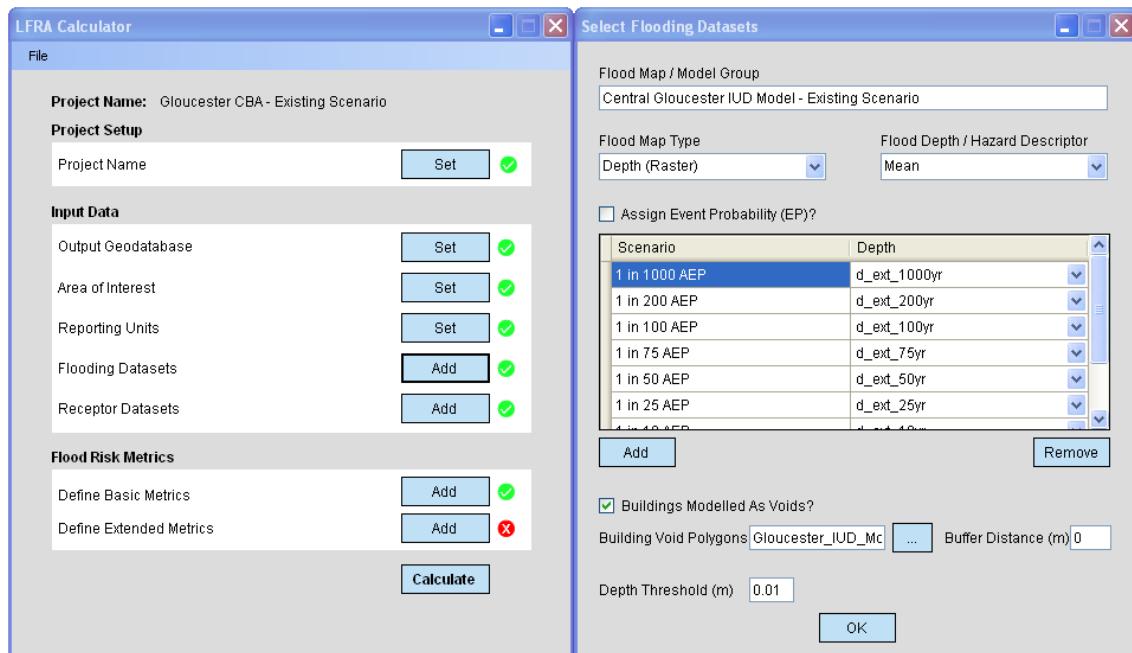


Figure 4.17 LFRA Calculator settings for extracting flood depth information at individual properties (Option 2)

3. **Option 3** where depth information is not available within the building footprint and property locations are described by polygon data (see Figure 4.16c).

Option 3 is based on a similar region inspection process as Option 2, except that the sampled raster values lie within a buffer of user-defined width around the building perimeter (the red hatched areas in Figure 4.16c) rather than within the building itself.

Option 3 is set up within the LFRA Calculator as per Option 2 above, except that the *Buffer Distance (m)* should be set to some value greater than zero (in this example, two metre). When choosing a buffer distance, users should consider the spatial resolution of the raster data and the distribution, size and orientation of buildings within the study area.

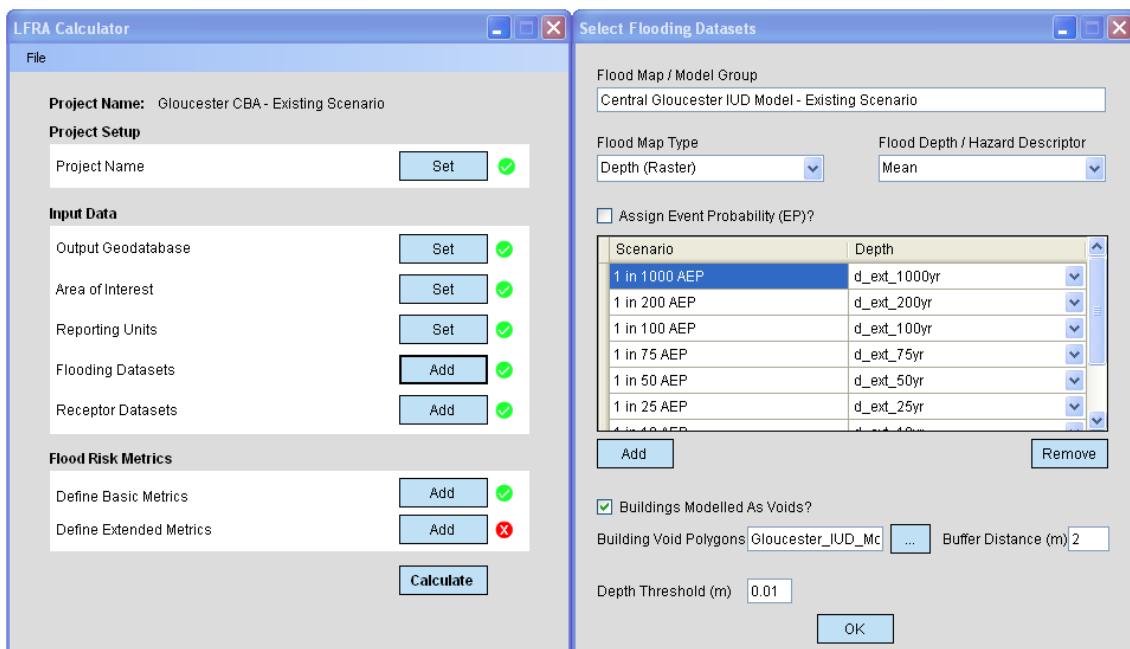


Figure 4.18 LFRA Calculator settings for extracting flood depth information at individual properties (Option 3)

For all three options, the property point dataset is referenced in the *Define Basic Metrics* form as per Step 7 above. It is this dataset that is attributed with a depth value for each property and therefore any missing locations or building footprints without a corresponding “centroid” point will not be assigned a value.

Although Sections 4.4.2-4.4.3 have focussed solely on “properties” there is no technical reason why these methods could not be applied to any asset or building-type feature. Similarly, if hazard rating information is available for the same scenarios, both maps (or sets of maps) can be processed simultaneously to derive property level information by selecting the “Depth and Hazard (Raster)” option from the *Flood Map Type* drop-down menu.

Finally, it is highly recommended that any property-level depth and hazard rating information derived using the LFRA Calculator is thoroughly checked before use in any subsequent economic or receptor vulnerability analysis.

4.4.4 Can I calculate economic damage to properties?

Yes, provided depth and suitably attributed property data are available in ArcGIS-compatible formats for the area of interest.

The LFRA Calculator uses the well-established methods set out in the Flood Hazard Research Centre Multi-Coloured Manual for estimating damages for different property types using depth-damage curves. These methods are implemented in the software as per the HR Wallingford (2008) Technical Note on NaFRA Economic Calculations and use the look-up tables recently updated as part of Defra/Environment Agency FCRM R&D project, “*Update of the Multi-Coloured Manual*”.

A summary of the damage calculation process is provided in Table 4.1. This summary also describes how to run these calculations within the LFRA Calculator.

The data and parameters required for evaluating property damages are set in an extended version of the *Define Basic Metrics* form (see Figure 4.19). The extended form is only available if depth data has been loaded (using the *Select Flooding Datasets* form) and the *Calculate Property Damages?* check box has been checked.

The property point dataset used in the analysis will require a number of additional attributes to enable damages to be calculated. These attributes (described in Table 4.1) have been predetermined for national property datasets, such as the NPD or NRD, but will require careful scrutiny to ensure local accuracy of the default information.

Economic damage to properties can be calculated for single or multiple events depending on the number of depth datasets loaded.

Table 4.1 Summary of the damage calculation process

Step	Description
1	Determine property threshold level and flood depth
1a	Property threshold levels are set globally using the <i>Property Threshold (m)</i> text box or on a per property basis from a user-defined attribute field. To <i>Apply Threshold Values on a Per Property Basis</i> , check the corresponding check box and select the attribute field of the property point dataset that contains the threshold level data. Note that all property thresholds are specified as a relative height above ground level rather than an absolute level above Ordnance Datum Newlyn. In the absence of individual property thresholds, a global threshold value of 0.25 m is recommended in Section 4.2.4 of the HR Wallingford (2008) Technical Note on NaFRA Economic Calculations.
1b	Flood depth at an individual property is calculated by subtracting the property threshold level from the single depth value evaluated using one of the three methods outlined above. Note that flood depths at a property can be negative as a result of this calculation.
2	Ascertain property categorisation
2a	Ascertain the property type from the FHRC coding. The relevant attribute field of the property point dataset is selected using the <i>MCM Code Field</i> drop-down menu. If the property is classified as residential (MCM Code equal to one) the “residential” depth-damage look-up tables are used (“MCM2010_Residential_ShortDuration.csv” in “C:\LFRA Calculator\MCM Curves” folder). If the property is classified as non-residential (MCM Code not equal to one) the “non-residential no basement” depth-damage look-up tables are used (“MCM2010_NonResidential_ShortDuration_No_Basement.csv” in “C:\LFRA Calculator\MCM Curves” folder).

Step	Description
2b	<p>Find the appropriate depth-damage curve to use.</p> <p>If the property is classified as residential, then identify the property type (Detached (DET), Semi-detached (SDET), Terraced (TERR), Flat (FLAT), Average (AVG)) from the relevant attribute field of the property point dataset. This is selected using the <i>Property Type Field</i> drop-down menu.</p> <p>Use the depth-damage curve in "MCM2010_Residential_ShortDuration.csv" that corresponds to this property type categorisation. If the property is classified as residential and has no property type information, the default MCM Code = 1 property curve is used.</p> <p>If the property is classified as non-residential, it is the depth-damage curve in "MCM2010_NonResidential_ShortDuration_No_Basement.csv" that corresponds to the MCM Code value used.</p>
3	<p>Ascertain floor level</p> <p>Determine whether the property is an "upper floor". The relevant attribute field of the property point dataset is selected using the <i>Floor Level Code Field</i> drop-down menu.</p> <p>A number of categories are used within national property datasets (such as NPD, NRD) which allow consideration of the floor level of a particular building. These are treated within the LFRA Calculator as per Section 4.2.5 of the HR Wallingford (2008) Technical Note on NaFRA Economic Calculations.</p> <p>If the <i>Calculate Damages for pU Floor Levels</i> check box is checked, damages will also be calculated for potential upper floor properties (FloorLevel = pU).</p>
4	<p>Adjust for basement flooding</p> <p>If the property is classified as a definite basement (the property itself is a basement, FloorLevel = dB) and the flood depth exceeds the property threshold, it is assumed that there is sufficient flood volume to completely fill the property and so the average ceiling height (2.2 m) is added to the residual water depth calculated in Step 1b.</p> <p>If the property is classified as a definite basement and the flood depth does not exceed the property threshold, 2.2 m is not added to the (negative) residual water depth and damages are calculated directly from the corresponding depth-damage curve.</p> <p>Properties classified as a potential basement (FloorLevel = pB) are included in the damage calculation but treated as standard ground-level properties (2.2 m is not added to the residual water depth).</p>
5	<p>Select option to cap damage value at property valuation</p> <p>To <i>Cap Damage Values at Property Valuation</i>, check the corresponding check box and select the attribute field of the property point dataset that contains the property valuation data.</p>
6	<p>Ascertain floor area</p> <p>Ascertain the floor area of the property. The relevant attribute field of the property point dataset is selected using the <i>Floor Area (sq m) Field</i> drop-down menu.</p> <p>Any missing values will be updated automatically with the <i>Default Floor Area (sq m)</i> entered in the corresponding text box.</p>
7	<p>Calculate unit damage value</p> <p>Based on the flood depth and property data provided and user settings selected, the LFRA Calculator uses the appropriate MCM depth-damage curve to calculate a unit damage value for each property (damage per metre squared).</p> <p>Linear interpolation is used to calculate damage values between data points in the depth-damage curves.</p>
8	<p>Multiply unit damage value by floor area</p> <p>The MCM depth-damage curves quote the cost of flood damage per square metre of floor area for each property type. Therefore, it is necessary to multiply the unit damage value by the floor area to obtain the property damage value.</p>
9	<p>Cap damage value at property valuation</p> <p>If the option to <i>Cap Damage Values at Property Valuation</i> was selected in Step 5 and the property damage value is greater than the user-supplied property valuation, cap the property damage value to the valuation.</p>
10	<p>Return the final property damage value</p> <p>Attribute the final damage value to each affected point in the property dataset. Two flood depths, (i) as extracted from the model and (ii) adjusted based on the property threshold, are also appended to the dataset to aid the checking/QA process.</p>

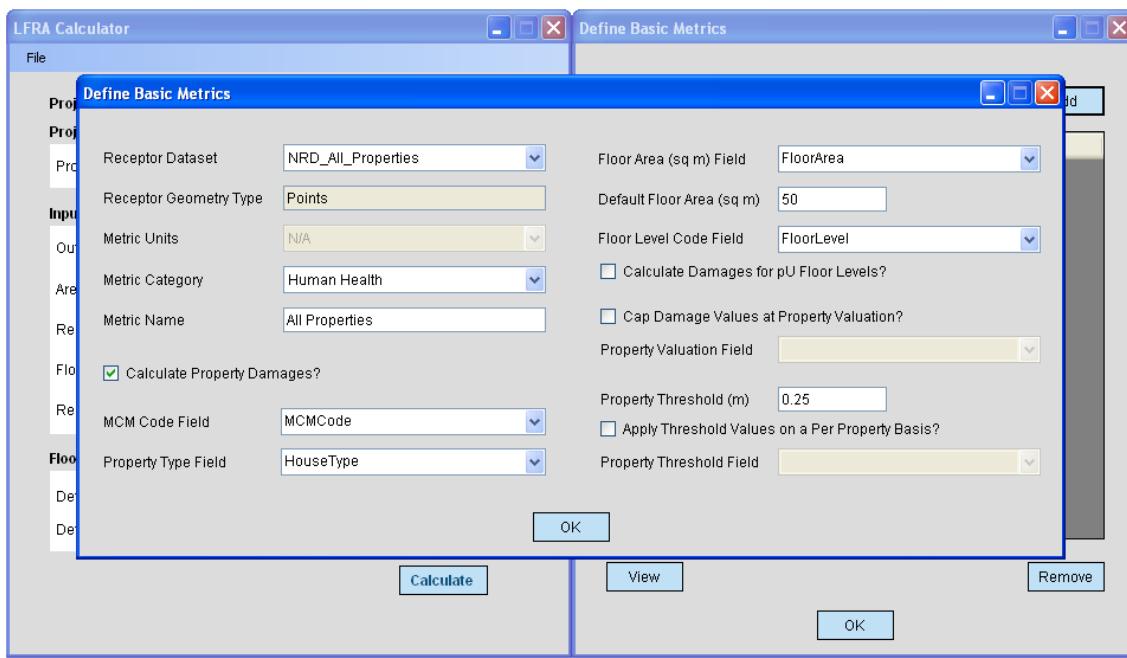


Figure 4.19 LFRA Calculator settings for calculating economic damage to properties

Users can also develop their own depth-damage curves following standard methods set out in Penning-Roswell *et al.* (2005) and Black *et al.* (2005). However, this can be expensive and time-consuming, and is only recommended for very high value properties that dominate local damage estimates and/or for large, mixed used sites such as hospitals, power stations and water treatment works.

Should you wish to create a new depth-damage curve, you must first choose a new property code that doesn't already exist in the MCM look-up tables, "MCM2010_Residential_ShortDuration.csv" and "MCM2010_NonResidential_ShortDuration_No_Basement.csv". It is suggested that new codes be prefixed with a selection of alphanumeric characters explaining the source of the data (such as author's initials and affiliation).

To define a new curve, known damages for a series of pre-defined depth intervals must be added to the bottom of the relevant look-up table following the examples provided in "MCM2010_Residential_ShortDuration.csv" and "MCM2010_NonResidential_ShortDuration_No_Basement.csv".

The new depth-damage curves will be available to use next time the software is launched.

4.4.5 Can I calculate annual average damages?

Yes, provided three or more probability-weighted depth datasets are available. Annual average quantities of other flood risk metrics, such as numbers of residential properties or critical services flooded, can also be calculated. These values represent the notional long-term average (statistically speaking the “expectation”) of the consequences of flooding in any given year and provide an objective basis for comparing flood risk between different areas.

Annual average quantities can be approximated with varying levels of statistical rigour. The LFRA Calculator uses a trapezium rule-based approach that is simple and well suited to the type of modelling typically carried out to support local flood risk studies where a model may be run for a range of loading conditions (usually expressed as storm events of specified annual exceedence probability (AEP)).

Figure 4.20 shows how, with values of a flood risk metric calculated for three different AEP events, the area under the curve can be integrated using the trapezium rule (dashed line) to give the annual average flood risk metric value. Figure 4.20 assumes that the onset of flooding (or zero damages) is the one in two (50 per cent) AEP event, and that the damages do not increase beyond those incurred for the one in 1,000 (0.1 per cent) AEP for even rarer events.

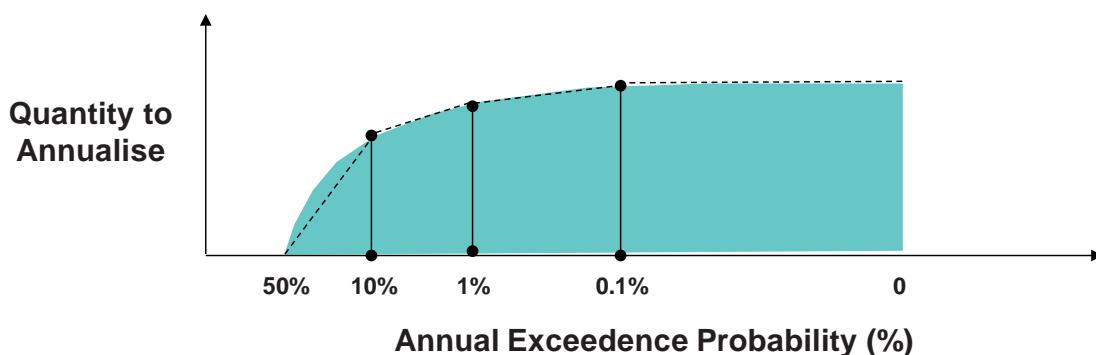


Figure 4.20 Approximation of annual average risk based on a limited number of system simulations. The vertical axis is a flood risk metric (such as economic damage, number of residential properties flooded). The AEP refers to the probability weight attached to the system simulation used to calculate the flood risk metric.

Probability weights are attached to flooding datasets within the *Select Flooding Datasets* form (see Figure 4.21).

Check the *Assign Event Probability (EP)?* check box and the *Zero Damages (EP)* text box and *EP* column will appear on the form. Probability weights are entered as the one in *X* annual probability of flooding, where users enter the number representing *X* as shown in Figure 4.21.

If three or more probability-weighted datasets are loaded, the software will automatically calculate average annual quantities of all the flood risk metrics defined.

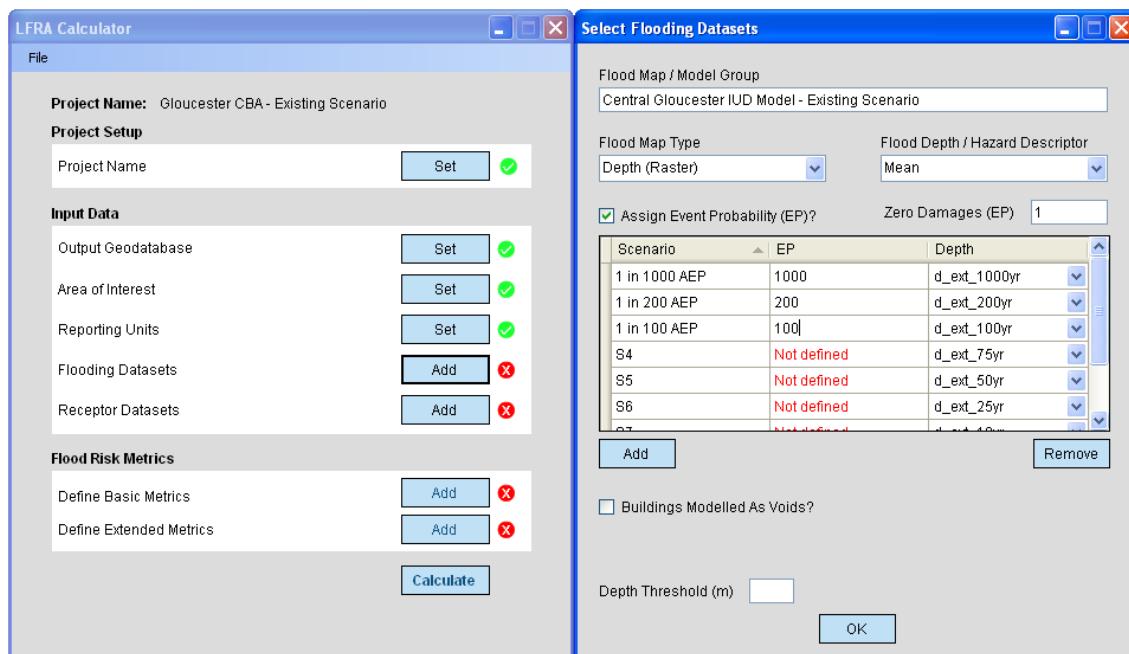


Figure 4.21 LFRA Calculator settings for calculating annual average quantities

4.4.6 Can I use flood extent polygons and raster depth maps in the same LFRA Calculator project?

No, these flooding datasets must be analysed using separate LFRA Calculator projects.

4.4.7 Can I save work in progress or modify and re-run a previous analysis?

Yes. Session settings can be saved to a Calculator Project File at any point using the *File* drop-down menu (*Save Project* option) on the main LFRA Calculator form. A Calculator Project File is also written automatically to the “Project Files” folder when the “Calculate” button is clicked.

A Calculator Project File contains details of all the input datasets and flood risk metrics to be calculated. As well as providing an important audit record, this file can be used to re-run a previous analysis. A Calculator Project File can be loaded into the software using the *File* drop-down menu (*Open Project* option) on the main LFRA Calculator form. Settings on individual forms can then be modified/completed as required.

Before (re-)running the LFRA Calculator, users will need to delete any existing geodatabases of the same name in the same output location.

4.4.8 What should I do if the software crashes?

The LFRA Calculator is designed to be a “proof of concept” for evaluation and demonstration purposes rather than a business-ready software application. As such, it incorporates very little in the way of error trapping or reporting.

As the software is currently unsupported, the best recommendation is simply to restart the software and try again.

5 LFRA Viewer

5.1 Installation

Create a new folder on the C: drive of the user's PC called "LFRA Viewer" (ensuring that there is a space between the two words). Copy the "LFRAViewer.zip" file from the installation disk to the "C:\LFRA Viewer" folder and extract the contents as shown in Figure 5.1.

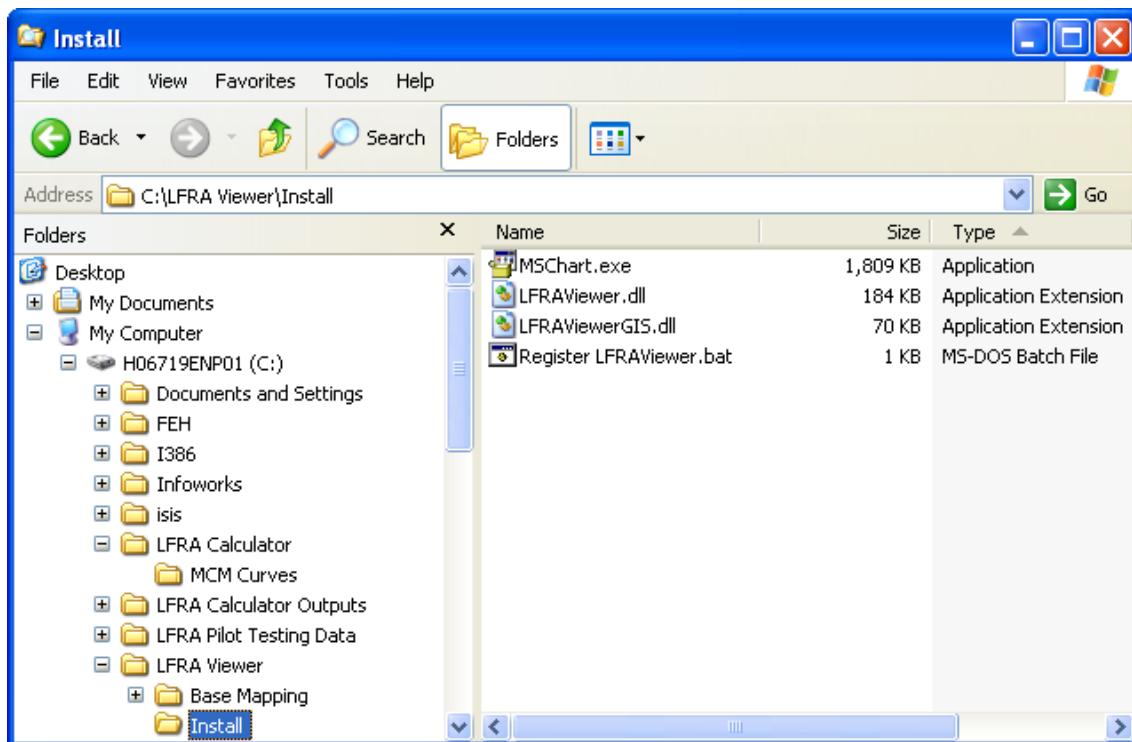


Figure 5.1 Location of the installed LFRA Viewer software in Windows Explorer

The LFRA Viewer requires MSChart to be installed on the user's PC. "MSChart.exe" is located in the "C:\LFRA Viewer\Install" folder. Double click on the file "MSChart.exe" to install the software.

Once the MSChart installation has completed, shut down all ArcGIS applications and double click on the file "Register LFRAViewer.bat" (also located in the "C:\LFRA Viewer\Install" folder). A Command Prompt window similar to that shown in Figure 5.2 indicates that the software has been registered successfully. You can ignore the subsequent "RegAsm : error RA0000" error message.

Administrator privileges will be required to install MSChart and run the "Register LFRAViewer.bat" file.

```

C:\WINDOWS\system32\cmd.exe
C:\LFRA Viewer\Install>C:\WINDOWS\Microsoft.NET\Framework\v2.0.50727\regasm.exe
"LFRAViewer.dll" /tlb:LFRAViewer.dll /codebase
Microsoft (R) .NET Framework Assembly Registration Utility 2.0.50727.3053
Copyright (C) Microsoft Corporation 1998-2004. All rights reserved.

RegAsm : warning RA0000 : Registering an unsigned assembly with /codebase can cause
use your assembly to interfere with other applications that may be installed on
the same computer. The /codebase switch is intended to be used only with signed
assemblies. Please give your assembly a strong name and re-register it.
Types registered successfully
RegAsm : error RA0000 : An error occurred while saving the exported type library
: Access is denied. <Exception from HRESULT: 0x80070005 (E_ACCESSDENIED)>

C:\LFRA Viewer\Install>PAUSE
Press any key to continue . .

```

Figure 5.2 Running the “Register LFRAViewer.bat” file

Launch ArcMap 9.3. Select the *Customize...* option from the *Tools* drop-down menu. Click the Commands tab and highlight the “~JBA LFRA Viewer” **category** (see Figure 5.3). Drag the “LFRA Viewer” **command** onto any Toolbar and then click on the “LFRA Viewer” icon (highlighted red in Figure 5.4) to launch the software.

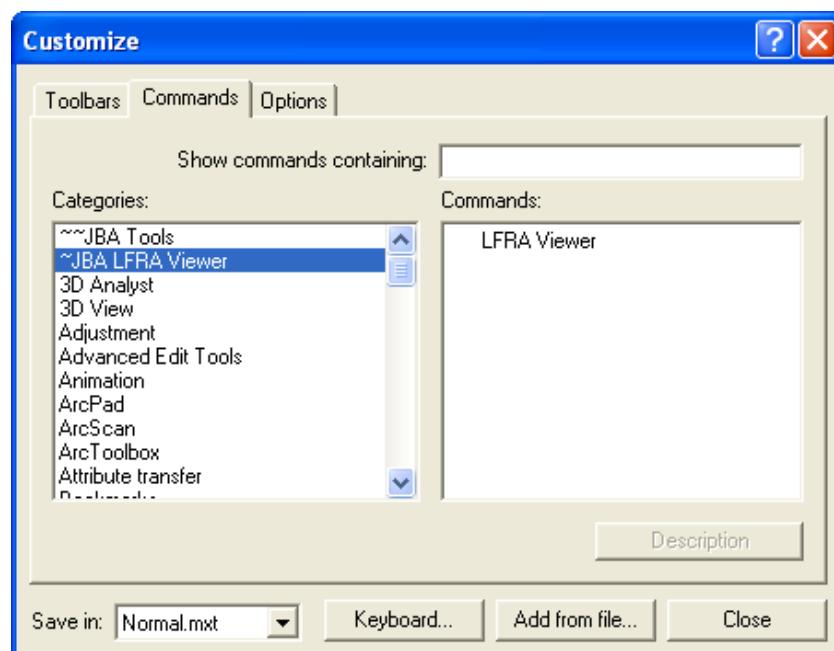


Figure 5.3 Installing the LFRA Viewer in ArcMap 9.3 (Step 1 – Using the Customize form)

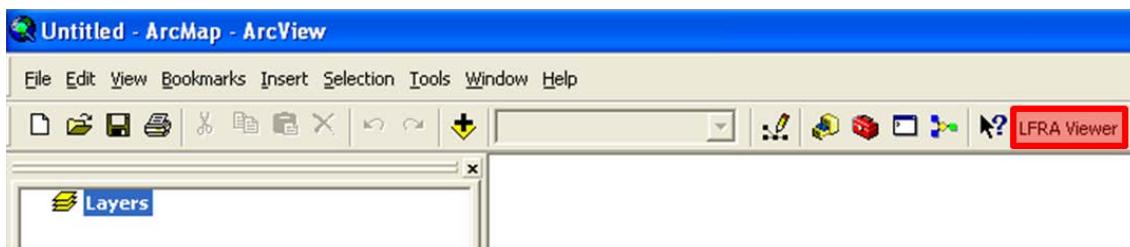


Figure 5.4 Installing the LFRA Viewer in ArcMap 9.3 (Step 2 – Adding the software icon to a Toolbar)

It is assumed that ArcGIS 9.3 has been installed previously.

5.2 Overview

The LFRA Viewer software offers an efficient means of visualising, interrogating and presenting the flood consequence/risk information contained in a geo-database produced by the LFRA Calculator. It does not make any assumptions on the inputs and outputs from the LFRA Calculator software.

In terms of functionality, LFRA Viewer can:

- provide maps, charts and summary tables of the flood risk metrics and property-level depth-damage analysis (if calculated);
- visualise depth, hazard and damages at individual receptors (if calculated);
- allow users to set thresholds and classify consequence/risk on a metric-by-metric basis;
- objectively identify flood risk hotspots using either the “single threshold” or “dual threshold” approaches (see Section 4.3.5 of SC070059/R3);
- prioritise identified hotspots using the simple priority scoring system described in Section 4.3.6 of SC070059/R3;
- help to visualise changes in consequence/risk between selected flooding scenarios.

5.3 Getting started

Section 5.3 provides step-by-step instructions for viewing the distribution of flood risk across an area of interest and how to automatically identify and prioritise flood risk hotspots that may require priority action or more detailed investigation in subsequent studies.

Steps 1-4 below make use of the example geo-database produced in Section 4.3.

5.3.1 Step 1 – Set project name and load geo-database

Launch ArcMap 9.3 and click on the “LFRA Viewer” icon to launch the software.

Check the *New Project* radio button and enter a *Viewer Project Name* (mandatory) and *Viewer Project Description* (optional) into the corresponding text boxes.

Use the “...” browse button to select the geo-database to be viewed.

Click the “Activate LFRA Viewer” button to initialise the software. The message “Project Setup Complete: Select Flood Risk Metric to View” will appear when the geo-database has been successfully loaded.

5.3.2 Step 2 – View and classify flood risk metrics across all reporting units

Click on the *Human Health* tab and you should see the LFRA Viewer main user interface appear as something similar to that shown in Figure 5.5. A map layout similar to that shown in Figure 5.6 will also be created automatically.

All flood risk metrics are calculated for each flood map dataset loaded into the Calculator project. The *Scenario/Event* and *Flood Risk Metric* drop-down menus allow users to view different flood map-metric combinations. Metrics are grouped as per the impact categories assigned in Section 4.3.7/4.3.8 and can be accessed by clicking on the corresponding tab.

Statistics for each flood map-metric combination are shown in the corresponding window and these can be used to help classify the count, length and/or area data into “low”, “medium” or “high” risk categories. The choice of thresholds will require careful investigation, based around understanding of how setting particular thresholds captures areas of known high risk for past or future floods. Thresholds are set by entering appropriate break values in the *Med* and *High* text boxes and clicking the “Recalculate” button. The histogram and map layout will update automatically to reflect the changes.

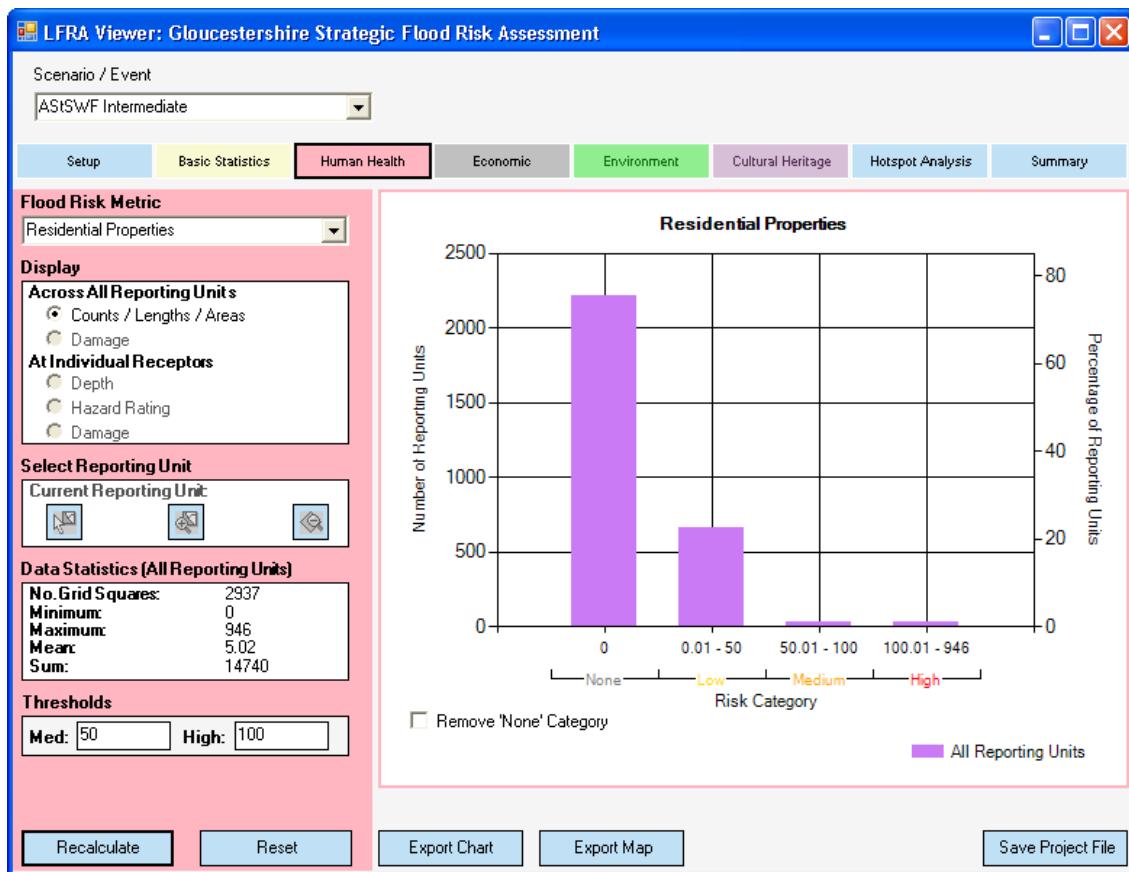


Figure 5.5 LFRA Viewer main user interface



Figure 5.6 LFRA Viewer map layout

5.3.3 Step 3 – Identify flood risk hotspots

As well as assisting with the understanding and communication of flood risk, setting thresholds and classifying flood risk metrics can help to identify flood risk hotspots.

Click on the *Hotspot Analysis* tab and select the *Single Threshold* or *Dual Threshold* classification method (see Section 4.3.5 of SC070059/R3 for full details).

Check the *Include?* check box for each flood risk metric to be included in the hotspot identification process.

Check the *Yes* radio button to display the identified hotspots in the map layout. A hotspot is displayed as a “negative” buffer feature inside the original reporting unit boundary. Click the “Update Hotspots” button to complete the process.

Note that flood risk hotspots are defined per flood map scenario/event and that any subsequent changes to risk thresholds for flood risk metrics will be incorporated automatically in the hotspot analysis after clicking the “Recalculate” button.

The *Sort By* drop-down menu allows reporting units to be sorted by individual flood risk metric counts, lengths or areas. In the example shown in Figure 5.7, reporting units are ranked in descending order according to number of residential properties flooded. In addition, by selecting a particular reporting unit (in this case, “X395Y222”), values for all calculated metrics can be viewed and colour-coded according to their respective risk classification.

Selected reporting units can be zoomed in to or out from using the  and  buttons respectively. Alternatively, a reporting unit can be selected from the map layout and its flood risk metric attributes queried using the  button.

Comments can also be added to individual reporting units using the User Comments text box.

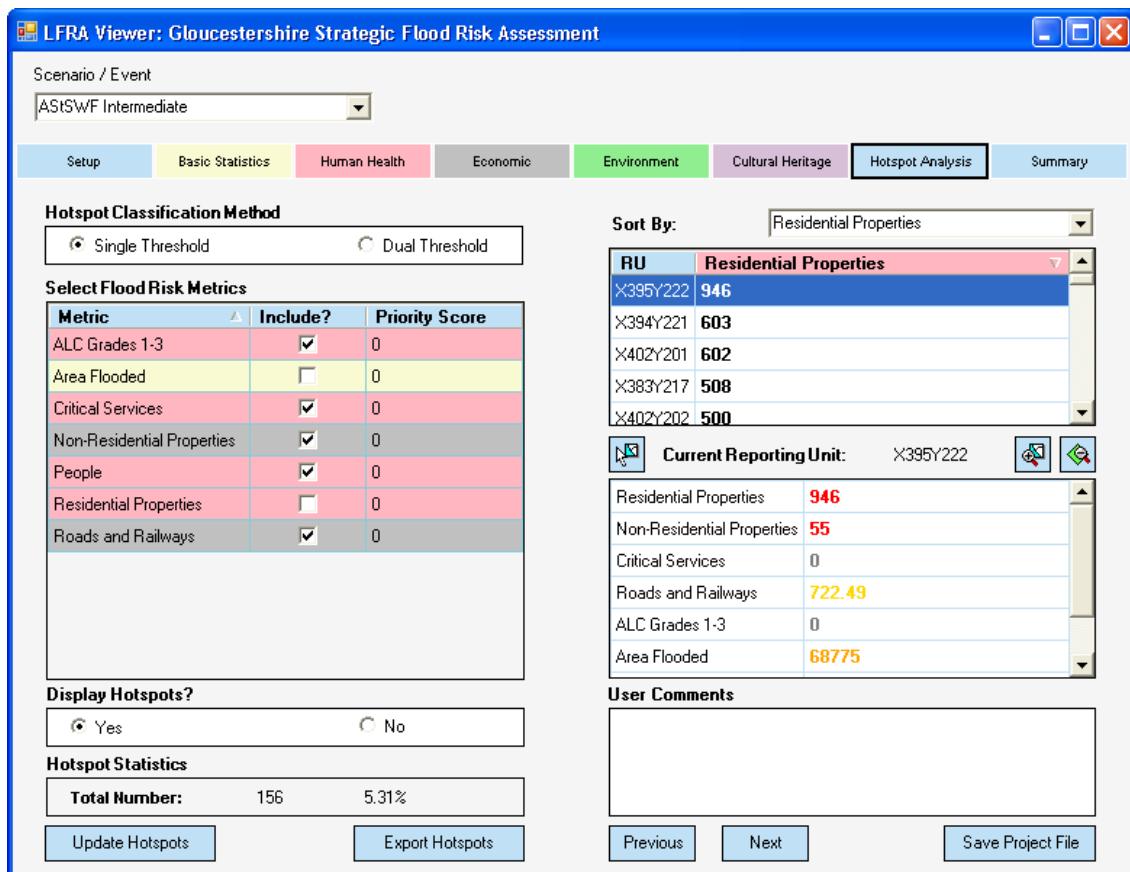


Figure 5.7 LFRA Viewer settings for identifying flood risk hotspots

5.3.4 Step 4 – Prioritise flood risk hotspots

Identified hotspots can be prioritised using the simple priority scoring system described in Section 4.3.6 of SC070059/R3.

Edit the *Priority Score* for each included flood risk metric following the example shown in Figure 5.8. Scores should be assigned based on the relative importance of each metric and will typically reflect local political and flood risk management priorities.

Click the “Update Hotspots” button and an overall priority score is calculated for each reporting unit. Select “Priority Score” from the *Sort By* drop down menu and use the zoom/select tools to interrogate the highest ranking priorities for further investigation.

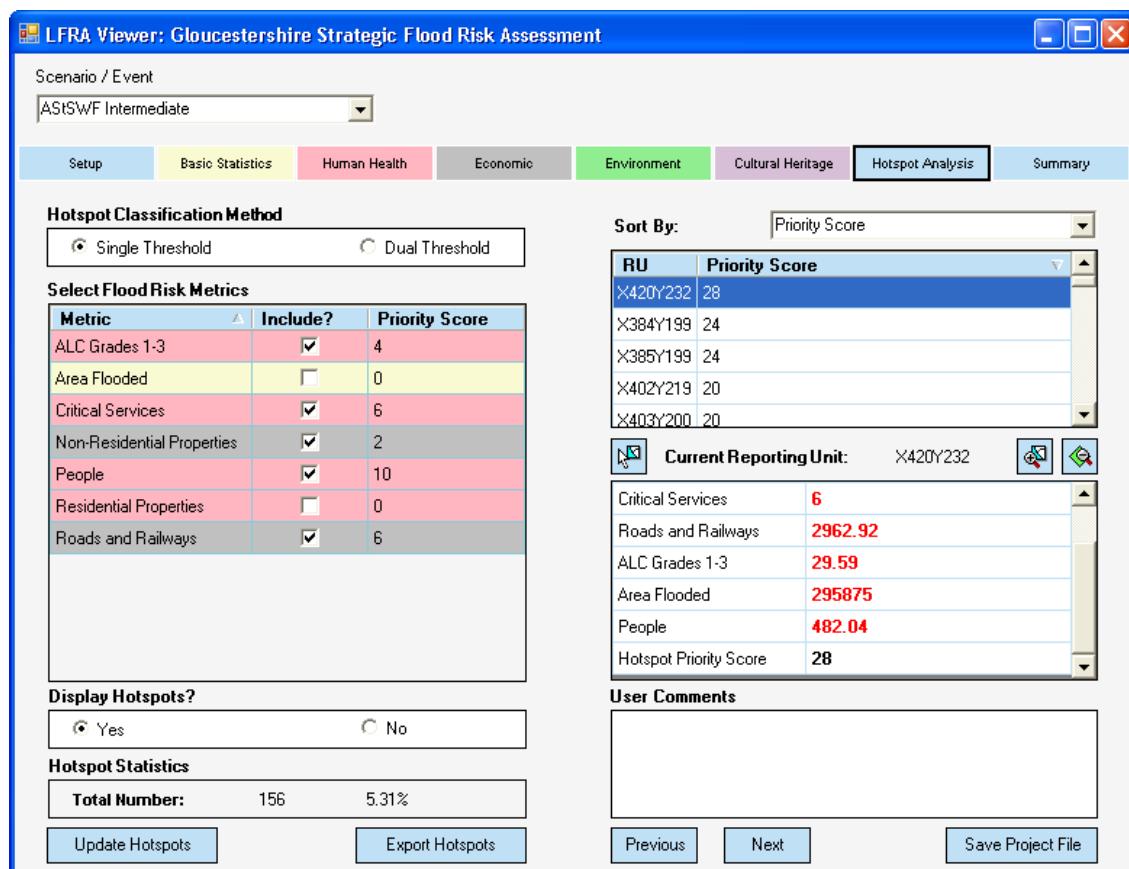


Figure 5.8 LFRA Viewer settings for prioritising flood risk hotspots

5.4 Additional functionality and frequently asked questions

Section 5.4 provides answers to the following questions on the functionality of the LFRA Viewer software:

- How do I view and classify depth, hazard rating and damages at individual receptors?
- How do I view annual average damages and other annualised quantities?
- Can I add my own spatial datasets to the map layout?
- Can I change the type and scale of the default base mapping?
- Can I change the layout and format of the charts?
- Can I export the charts, map layouts and GIS data?
- Can I compare flood risk metrics for a given reporting unit across all flood scenarios/events?
- Can I combine flood risk hotspots for multiple flood scenarios/events?
- Can I save work in progress or modify a previous analysis?
- What should I do if the software crashes?

5.4.1 How do I view and classify depth, hazard rating and damages at individual receptors?

If depth data have been used to calculate flood risk metrics, the option to view the information extracted at individual receptors (see Section 4.4.3) is available automatically within the LFRA Viewer.

Check the *Depth* radio button and use the  button to select a reporting unit from the map layout as shown in Figure 5.9.

Click the  button to zoom in to the selected reporting unit. The map layout will update automatically and appear similar to that shown in Figure 5.10. Depths at individual receptors can be thresholded by entering appropriate break values in the *Med* and *High* text boxes and clicking the “Recalculate” button. The histogram and map layout will update automatically to reflect the changes.

Click the  button to zoom out from the selected reporting unit and return to the “all reporting units” view.

If available/calculated, hazard rating and damages information can also be viewed at individual receptors in a similar way.

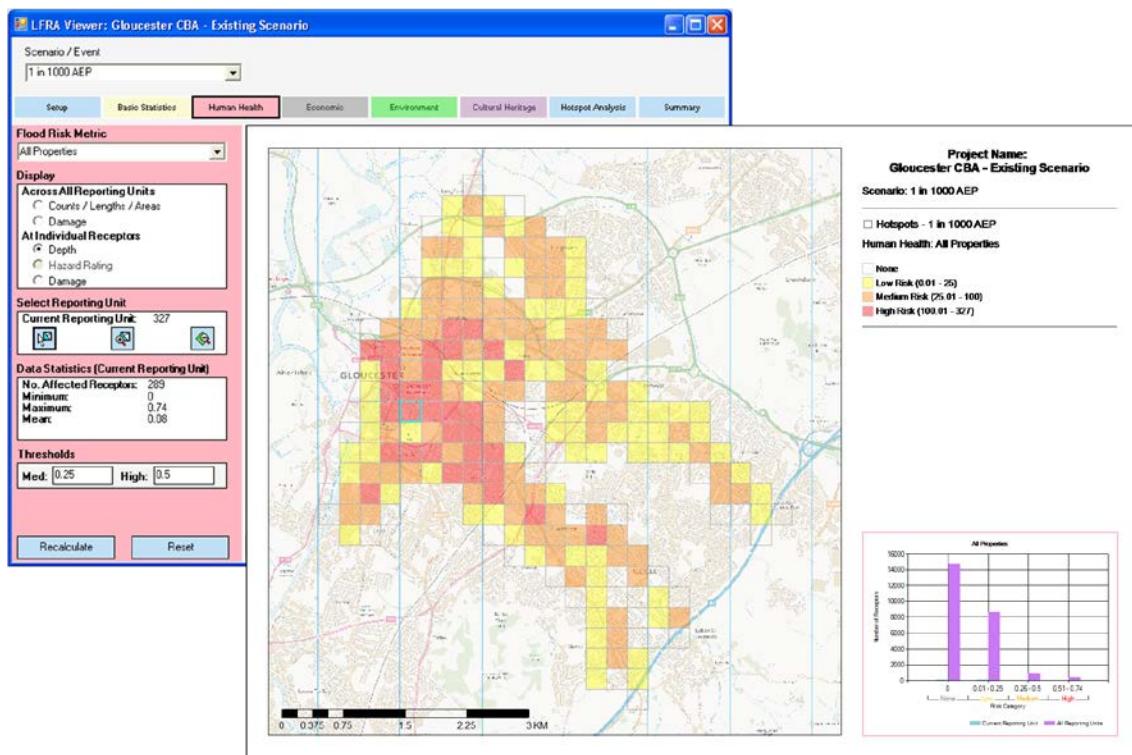


Figure 5.9 Select a reporting unit (shown with a blue border) from the map layout in order to view depth information extracted at individual receptors within that reporting unit



Figure 5.10 Depth of flooding at individual receptors within a selected reporting unit

5.4.2 How do I view annual average damages and other annualised quantities?

Provided they have been calculated (see Sections 4.4.3-4.4.5), use the *Flood Risk Metric* drop-down menu and *Display* radio buttons to select damages or a count/length/area-based flood risk metric to view.

Select “Annualised” from the *Scenario/Event* drop-down menu (see Figure 5.11).

The map shown in Figure 5.11 shows annual average damages calculated for each reporting unit. Summary statistics, such as the total annual average damages for the whole study area, are reported in the *Data Statistics (All Reporting Units)* window.

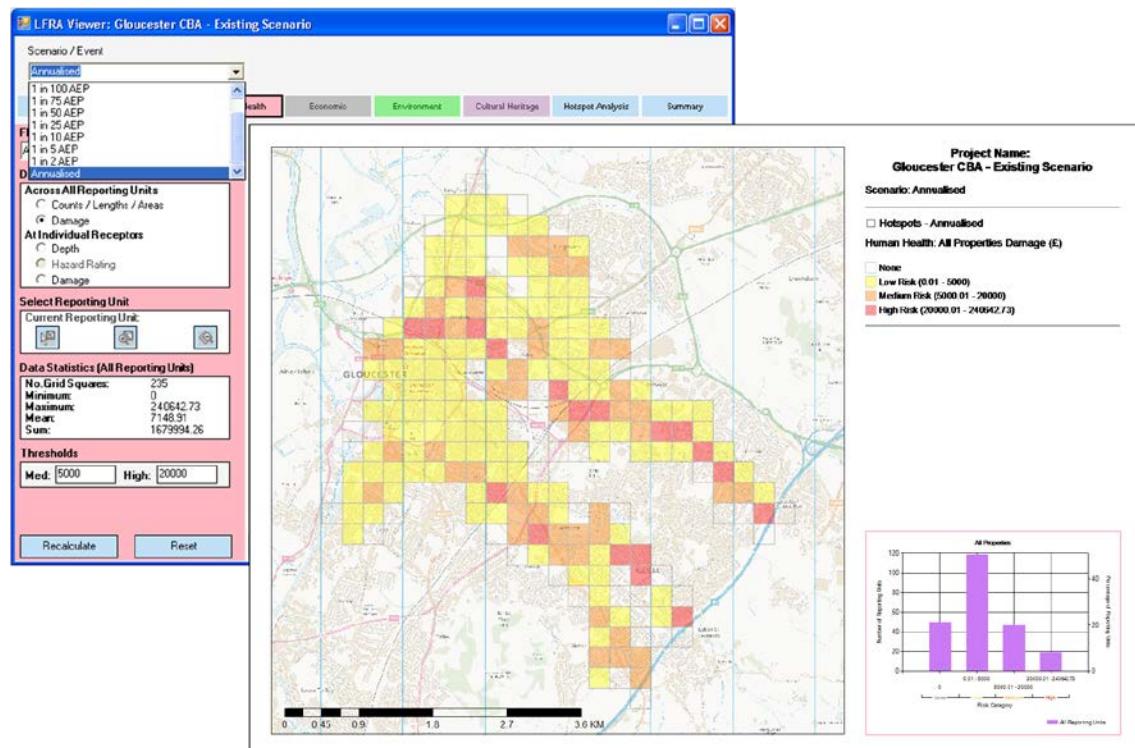


Figure 5.11 Viewing annual average damages within the LFRA Viewer

5.4.3 Can I add my own spatial datasets to the map layout?

Yes. The LFRA Viewer allows the full functionality of ArcMap to be used. However, the map legend may require some manual adjustment to display information relating to the additional data. Also note that these settings may be lost if the map layout is updated through the LFRA Viewer user interface (for example, by changing risk thresholds) and so it is recommended that manual edits to the map legend are made at the final stage before printing/publication.

5.4.4 Can I change the type and scale of the default base mapping?

Yes, but these changes may be lost each time the map layout is updated through the LFRA Viewer user interface.

The LFRA Viewer uses three Ordnance Survey OpenData products, *1:250,000 Scale Colour Raster*, *VectorMap District (Raster)* and *Street View*, and automatically loads the data set that is most appropriate for the current map scale. Full details on these products are available at <http://www.ordnancesurvey.co.uk/oswebsite/products/os-opendata.html>.

Unfortunately, very large file sizes mean that it is not possible to provide complete coverage of *VectorMap District (Raster)* and *Street View* data across England and Wales within the standard LFRA Viewer installation. Therefore, these data are only provided for the pilot test areas used in SC070059/R3 (Torbay and Gloucestershire).

However, the existing coverage can be supplemented to cover areas of interest by adding *VectorMap District (Raster)* and *Street View* map tiles to the corresponding raster dataset in the base mapping geo-database (“OS_OpenData.gdb” found in the “C:\LFRA Viewer\Base Mapping” folder, see Figure 5.12).

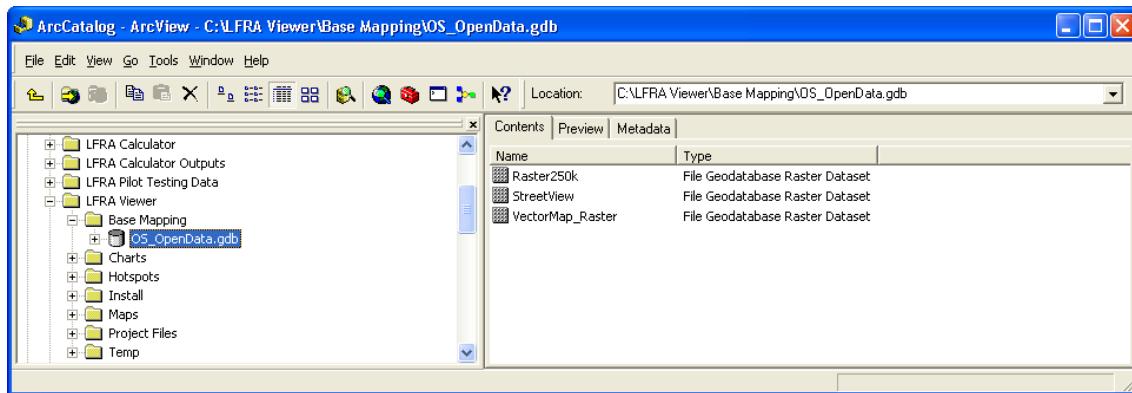


Figure 5.12 ArcCatalog view of the base mapping geo-database “OS_OpenData.gdb”

5.4.5 Can I change the layout and format of the charts?

No. The layout and format of the charts is controlled by the LFRA Viewer software. However, the underlying data from any chart can be exported as a .csv file using the “Export Chart” button. The chart can also be deleted from the map layout before printing/publication.

5.4.6 Can I export the charts, map layouts and GIS data?

Yes. Charts, map layouts and hotspots can all be exported using the corresponding “Export” button on the LFRA Viewer user interface:

- **Charts** can be exported as images or as comma delimited values (a .csv file).
- **Map layouts** can be exported as images.
- **Hotspots** can be exported as shapefiles or as Feature Classes within an existing geo-database. Exported hotspots are attributed with the flood risk metric values and priority score calculated, and any additional comments added by the user. Exported hotspots can also be converted for use in other GIS software (such as MapInfo) using built-in format conversion tools, such as ArcToolbox or Universal Translator.

5.4.7 Can I compare flood risk metrics for a given reporting unit across all flood scenarios/events?

No, not automatically within the LFRA Viewer. This is best done by extracting/exporting the *Scenario/Event*-specific information for a given reporting unit or receptor feature from the geo-database produced by the LFRA Calculator within ArcCatalog.

5.4.8 Can I combine flood risk hotspots for multiple flood scenarios/events?

No, not automatically within the LFRA Viewer. Exported hotspots can be merged within ArcMap to create “composite” hotspots, although care will be needed to preserve/update useful attribute information.

5.4.9 Can I save work in progress or modify a previous analysis?

Yes. Session settings can be saved to a Viewer Project File (*Viewer Project Name_VPF.txt*) at any point using the “Save Project File” button on the LFRA Viewer user interface.

A Viewer Project File contains details of all the risk thresholds set and hotspot analysis options/parameters selected. As well as providing an important audit record, this file can be used to re-start a previous session. A Viewer Project File can be loaded into the software using the *Load Project File* option on the *Setup* tab.

5.4.10 What should I do if the software crashes?

The LFRA Viewer is designed to be a “proof of concept” for evaluation and demonstration purposes rather than a business-ready software application. As such, it incorporates very little in the way of error trapping or reporting.

As the software is currently unsupported, the best recommendation is simply to restart ArcMap and click on the “LFRA Viewer” icon to launch the software again.

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List of abbreviations

AEP	Annual Exceedence Probability
AStSWF	Areas Susceptible to Surface Water Flooding Map
CLF	Calculator Log File
CPF	Calculator Project File
EP	Event Probability
FCRM	Flood and Coastal Risk Management
FHRC	Flood Hazard Research Centre
GIS	Geographical Information System
LFRA	Local Flood Risk Assessment
LLFA	Lead Local Flood Authority
MCM	Multi-Coloured Manual
NaFRA	National Flood Risk Assessment
NPD	National Property Dataset
NRD	National Receptor Dataset
PFRA	Preliminary Flood Risk Assessment
R&D	Research and Development
RU	Reporting Unit

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