

DISCOVERY SOFTWARE LTD

Dynamic Software Solutions

FloodRanger World Manual



EDUCATIONAL FLOOD MANAGEMENT GAME

FloodRanger World Manual

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Introduction

What is FloodRanger World and how do I get started?

FloodRanger World is an educational game used to explore aspects of Flood Management in relation to different climate change and world futures scenarios. FloodRanger World may be setup for any location in the world and as default comes with two predefined projects, one for the Thames catchment in the UK and one for the tidal stretch of the Thames Estuary. To play the game with either of these projects run FloodRanger World and then open the appropriate project file.

How to Get Started

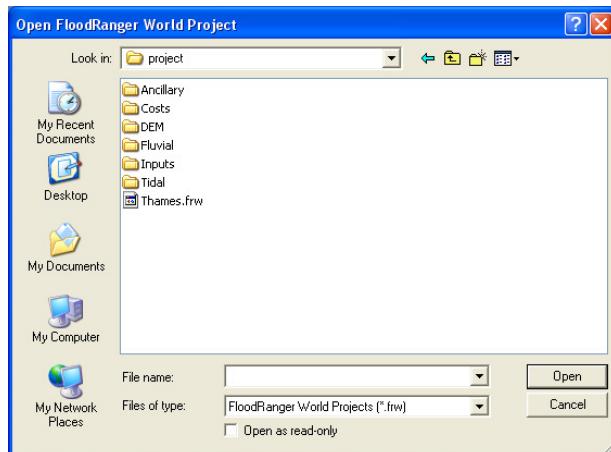


Figure 1 – Open and select a FloodRanger World project

Click on 'Open Project' and then select the appropriate file using the standard file browser. If you have installed in the default location the filename for the Thames Catchment project is C:\Program Files\Discovery Software\FloodRangerWorld\project\Thames.frw and the filename for the Tidal Thames project is C:\Program Files\Discovery Software\FloodRangerWorld\TE2100\TE2100.frw. N.B. some versions will not have the tidal Thames data as some of the data is copyright.

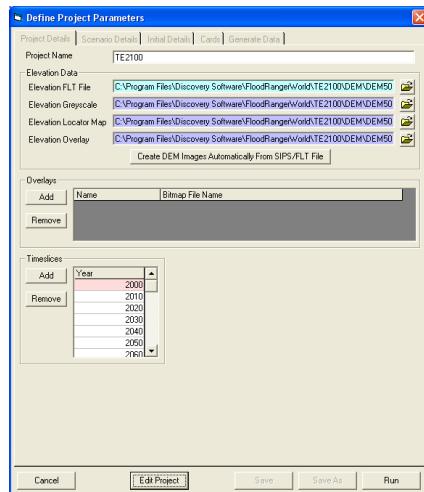


Figure 2 – Edit project properties form. Used here to run the selected project.

Once you have selected a project you are presented with a form that lets you change the project settings. This form will be discussed in a later chapter. For now, you simply need to click on the Run button.

Playing FloodRanger World

The basic premise of FloodRanger is that you have a certain amount of money to spend on defences, housing and industry. Your job is to keep your population happy in terms of employment, housing and keeping them dry while also looking after the environment. If your population are flooded, homeless or out of work then they will become unhappy and your score will decrease. At the start of the game you choose which scenarios you wish to play. You can choose from a number of different world futures scenarios and a number of different climate change scenarios. Each scenario is different and whichever combination you pick will result in a different budget and social conditions for the world futures and a different level of flooding, storminess and drought conditions for each of the climate change scenarios.

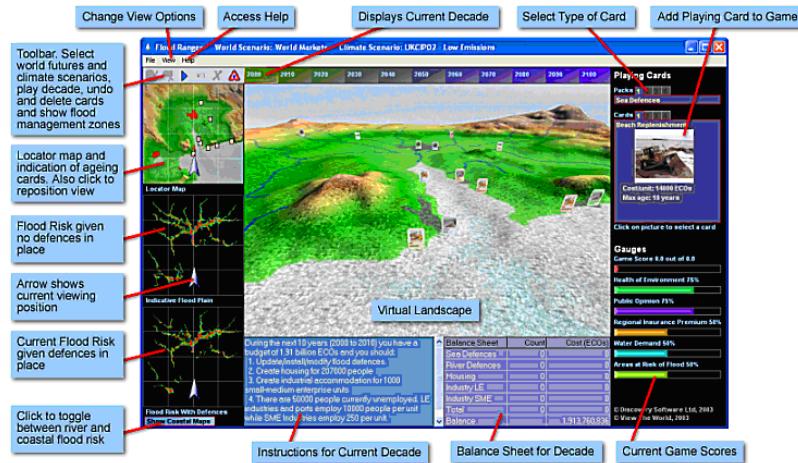


Figure 3 – An open project in FloodRanger World



Figure 4 – Open project in FloodRanger World

Selecting a world futures scenario

The first task when playing the game is to select a world futures scenario. To do this click on the Paint icon  towards the top left of the screen on the toolbar.

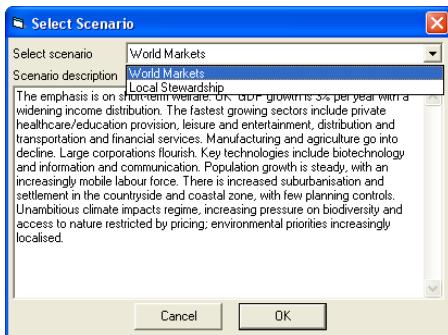


Figure 5 – Selecting a world futures scenario

Use the above form to select the world futures scenario you wish to play. Each scenario has a brief description and you can select the scenarios using the drop down list. Click on the OK button once you have selected your scenario.

Selecting a climate change scenario

Similarly, you must then select a climate change scenario by clicking on the cloud/rain icon on the toolbar and then selecting the scenario from the form shown below..

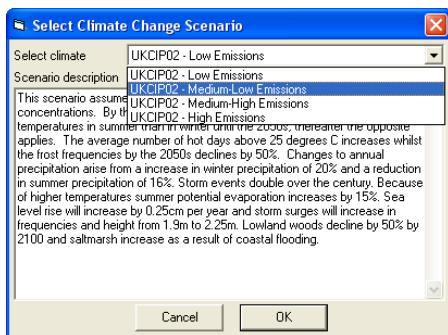


Figure 6 – Selecting a climate change scenario

Moving around the terrain and viewing options

To fly around the terrain use the arrow keys to move forwards, backwards and from side to side. Use the Page Up and Page Down keys to increase or decrease your elevation. The arrow keys in the NumPad area may be used to rotate your look angle left/right and up/down (N.B. on a laptop you will need to use equivalent keys on the QWERTY keyboard area by holding down the function key and pressing 4 for left, 6 for right, 8 for up and 2 for down).

To move directly to a point, click on the location map (to the left of 3D terrain display). Your view angles will remain the same.

To move to a corner of the study area, select the corner from the View menu.

Display Options

To change the display options select options from the view menu. The form that appears lets you change the speed of movement across the landscape, the size of the cards as they appear on the landscape and their orientation in respect to your view, your viewing height above the terrain, your field-of-view (similar to a camera's field-of-view), and the vertical exaggeration of the landscape. Two additional options allow you to

display the number of frames that your computer is drawing per second and to draw arrows above each new card that is added to the game for the current decade.

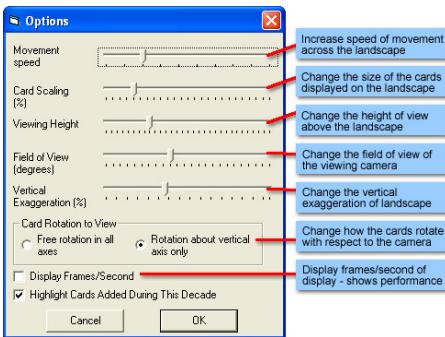


Figure 7 – Display Options

Playing cards and spending money

To add a defence to the virtual landscape you must select a card from those available in the upper-right corner of the game window. Move your cursor over the 'pack' heading to select cards from the different groups, e.g. Sea Defences, River Defences, Housing, and Industry. Similarly, once you have chosen a pack, move your cursor over the numbers available to highlight the card you require. To add it into the game click on the picture, this is then highlighted with a red border.



Figure 8 – Packs of cards

You must then position the card on the terrain. A cost surface is shown in the bottom-left corner of the window. This helps you position your card. As you move your cursor across the landscape you will notice a target marker drawn upon the cost surface corresponding to the cursor's position within the overall map of the area. The colour of the cost surface indicates the relative cost of building at any point in the map. Blue is relatively cheap while red is the most expensive. Black indicates that you cannot build at that location. As you move your cursor around the terrain, the cursor displays (in the text next to the arrow) the relative cost from the cost surface. A value of 1.0 is the cheapest. The maximum may be anything from 3 to 20 depending on the type of card selected. Once you have selected an area to add the card left-click on the terrain at that

location. You can undo the card placement using the undo icon on the toolbar or delete it later (but only during the current decade of the game) using the delete icon .

When not adding a card, the image in the lower left corner displays the current flood risk given the defences that you have in place. If you have defences in place for a stretch of river or coastline then the pixels within that stretch will not be coloured and will appear black. If your level of defences have degraded or have been purchased at < 1:100 for rivers or < 1:200 for coastal stretches then pixels to the outermost reaches of the flood plains will be coloured, indicating that floods will reach these areas if a future flood event is large

enough to breach the defences currently in place (obviously all pixels within the floodplain extent of these areas will also be flooded).

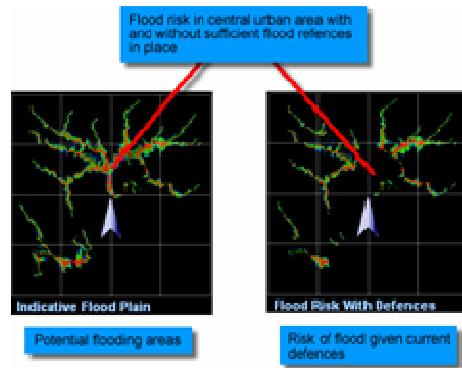


Figure 9 – Comparison of indicative flood plain and current flood risk

The idea of the game is to minimise the risk of flooding, so when playing the game you need to reduce the risk shown on this map particularly in or near urban areas. An important point to note is that any particular point in the landscape may be flooded from more than one source location. For example, areas near to the confluence of two rivers may be flooded from the direction of either river and in order to defend such locations you will need to defend flooding events from both rivers. The major city in the centre of the landscape is a good example of this and the flood risk map will not turn black unless all sources of possible flooding are defended against.

Each river and coast is divided into management sections (or stretches). These can be seen on the terrain by clicking on the warning icon on the toolbar. Once on the river and coast regions are on the icon on the toolbar turns to a tap icon . Click on the tap to turn off the river and coast region and turn on the water resource management regions. To turn all regions off click on the tap icon again.

The levels of defences are shown as 'walls' on the terrain delimiting the each management area. If a wall is coloured red then it is not currently defended, conversely if it is coloured blue then defences are in place. Colours in between indicate a non maximum level of defence for that region.

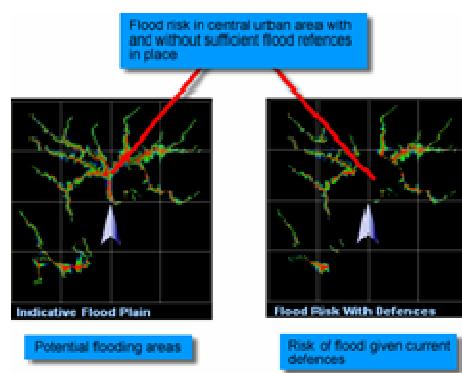


Figure 10 – Defence management regions

Ageing of cards

When new cards are added to the landscape they appear with arrows above them so that you can easily distinguish new cards from existing cards. These cards are given an age of zero.

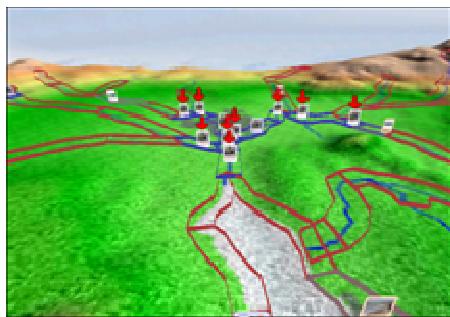


Figure 11 – Cards added during the current time slice have red arrows above them

As you progress from time slice to time slice the cards will age by the difference in years. Different cards have different life times in the game. As defences age their performance degrades. As the Flood Ranger you may feel it is therefore important to replace ageing defences before they fail. Ageing cards are shown by their colour which reflects their Maintenance State (1 = OK through to 5 = needs replacing). Orange and pink cards show maintenance states of 4 and 5 respectively, indicating that they should be replaced.



Figure 12 – An ageing card has an orange or pink background

Orange and pink cards are also shown on the Locator Map for easy identification. New cards are also shown as white markers on the locator map.

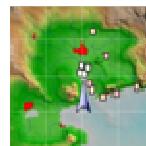


Figure 13 – Ageing cards shown on the locator map

Meeting the demands of world future scenarios with FloodRanger

At the start of each decade, FloodRanger issues a set of instructions regarding development and construction of flood defences in order to meet the demands of the selected world futures scenario. These are based on the projected increases in population and family unit size, changes in industry and enterprises and changes in visitor numbers.

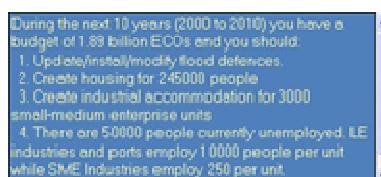


Figure 14 – Socio-economic requirements for a time slice

There are two key elements, depicted by sets of playing cards, to be manipulated: housing and industry. If insufficient houses or industrial developments of the right kind are built then the number of homeless and unemployed will rise and as a consequence public opinion will fall.

- i) **Housing** - there are three types of small housing (cheap, standard and eco i.e. energy efficient and flood-proofed) and three types of large housing (cheap, standard and eco). Eco housing has the benefit of reduced insurance premiums. Also, the different housing types can have different life expectancies.
- ii) **Industry** - three types of industry card are available to meet the demands of the economy; small and medium sized enterprises (SME), large industry and port development with different investment costs and life expectancies.
- iii) **water demand** - as the population and industry increase there will also be an associated increase in water demand. This is tied in with the climate change scenario chosen for the game. Increasing temperatures will increase tourism but decreasing rainfall will reduce the amount of available water.

Meeting the demands of world future scenarios with FloodRanger

At the start of each decade the player has a budget (in ECOs) which they can spend (or save!) as they wish. The budget available for each decade depends on the world futures scenario chosen, a Flood Tax from the population (Eco Housing population pays less Flood Tax) and Industries, and the interest paid on loans in previous years.

Whenever the player adds a card to the landscape, the cost of the card is calculated and added to the balance sheet.

Balance Sheet	Count	Cost (ECOs)
Sea Defences	2	130,951,336
River Defences	1	206,721,961
Housing	100,000	526,786,415
Industry LE	0	0
Industry SME	100	17,907,259
Total	100,103	882,366,971
Balance		1,005,874,896

Figure 15 – Socio-economic requirements for a time slice

Money can be borrowed in any decade. Interest is charged on these loans and repayments for the loans are automatically spread over the next 3 decades of the game. In the last 30 years of the game repayments are shortened and in the last 10 years the player cannot borrow further money.

Playing onto the next time period

Once you have added all the cards you require for the current decade press the  icon on the toolbar to proceed to the next decade. Behind the scenes, FloodRanger will process all the cards that you have added, creating new towns and industries. It will also sample the next ten years of the climate change scenario that you have chosen to give a series of river and coastal flood events at different frequencies (e.g. 1:5 to 1:200 events). The size of these flood events is then analysed in conjunction with the Indicative Flood Plains and the defences you have in place. Areas of flooding and other important results are then calculated and displayed in a results window, overlaying the landscape window.

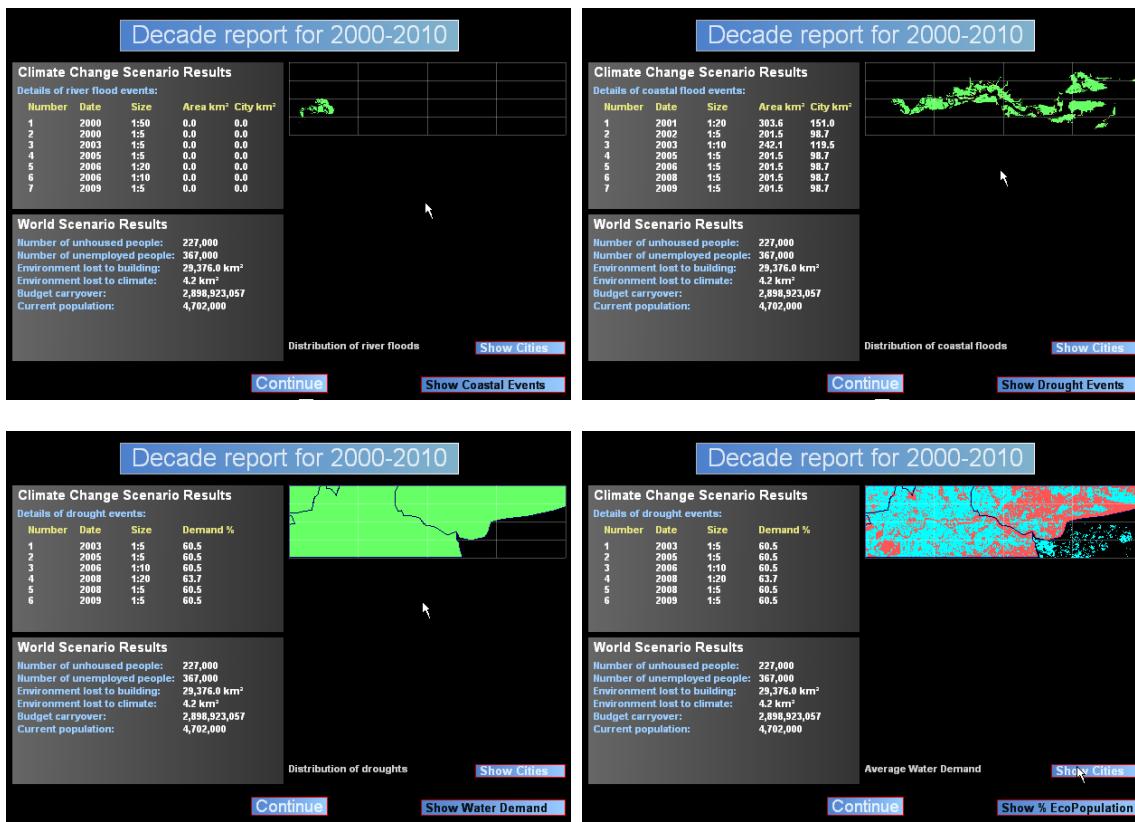


Figure 16 – Results window – river floods, coastal floods, droughts, water demand, eco population

The results window shows the river flood events by default. The flood events are listed individually, detailing their size, year and area of flood (both total and urban). The map to the right of these results provides a spatial distribution to the floods. The colours indicate the number of floods that have occurred in any area during the decade. The cities can be shown as an overlay to this map by hovering over the show cities button.

To show the flooding from coastal sources click on the Show Coastal Events button. Similarly click on the same button to show drought events, water demand and eco population per water resource region.

When you have finished perusing the results pages, click on the Continue button to play the next decade..

Scoring

After each decade the game scores are calculated and shown to the right of the main landscape window. Scores are displayed for:

- Overall game score** - a combination of the other five scores.
- Health of the environment** - an indication of number of roads, industries, houses built coupled with the health of SSSIs, forests and National parks.
- Public Opinion** - related to housing, unemployment, health of the environment and the state of flooding. If public opinion falls below 30% then the game will end.
- Regional Insurance Premium** - related to risk of flooding and past history of flooding.

- v) **Water Demand** - related to population, tourism, industry usage and climate change.
- vi) **Areas at risk of flood** - areas remaining at risk, which affects public opinion and insurance premiums

You can view a time history of any of the scores by hovering over the game score gauge that you wish to see. In the example on the right the user is hovering over the Public Opinion gauge. The time history is shown in a graph underneath a brief explanation the gauge itself.



Figure 17 – Game scores and viewing score history

Creating and editing a FloodRanger World Project

How do I create a game for my area of interest?

A FloodRanger World project can be made for any location in the world. To make one for your area of interest you will need a minimum number of input datasets including a digital elevation model (DEM), a grid showing urban areas, a grid indicating land and sea values, grids for sites of special scientific interest (SSSI), woodland and national parks, a vector file describing roads, and vector files indicating the spatial extent of management regions along rivers, along the coast and regional districts for the management of water resources. If you wish FloodRanger World to automatically create river and tidal floodplain data for you then you will also need to provide a river head points file and a grid indicating rain volume data.

The following sections will describe these and other inputs datasets and the various parameters that can be edited to change the game settings.

Input datasets

DEM^s

A DEM is a raster grid where each pixel value represents the height at that point. It is worth mentioning at this point what raster formats FloodRanger World uses. There are two different types of raster data used in FloodRanger World:

- those that maybe used for pictures and image overlays in the game – formats here include windows bitmap (BMP), and JPEG (JPG)
- those that are used for internal calculations where each pixel needs to represent a real or decimal number and not simply a colour in an image – formats used here are the ESRI FLT format and the Discovery Software SIPS format

A DEM is of the latter type and may be created using a number of off-the-shelf programs. For example FLT files can be created using a number of ESRI ARC GIS programs (www.esri.com) while SIPS files can be created using the STEMgis program (www.discoverysoftware.co.uk). Another useful tool for converting raster grids to the ESRI FLT format is GDAL (www.gdal.org). The SIPS format is described in Appendix 1.

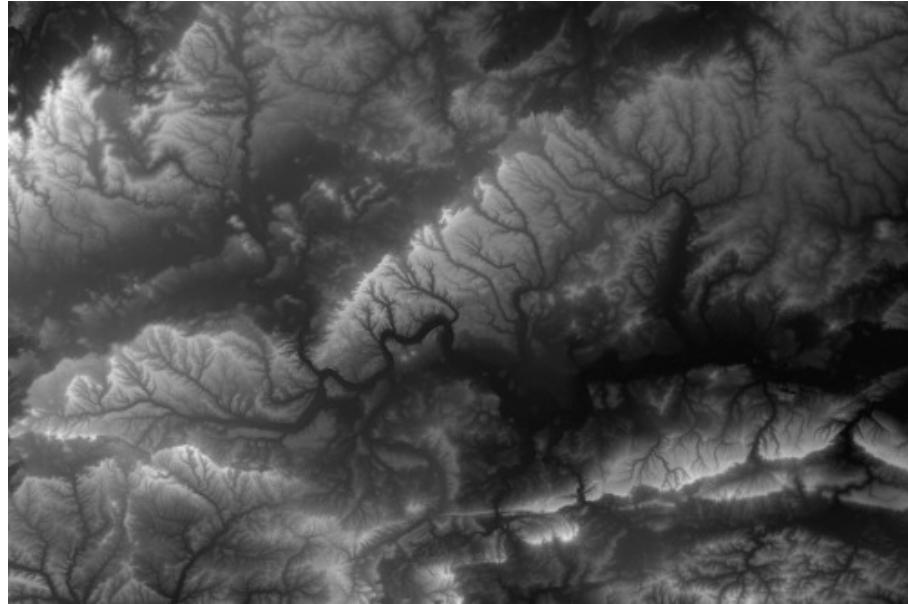


Figure 18 – DEM of the Thames Catchment

Urban Areas

The second input data set is a grid representing urban area. The grid highlights areas that are already built on, those that can be built on and those where it is not possible to build, i.e. in the sea or a lake. N.B. although you may wish to prevent people from building in national parks and SSSIs etc it is better to not include these areas in this grid. FloodRanger World will use other grids to determine any penalties that need to be applied to players building in these areas.

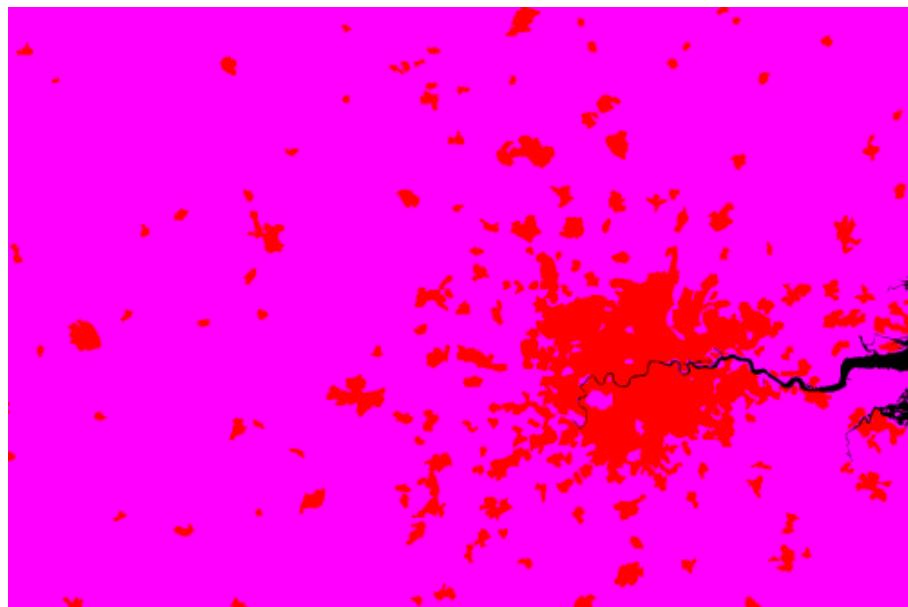


Figure 19 – Urban grid for the Thames catchment

Pixel values in the grid should have a value of 1 for built up area (red in the above figure), a value of 0 for areas that can be built on (pink above) and a no data value (e.g. -9999) for those areas that cannot be built upon (black above). *Please note that the colours shown here are simply a reflection of what the display software uses to colour the pixels and that it is important that the pixel values are only 1, 0, and no data.*

Land Sea Grid

The land/sea grid should have pixel values of 1 where there is land and 0 where there is sea (red and pink, respectively, in the figure below).



Figure 20 – Land/Sea grid for the Thames Catchment

Natural Environment Grids

There are three grids required to describe aspects about the natural environment, a SSSI grid, a woodland grid and a National Parks grid. In each case the pixel value should be 1 where the feature exists and a no data value where it does not exist.

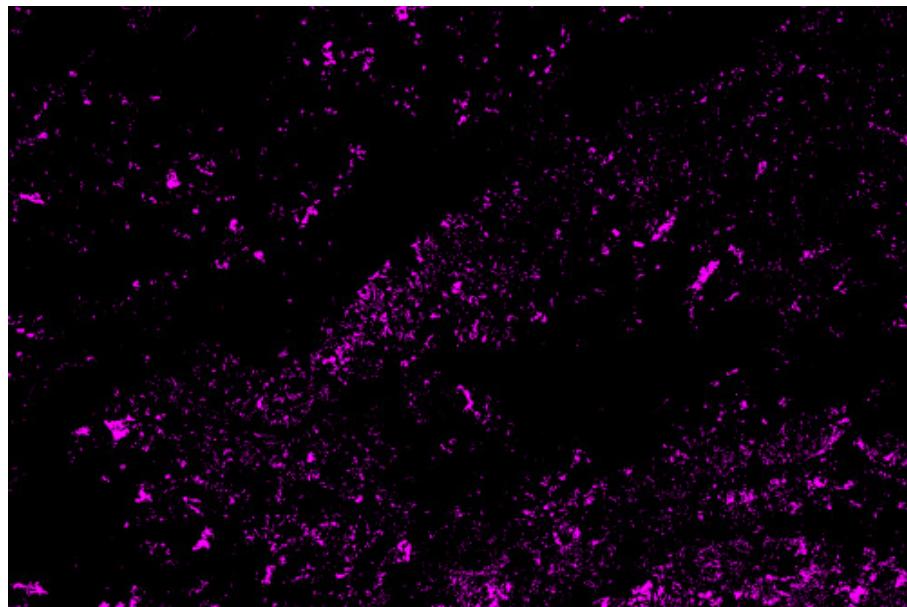


Figure 21 – Woodland grid for the Thames Catchment

Road Lines

The road lines should represent major roads in the area. They are used to calculate the cost of building in certain locations with it being more expensive to build further away from existing urban areas and existing roads. The vector file used to describe the roads is a comma separated variable file (CSV) formatted in a way used in the STEMgis program. The format is described in Appendix 2.

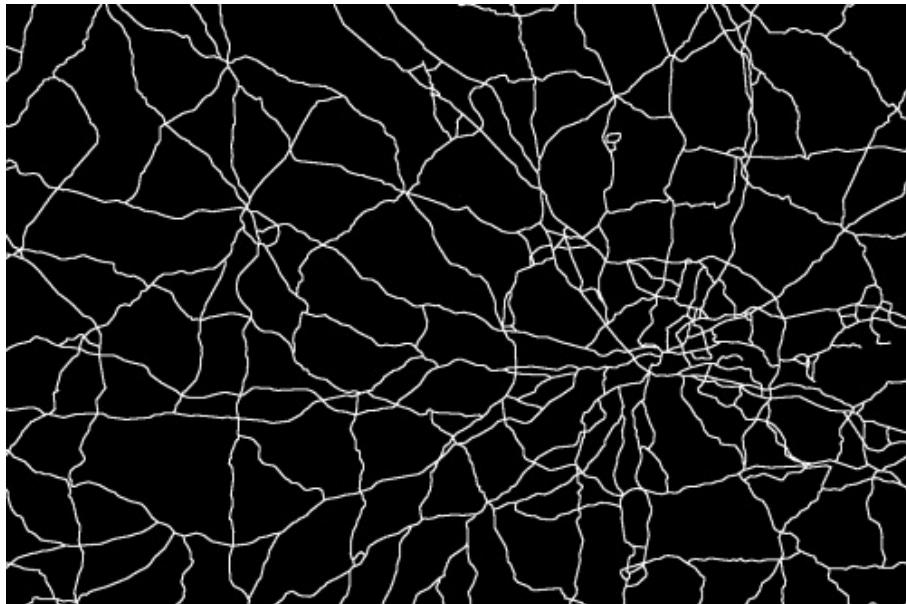


Figure 22 – Major roads in the Thames Catchment

Management Regions

Within the game defences can be placed within ‘management regions’. These regions describe certain sections of rivers or the coastline which should relate real world management regions if possible. If a defence is placed within one of these regions then it is assumed that the defence applies along the entire length of that region. As shown in the figure below, each region should describe a narrow polygon along the path of a river or along the coast. Each region should be connected to its neighbours as shown in the figure.

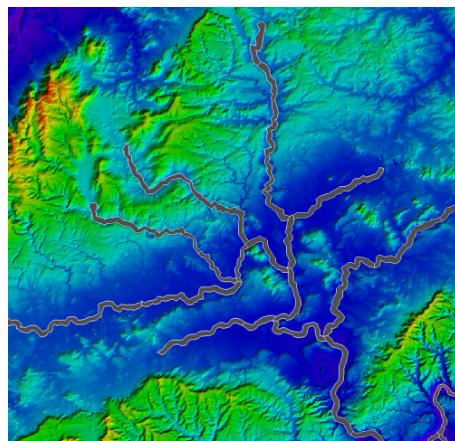


Figure 23 – River Management regions overlaid on a shaded DEM

The format for the management region CSV files is described in Appendix 2 and is very similar to that of the Roads CSV format; however, this format includes two extra columns of information. For the river management regions, the first column describes which downstream region each region links to. For example,

if the region linked to the third region in the file then the link number would be 2 (N.B. the numbers start from zero). For a coastal file the link number refers to an upstream region and is only used within an estuarine environment (pure coastal regions would have a value of -1). If you have an estuary in your area then you should try to make regions either side of the estuary roughly equal in length. The value used to indicate no further downstream (i.e. at the mouth of a river) or upstream (i.e. at the tidal limit of an estuary) links is -1. The second column in both files should contain values for the length of each management region in km.

An example of the river and coastal management regions CSV files can be seen at c:\Program Files\Discovery Software\FloodRangerWorld\project\Inputs\FluvialRegions.csv and c:\Program Files\Discovery Software\FloodRangerWorld\project\Inputs\TidalRegions.csv respectively.

In addition to river and coastal region files, a third file is required which describes water resources management regions. These are again in a similar format but describe regions which may cover the entire area of the DEM and are likely to be more politically related than physically.

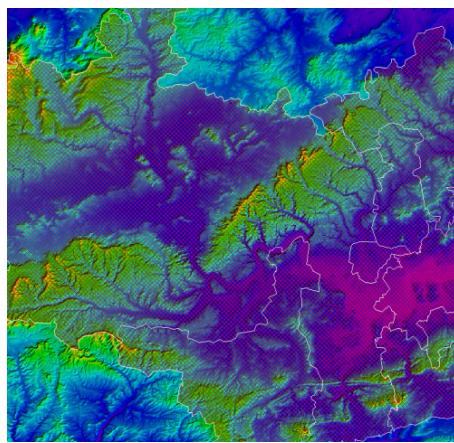


Figure 24 – Water management regions overlaid onto a shaded DEM

There are five additional columns of data required in the water resources CSV file format. These are:

- i) POPULATION – the number of people living in each region
- ii) LE – the number of large enterprises existing in each region
- iii) SME – the number of small-medium enterprises existing in each region
- iv) ECOPOPULATION – the number of people living in eco-friendly housing
- v) WATERDEMAND – the water demand in % for each region at the start of the game

An example of the water resources management regions CSV file can be seen at c:\Program Files\Discovery Software\FloodRangerWorld\project\Inputs\WaterResources.csv.

Rainfall Grid

There are two optional input datasets that are required if you wish FloodRanger World to automatically create the river and tidal flood data. These are a rainfall grid, indicating rainfall volumes for year 0, and a river head points file. The pixels in the rainfall grid should indicate (in metres) the amount of water expected to run off from that pixel into the drainage system at a maximum 1:100 year event. You can incorporate as much into the precalculation of these values as you wish. For instance, you may wish to use geographical variations in

rainfall (e.g. elevation difference, north-south gradients), soil types, urban runoff etc. The image below shows a constant rainfall modified by soil type and urban runoff.

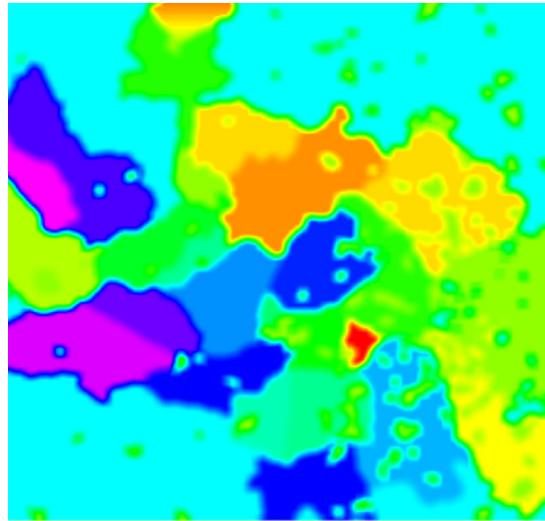


Figure 25 – Rainfall volume grid

River head points file

The river head points file is another STEMgis formatted CSV file which describes the point locations of the major rivers within your study area. The format for this file is described in Appendix 2.

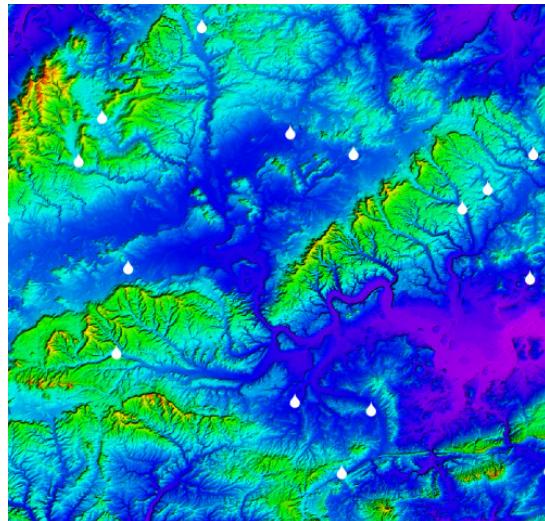


Figure 26 – River head points shown as white raindrop symbols

Creating a FloodRanger World Project

Once you have collated and formatted your input data you can start to create a new FloodRanger World project. There are then a number of steps you will need to follow before you can play the game. FloodRanger World can be used to automatically create the further datasets that are required to run the game or you can again create these yourself and feed them into the project.

To create a new project, run FloodRanger World and select the 'Create New Project' option.



Figure 27 – Create a new FloodRanger World project

There are a number of parameters that are set up for you by default. These include the time slices (2000-2100 in decades), four climate change scenarios, two world futures scenarios, 23 cards that can be played during the game and a series of baseline parameters used for the game.

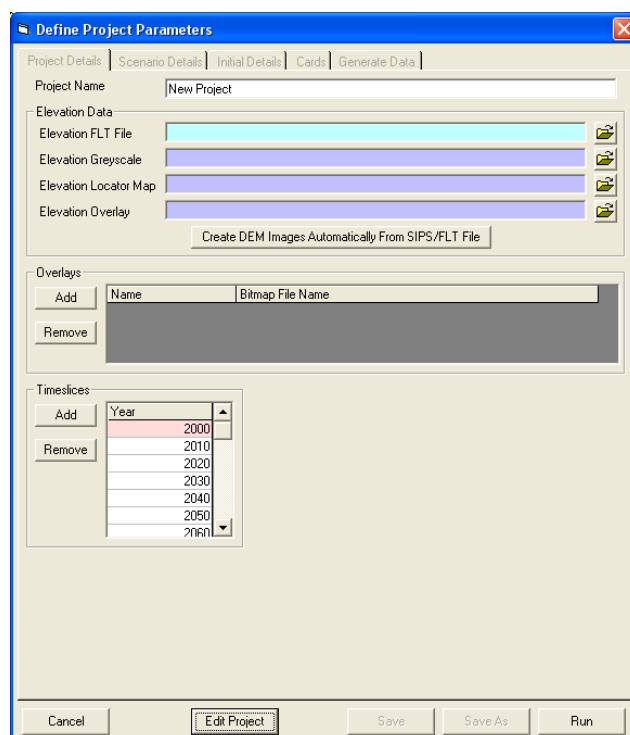


Figure 28 – The project definition and edit form

The first form you will see is shown above. To edit the project and to add your inputs you will need to click on the 'Edit Project' button.

Step 1 – Naming the project

The first step is to name your project. This can be done by entering the name in the 'Project Name' text box.

Step 2 – Adding your input datasets

DEM File

You may now add your input datasets. To add a reference to your DEM file click on the file browse icon to the right of the 'Elevation FLT file' text box. You can then select the file using the standard Windows file browser.

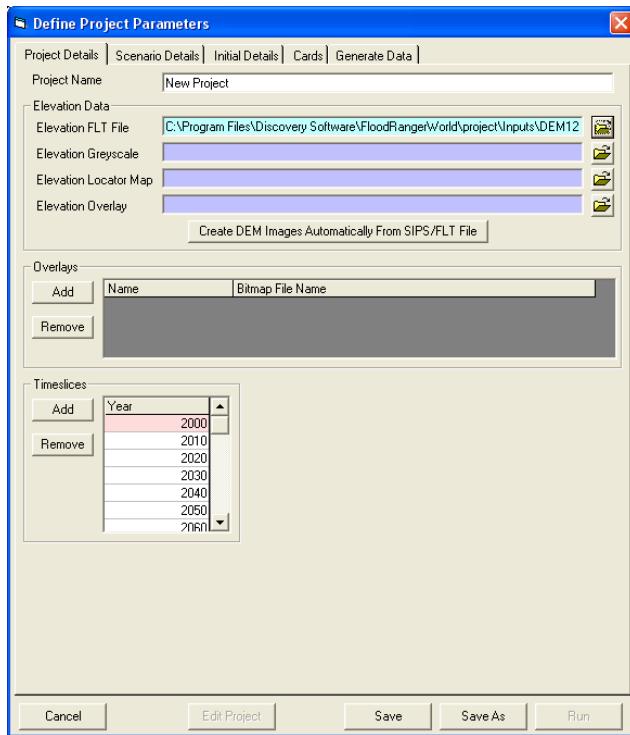


Figure 29 – Adding a DEM Input

You may have noticed that the DEM text box has a blue background. This colour is used to signify inputs that need to be supplied by you. The purple background is used to signify those that can be created by you or that can be created automatically by the program. For instance, with the elevation data the greyscale image, the locator map and the overlay image can all be created automatically by clicking on the 'Create DEM Images Automatically From SIPS/FLT File' button. Don't do this just yet as you will need to add your Urban Areas grid first.

Other Input Data

The remaining input data is added via the 'Generate Data' tab. After clicking on the tab you will see the following form.

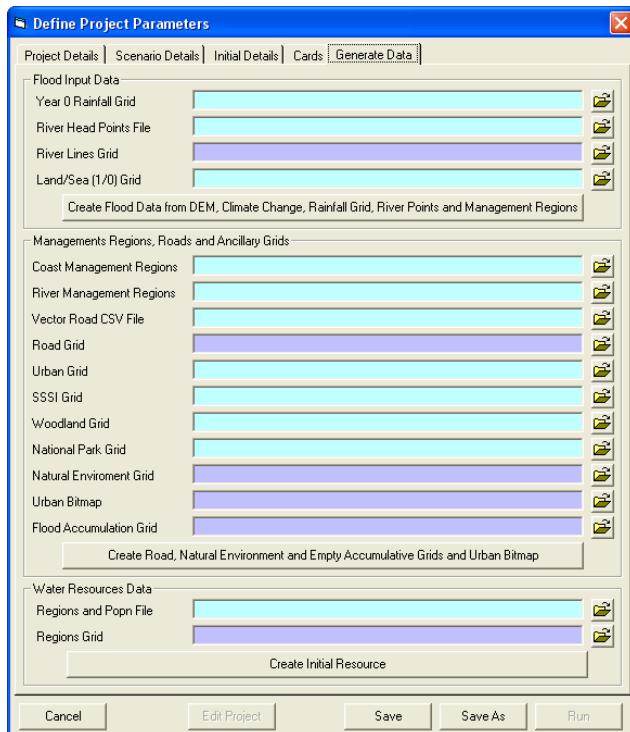


Figure 30 – Adding remaining input data

If you have your own river and tidal flood data (see Creating river and tidal flood data) then you do not need to add inputs for the top two boxes, 'Year 0 Rainfall Grid' and 'River Head Points File'. The remainder of the inputs you can now add in the same way as adding the DEM file.

Step 3 - Creating additional data from your input data

If you wish FloodRanger World to create the flood data for you then you must make sure that you have the DEM, Rainfall, River Head Points, Land Sea grid, and Coast and River management regions files all specified. You may then click on the 'Create Flood Data ...' button to create the flood data. BE WARNED this may take a VERY long time to process. On a dual processor PC with a DEM of 1536 x 1024 this took approximately 24 hours of processing time to complete.

Once you have added the remaining input files to the project you may also click on the 'Create Road ...' button, the 'Create Initial Resource' button and the 'Create DEM Images ...' button on the 'Project Details' tab. These buttons create a number of datasets automatically using your original input datasets.

Step 4 – Creating cost surfaces for each card type

Each card that can be used in the game needs a cost surface associated with it. A cost surface is a grid that represents the relative cost of placing that card in a certain position. For instance, you might find that it costs X ECOs/km to build a defence in agricultural land but it might cost 5X ECOs/km to build the same defence in an urban area. The cost surface may therefore have a value of 1 in the agricultural area and a value of 5 in the urban area. The cost surface should also indicate area where a card cannot be placed – pixel values here should be the no data value, e.g. -9999. For instance a housing cost surface would have no data values where there are already houses built and also in the sea.

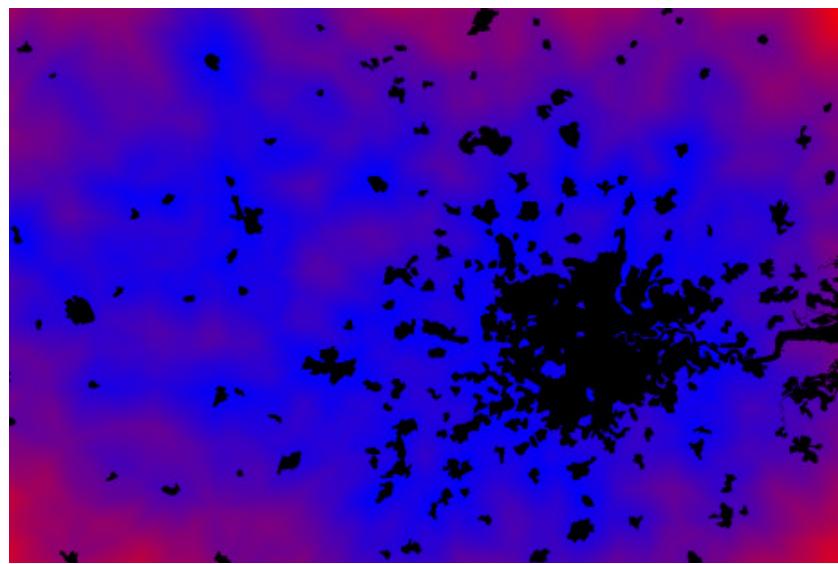


Figure 31 – A housing cost surface – blue areas are the cheapest and red areas the most expensive

Each type of card is defined under the ‘Cards’ tab. This tab lets you add new packs of cards, edit or add cards and add initial cards that appear at the start of the game. For now, we will just be editing the existing card types which you will have been given by default when creating a new FloodRanger World project.

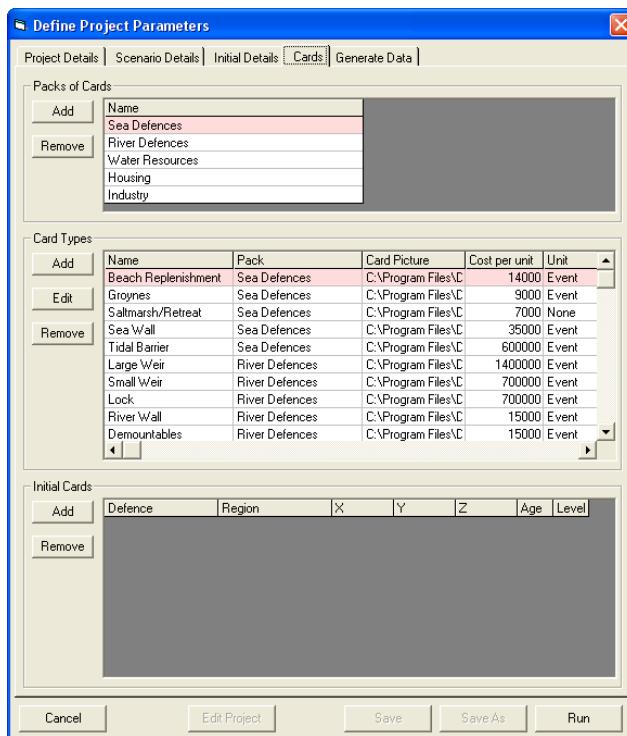


Figure 32 – The card tab for editing game cards

To create a cost surface for each card you will need to select the card from the ‘Card Types’ list and then click on the Edit button. This will bring up the form shown below.

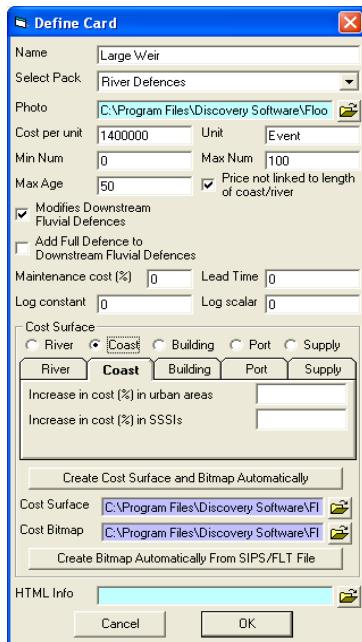


Figure 33 – The card tab for editing game cards

You will notice that there are a number of options relating to the definition of the card on this form that may be changed if you wish. To add a cost surface you may wish to use your own, in which case you can click on the File Browser icon next to the 'Cost Surface' text box and select a file. Alternatively, you can use the options available on the form. First you must select what type of card it is, i.e. river, coastal, building, industry or supply (Water supply). Each type has different options:

- i) River type has four options
 - a. Minimum height – the minimum height at which this type of defence can be placed
 - b. Maximum height - the maximum height at which this type of defence can be placed
 - c. Urban increase – the percentage increase in cost when placing the defence in an urban area – the number of urban pixel within a management region are calculated to determine the relative increase. For example, if the urban increase was set to 1000% (i.e. 10 times more expensive) and the amount of urban pixels within the region was half then the cost would be 5 times more expensive.
 - d. SSSI increase - the percentage increase in cost when placing the defence in a SSSI area. The same relative cost is calculated as per the urban area pixels.
- ii) Coast type has two options
 - a. Urban increase – as above
 - b. SSSI increase – as above
- iii) Building type has three options
 - a. Road increase – the distance from a road at which there is a 10% increase in the cost of building

- b. River increase – the distance from a river at which there is a 10% increase in the cost of building
- c. Urban increase – the distance from an urban area at which there is a 10% increase in the cost of building
- iv) Port type has two options
 - a. Road increase – the distance from a road at which there is a 10% increase in the cost of building
 - b. Urban increase – the distance from an urban area at which there is a 10% increase in the cost of building
- v) Water supply type has no options

Once you are happy with the options that you have set you can click on the 'Create Cost Surface and Bitmap Automatically' button to create these data for you. This should be repeated for each card that you may wish to use in the game. Each card type can also be linked to a html file so that users can discover more information about the type of defence by clicking on an information button next to the card photograph in the game. Use the html text box to point to the appropriate file.

Step 5 – Adding initial defences to the game

When you begin the game you need to have some initial defences in place otherwise it will be extremely difficult for the user to defend their urban area during the first decade. You can add some initial defences to the game by clicking on the 'Add' button in the Initial Cards section of the Cards tab.

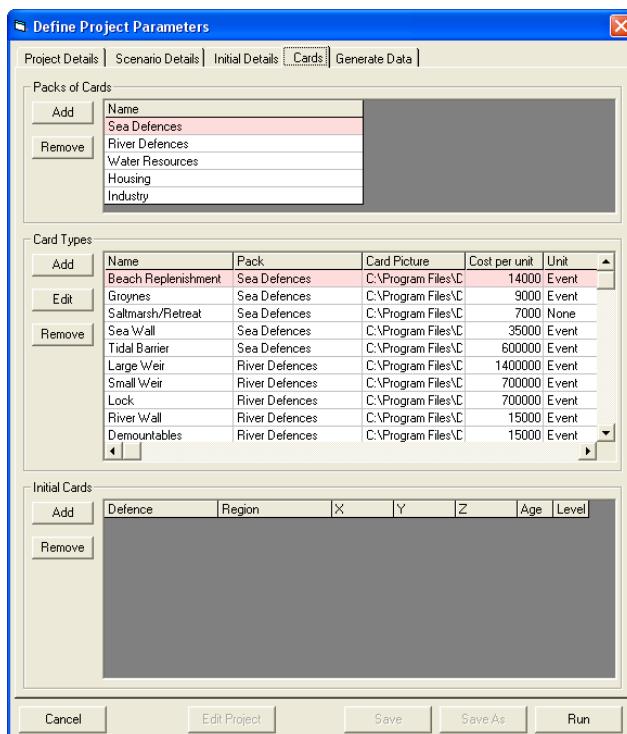


Figure 34 - The card tab for adding initial defence cards

By clicking on the Add button the following form will appear:



Figure 35 – Adding an initial defence card

To add a new card, firstly select whether you wish to add a fluvial or tidal defence. Changing this option will change the ‘Type of Card’ and ‘Management Region’ drop down lists. Then select the ‘Type of Card’ and the ‘Management Region’ within which you wish to place the card. You can also specify an age for the card. Remember that as defences age they lose some of the effectiveness. Finally, you can select the level of event for which the defence was designed for.

Step 6 – Save the Project

Finally, you should save the project. It is a good idea to save all of your files into the same directory and/or sub-directories. This will make it easier to maintain your files and also to distribute them if you wish to share them with others. You could use the directory structure used within the c:\Program Files\Discovery Software\FloodRangerWorld\project folder.

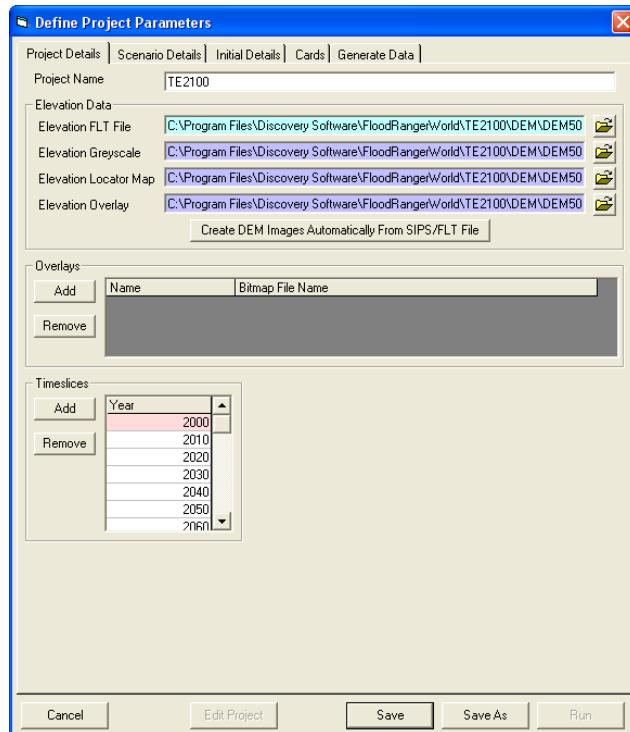


Figure 36 – Save the project

Once you have saved the project file you can run the project via the ‘Run’ button on the above form or go back to the opening screen and select the project from the ‘Open Project’ option.

Editing a FloodRanger World Project

In setting up a new project we have already seen a number of options and datasets that can be changed within the FloodRanger World project. This section will describe and illustrate a number of other parameters

that can be changed to match your study area. The default settings that you are provided with, for instance the climate change scenarios, are based on parameters for the East coast of England.

Defining time periods

You may decide that you want your game to start at some time other than the year 2000, in which case you can define the actual years individually. Click on the 'Add' button to add a time or select a year and then click on the 'Remove' button to remove the year. Please be aware that your number of years should match the number of entries you have in the scenarios data.

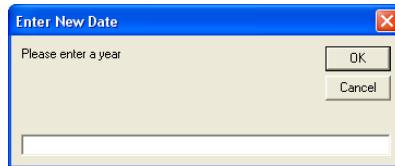


Figure 37 – Adding a year

Adding overlays

You can add overlays to the game. These can be overlaid on the DEM within the game and might be used to highlight roads, rivers, SSSIs etc. The overlays can be in the Windows Bitmap (BMP) or JPEG (JPG) formats. You should note that the overlays should have the same number of rows and columns as the DEM and they should also be mirrored in the X dimension.

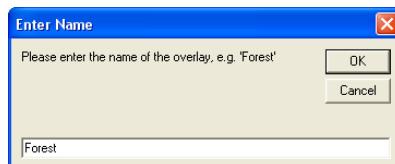


Figure 38 – Naming an overlay

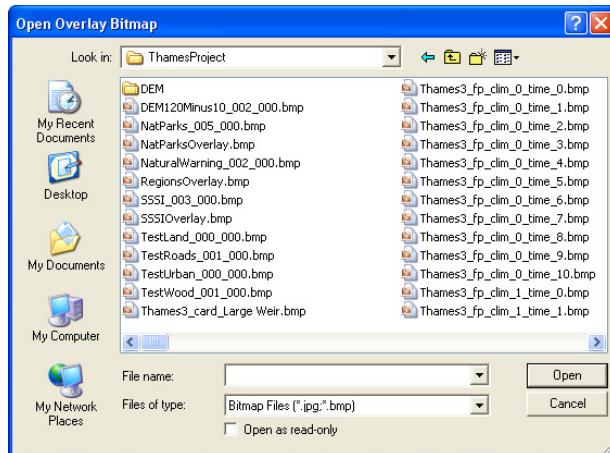


Figure 39 – Selecting the overlay file

World Futures Scenarios

On the Scenario Details tab you can add, edit or remove world futures scenarios and climate change scenarios. By default, you will see two world futures scenarios, World Markets and Local Stewardship. Each scenario has a number of parameters which can be edited to suit your models of the future.

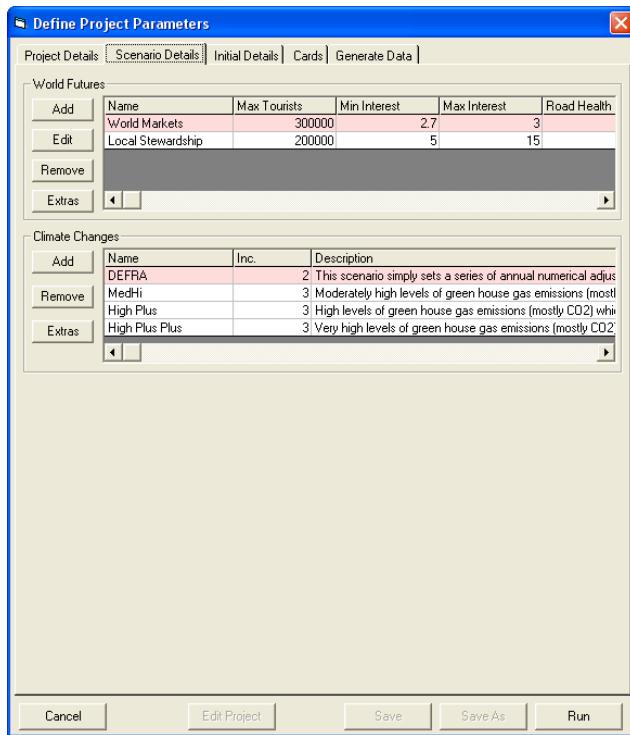


Figure 40 – World Futures parameters

For each world futures scenario there are a number of baseline parameters and a number of parameters that vary for each time slice. To edit the baseline parameters for a scenario, select the scenario and then click on the edit button.

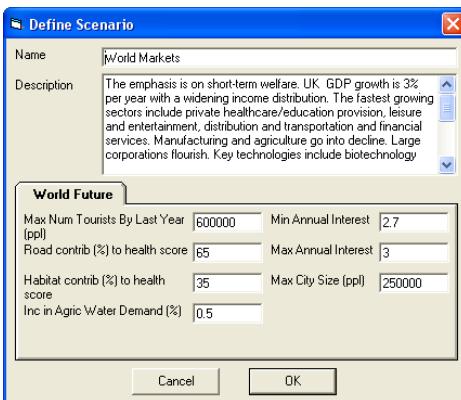


Figure 41 – Editing a world futures scenario

There are two text boxes provided to change the name and description associated with the scenario. The remaining parameters are explained in more detail below:

- i) **Max Number Tourists By Last Year** – The number of tourists (equivalent to residents) that are expected to visit the area by the end of the game. There is also a baseline number of tourists parameter that is the same for each scenario. The baseline and last year numbers are used to determine the number of tourists at each time slice during the game. This number is added to the population figure for each time slice to determine the water demand at each time slice. The number of tourists should be made equivalent to an equivalent amount of people that could be considered permanent resident. For example, if your estimate was that there would be 1,000,000 million visitors per year, then assuming each visitor stayed in the area for an average

of one week, then the equivalent number would be 1,000,000 / 52, i.e. approximately 19,200 permanent residents.

- ii) **Road contrib. (%) to health score** – The health of the environment is calculated using three different factors, namely,

- a. **The existing health score**

- b. **The environmental area lost** – has a maximum value of 1.0 and is calculated using:

$$\text{i. } \text{EnvironmentAreaLost} = \text{area_lost}/31.25$$

- c. **The length of new roads** – has a maximum value of 1.0 and is calculated using:

$$\text{i. } \text{LengthNewRoads} = \text{length_roads}/125$$

$$\text{Health score} = 0.8 * (100 - \text{EnvironmentAreaLost} * \text{HealthHabitatWeighting} - \text{LengthNewRoads} * \text{HealthNewRoadsWeighting}) + 0.2 * \text{PreviousDecadeHealthScore}$$

The road contribution % is used to give a weighting to the LengthNewRoads value. This and the habitat should add up to 100%.

- iii) **Habitat contrib. (%) to health score** – as above but represents the weighting for the EnvironmentAreaLost value.
- iv) **Inc in Agric Water Demand (%)** – The increase in agricultural water demand due to the world futures scenario. There is a similar figure for each climate change scenario and the two figures are added together when calculating the agricultural water demand.

$$\text{Agriculture Water Demand} = \text{BaseWDAgriculture} * (1 + 0.01 * \text{CurrentTimeSlice} * (\text{Scenarios}(\text{CurrentScenario}).\text{AgricultureWaterDemand} + \text{Climates}(\text{CurrentClimate}).\text{AgricultureWaterDemand}))$$

- v) **Min Annual Interest** – If you user borrows money at any point during the game then interest is charged on that money for the following decades. The interest that is charged depends on the Min Annual Interest and Max Annual Interest settings and is randomly sampled between these two figures. This is done in an attempt to mimic what might happen naturally.

$$\text{Annual Interest} = \text{Scenarios}(\text{CurrentScenario}).\text{InterestMin} + \text{RandomNumber} * (\text{Scenarios}(\text{CurrentScenario}).\text{InterestMax} - \text{Scenarios}(\text{CurrentScenario}).\text{InterestMin}))$$

- vi) **Max Annual Interest** – The Max Annual Interest in the above calculation
- vii) **Max City Size (ppl)** – The maximum number of people that can be housed in a new city/town when a housing card is placed on the terrain.

There are also a number of parameters that change per time slice. These can be accessed via the 'Extras' button on the 'Scenario Details' tab.

Extra data for world futures - World Markets

Parameter	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Population to house	0	202000	158000	124000	120000	100000	120000	120000	50000	90000	77000
Number of LEs	0	0	0	0	50	25	10	5	10	25	25
Number of SMEs	0	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Budget	0	2	2.06	2.12	2.18	2.24	2.08	1.84	1.6	1.36	1.12

Figure 42 – Parameters per time slice for world futures scenarios

The parameters shown above relate to the demands placed on the players per time slice and the budget that the player has to spend during that time. In more detail:

- i) **Population to house** – The number of people that require housing between two successive time slices
- ii) **Number of LEs** – The number of Large Enterprises that the player must build between successive time slices
- iii) **Number of SMEs** – The number of Small/Medium Enterprises that the player must build between successive time slices
- iv) **Budget** – The amount of money in billions of ECOs that the player has to spend between successive time slices

Each box is editable and when you have finished edited the items simply click on the 'OK' button to keep your changes.

Climate Change Scenarios

In a similar fashion to the World Futures scenarios, Climate Change scenario have some time dependent and independent parameters that can be defined or changed. By clicking on the 'Add' button you can add a new climate change scenario.

Define Scenario

Name	New scenario
Description	This scenario includes ...
Climate Change	
Increase in frequency of flood events to end of the time sequence. A value of 1 indicates that the frequency will remain the same, a value of two will double the frequency and so on.	
1.0	
Cancel OK	

Figure 43 – Adding a climate change scenario

You should define the name of the scenario and provide a description of the scenario which the player will see when they select a climate change scenario at the start of their game. There is only one time independent parameter for a climate change scenario which relates to the way in which the frequency of certain flood events increases over time. All events in the game are assumed to relate to the first time slice in

the game. However, as storminess and other factors will increase in certain climate change scenarios then what is a 1:100 year event in the year 2000 may become more frequent, e.g. a 1:75 year event by 2100. This parameter can be used to specify the relative increase in the frequency of events. A value of 1 will indicate that there is no increase in frequency while a value of 2 will indicate that the events become twice as frequent.

To access the time dependent parameters you can again click on the 'Extras' button.

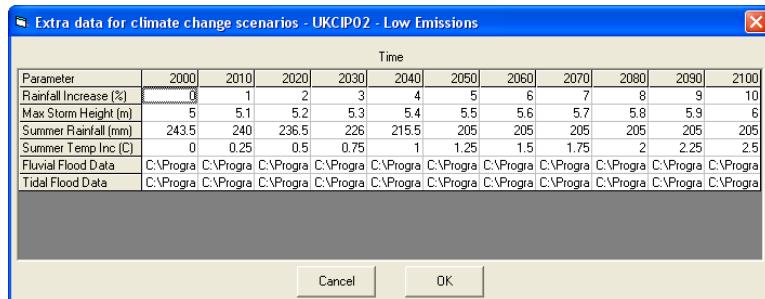


Figure 44 – Time dependent parameters and data for climate change scenarios

- i) **Rainfall Increase (%)** – The percentage increase in rainfall in comparison to the first time slice. This parameter is used when you ask the program to automatically create the flood plain data. The volume of water in each river will be increased by this amount and therefore the floodplains will be wider.
- ii) **Max Storm Height (m)** – This is the height of a maximum storm event at each time slice. The figure includes any related factors such as sea level rise. It is only used in the automatic creation of tidal flood plain data, so if you have used your own flood data this set of parameters is not important.
- iii) **Summer Rainfall (mm)** – This figure indicates the summer rainfall over a 3 month period and is used to modify the water resources for each water resource region. The modification factor is SummerRainfall/200, so a value of less than 200 will reduce available water resources while a greater value will increase it.
- iv) **Summer Temp Inc (C)** – The increase in summer temperature for each time slice. This figure is used to calculate the number of tourists for each time slice which in turn is used within the water demand calculation.

$$\text{NumTourists} = \text{MinTourists} + (\text{MaxTourists}-\text{MinTourists}) * (\text{CurrentDecade}/10) * (\text{CurrentScenarioSummerTemperature} - \text{MinScenarioSummerTemperature}) / (\text{RangeScenarioSummerTemperatures})$$

- v) **Fluvial Flood Data** – These are fluvial flood plain grids for each time slice. Each grid should be in the SIPS format and should have two frames (or bands) per file. The first frame should have pixel values between 0 and 1, where a value of 1 would indicate that the pixel would be flooded on a 1:1 event and a value of 0 would be that the pixel would never be flooded. The value is a probability that the pixel would be flooded and the following values are used to convert probabilities into flood events.

Probability	Flood event
1	1:1
0.68	1:10
0.5	1:20
0.38	1:30
0.21	1:50

0.06	1:75
0.01	1:100

The second frame is used to indicate where each pixel is flooded from in terms of which river management region. The pixel value is a long integer made up of string values indicating the number of the management region defined in the river management regions CSV file (see above). For instance if a pixel was flooded from management regions 3 and 4 then string would be "0203" which would give a number of 203 which is stored as the pixel value.

- vi) **Tidal Flood Data** – The same as above but for the flooding from tidal sources and tidal management regions.

Initial Baseline Parameters

By clicking on the Initial Details tab you can access and edit these initial parameters.

Population			
Population	4500000	Eco Population	100000
Num Tourists	50000		

Housing and Industry			
People per pixel - Eco Large	2000	People per house - Eco Large	2
People per pixel - Eco Small	5000	People per house - Eco Small	8
People per pixel - Standard Large	2500	People per house - Standard Large	4
People per pixel - Standard Small	4000	People per house - Standard Small	6
People per pixel - Cheap Large	4000	People per house - Cheap Large	3
People per pixel - Cheap Small	4000	People per house - Cheap Small	5
Num Unhoused	5000	Num Unemployed	50000
LE Industries per pixel		SME Industries per pixel	
Ports per pixel		People employed per LE Industry	
People employed per SME Industry		LE Industries	
SME Industries		SME Industries	

Finance			
Person Flood Tax	120	Eco Person Flood Tax	90
Unemployed Tax Penalty	180	Unhoused Tax Penalty	220
LE Flood Tax	2000000	SME Flood Tax	20000
Level of Borrowing		10000000	

Water Demand (litres)			
Base Water Supply	100000000	Water Demand per person	5
Water Demand per LE	5000	Water Demand per SME	50
Water Demand per ECO person		2.5	
Water Demand - Agriculture		26250000	

Miscellaneous			
Area considered a catastrophic flood (km2)	50	Expected area of flooding for insurance purposes (km2)	10
Multiplier (x) for regional insurance calculation where RI = AreaFlood * x		0.02	

Figure 45 – Editing the initial baseline parameters

- i) **Population** – The initial population in the whole study area
- ii) **Eco Population** – The number of the population that can be considered eco-friendly. This population has a different water demand to the remaining population (see below).
- iii) **Num Tourists** – Number of tourists at the start of the game. This number is made equivalent to full-time residents – see previous section
- iv) **People per pixel, Eco Large** – The number of people that can be housed per pixel for Large Eco housing. Used to calculate how big a new town will be.
- v) **People per pixel, Eco Small** – The number of people that can be housed per pixel for Small Eco housing. Used to calculate how big a new town will be.

- vi) **People per pixel, Standard Large** – The number of people that can be housed per pixel for Large Standard housing. Used to calculate how big a new town will be.
- vii) **People per pixel, Standard Small** – The number of people that can be housed per pixel for Small Standard housing. Used to calculate how big a new town will be.
- viii) **People per pixel, Cheap Large** – The number of people that can be housed per pixel for Large Cheap housing. Used to calculate how big a new town will be.
- ix) **People per pixel, Cheap Small** – The number of people that can be housed per pixel for Small Cheap housing. Used to calculate how big a new town will be.
- x) **Num Unhoused** – The number of homeless people at the start of the game.
- xi) **People Per House, Eco Large** – The number of people that live in a Large Eco House. For information purposes only.
- xii) **People Per House, Eco Small** – The number of people that live in a Small Eco House. For information purposes only.
- xiii) **People Per House, Standard Large** – The number of people that live in a Large Standard House. For information purposes only.
- xiv) **People Per House, Standard Small** – The number of people that live in a Small Standard House. For information purposes only.
- xv) **People Per House, Cheap Large** – The number of people that live in a Large Cheap House. For information purposes only.
- xvi) **People Per House, Cheap Small** – The number of people that live in a Small Cheap House. For information purposes only.
- xvii) **Num Unemployed** –
- xviii) **LE Industries per pixel** – The number of LE Industries that can be built per pixel. Used to calculate how big a new urban area will be.
- xix) **SME Industries per pixel** – The number of SME Industries that can be built per pixel. Used to calculate how big a new urban area will be.
- xx) **Ports per pixel** – The number of Ports that can be built per pixel. Used to calculate how big a new urban area will be.
- xxi) **People employed per LE Industry** – used in the calculation of unemployment figures.
- xxii) **People employed per SME Industry** – in the calculation of unemployment figures.
- xxiii) **LE Industries** – The number of LE Industries in the area at the start of the game. This is used to help calculate the budget at each time slice.

Budget = Budget + TimeSlices(.currentTimeMillis).IndustryLE * BaseFTIndustryLE

Where BaseFTIndustryLE is the Flood Tax per LE (see below)

The budget calculation as a whole is shown in the following table.

Description	Formula
Initial Budget from scenario timeslice	Budget = Scenarios(CurrentScenario).AnnualPressures(.currentTimeMillis + 1).Budget * 1000000000#
Add income from non-eco population	Budget = Budget + (TimeSlices(CurrentTime).Population - TimeSlices(CurrentTime).EcoPopulation) * BaseFTPPerPerson
Add income from eco population	Budget = Budget + TimeSlices(CurrentTime).EcoPopulation * BaseFTEcoPerson
Add income from LE	Budget = Budget + TimeSlices(CurrentTime).IndustryLE * BaseFTIndustryLE
Add income from SME	Budget = Budget + TimeSlices(CurrentTime).IndustrySME * BaseFTIndustrySME
Add income for each tourist	Budget = Budget + TimeSlices(CurrentTime).Tourists * BaseFTTourist
Subtract penalty for each unemployed person	Budget = Budget - TimeSlices(CurrentTime).Unemployed * BaseUnemployedPenalty
Subtract penalty for each homeless person	Budget = Budget - TimeSlices(CurrentTime).Homeless * BaseHomelessPenalty
Calculate random interest value between min and max	BaseInterest = Scenarios(CurrentScenario).InterestMin + Rnd() * (Scenarios(CurrentScenario).InterestMax - Scenarios(CurrentScenario).InterestMin)
Subtract loans and interest	Budget = Budget - CompoundInterest(TimeSlices(CurrentTime).Borrowing10, BaseInterest, 10)

- xxiv) **SME Industries** – The number of SME Industries in the area at the start of the game. This is used to help calculate the budget at each time slice.
- xxv) **Person Flood Tax** – The income from each non-eco person in the population
- xxvi) **Eco Person Flood Tax** – The income from each eco person in the population
- xxvii) **Tourist Flood Tax** – The income from each tourist
- xxviii) **Unemployed Tax Penalty** – The penalty for each unemployed person
- xxix) **Unhoused Tax Penalty** – The penalty for each unhoused person
- xxx) **Level of borrowing** – The maximum amount of borrowing
- xxxi) **LE Flood Tax** – The income from each LE
- xxxii) **SME Flood Tax** – The income from each SME
- xxxiii) **Base Water supply** – The initial level of water supply. Used in the calculation of water demand. The full calculation of water demand is as follows.

Description	Formula
Initial Water Demand from scenario time slice	WaterReservoir = BaseWaterSupply
Add all water supply cards	For each water supply card WaterReservoir = WaterReservoir + CardValue
Calculate usage – add usage from tourists	WaterNow = NumTourists * BaseWDPerson N.B. NumTourists calculated above
Add usage from non-eco people	WaterNow = WaterNow + (TimeSlices(CurrentTime).Population - TimeSlices(CurrentTime).EcoPopulation) * BaseWDPerson

Add usage from eco people	$\text{WaterNow} = \text{WaterNow} + \text{TimeSlices}(\text{CurrentTime}).\text{EcoPopulation} * \text{BaseWDEcoPerson}$
Add usage from LE Industries	$\text{WaterNow} = \text{WaterNow} + \text{TimeSlices}(\text{CurrentTime}).\text{IndustryLE} * \text{BaseWDLE}$
Add usage from SME Industries	$\text{WaterNow} = \text{WaterNow} + \text{TimeSlices}(\text{CurrentTime}).\text{IndustrySME} * \text{BaseWDSME}$
Add usage from agriculture	$\text{WaterNow} = \text{WaterNow} + \text{BaseWDAgriculture} * (1 + 0.01 * \text{CurrentTime} * (\text{Scenarios}(\text{CurrentScenario}).\text{AgricultureWaterDemand} + \text{Climates}(\text{CurrentClimate}).\text{AgricultureWaterDemand}))$
Calculate water demand	$\text{WaterDemand} = \text{WaterNow} * 100 / \text{WaterReservoir}$

- xxxiv) **Water demand per person** – used in the calculation of water demand
- xxxv) **Water demand per eco person** – used in the calculation of water demand
- xxxvi) **Water demand per LE** – used in the calculation of water demand
- xxxvii) **Water demand per SME** – used in the calculation of water demand
- xxxviii) **Water demand for Agriculture** – used in the calculation of water demand
- xxxix) **Area considered a catastrophic flood** – this figure is used to end the game. If this area or more is flooded during one particular flood episode then it is considered a catastrophe where many people may have died.
- xl) **Expected area of flooding for insurance purposes** – this figure is used in the calculation of the regional insurance score. It is assumed that insurance covers a certain amount of flooding per decade before any additional premiums are required. This figure represents this assumption
- xli) **Multiplier (x) for regional insurance calculation** – where regional insurance = area_flooded * x

Card Parameters

Card parameters can be edited by clicking on the Cards tab and clicking on the Edit button in the Card Types section.

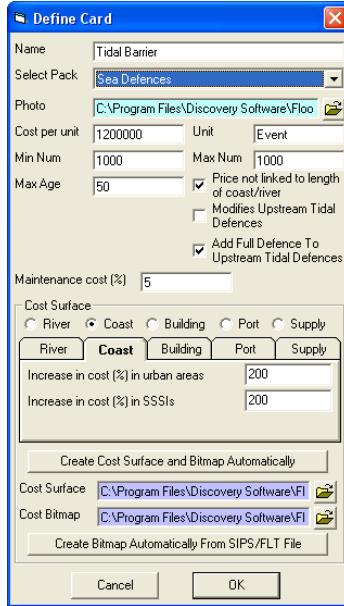


Figure 46 – Editing the card parameters

There are a number of different possible types of card, sea defences, river defences, flood management, water resources and building types. There are some specific parameters to each type and some common parameters.

The common parameters are:

- i) **Cost per unit** – The cost per unit of the card, e.g. 100000 ECOs per person for building a house
- ii) **Unit** – The unit by which the card is measured, e.g. people for housing or event for defences
- iii) **Min Num** – The minimum value for a card e.g. 1000 people for housing
- iv) **Max Num** – The maximum value for a card e.g. 100000 people for housing

The cost of a card is the value selected (between min and max) * Cost per Unit * the pixel value of the associated cost surface.

The specific parameters are:

- i) **Max Age** – The maximum age of a card. Valid for defence cards only. When a card approaches its maximum age the defence level falls according to the following rules:

Condition	Formula
If MaxAge < 40 and MaxAge >=20 and CurrentAge > MaxAge - 10	DefenceLevel = DefenceLevel - DefenceLevel * 0.4 * (CurrentAge - (MaxAge - 10)) / 10
Else If CurrentAge > MaxAge - 10	DefenceLevel = DefenceLevel - DefenceLevel * 0.3 - DefenceLevel * 0.3 * (CurrentAge - (MaxAge - 10)) / 10
Else If CurrentAge > MaxAge - 20	DefenceLevel = DefenceLevel - DefenceLevel * 0.1 - DefenceLevel * 0.2 * (CurrentAge - (MaxAge - 20)) / 10
Else If CurrentAge > MaxAge - 30	DefenceLevel = DefenceLevel - DefenceLevel * 0.1 * (CurrentAge - (MaxAge - 30)) / 10

- ii) **Price not linked to length of coast or river** – A flag which is set if the defence has a one off cost and is not costed per km. Valid only for defences.
- iii) **Modifies upstream coast defences** – A flag which defines whether a defence reduces upstream (i.e. in terms of an estuary) flooding. Valid only for sea defences. In practise this works by increasing the upstream defences on both sides of the estuary. Every upstream region's defence is increased by:

$$\text{UpstreamDefenceLevel} = \text{UpstreamDefenceLevel} + \text{DefenceLevelAtCard} / (\text{Numlinks}+3)$$

Where NumLinks is the number of regions away from the region with the card.

- iv) **Add full defence to upstream coastal regions** – A flag which sets full defences for upstream regions. If the defence level is higher where the card is located then each upstream region assumes the higher defence level. Valid only for sea defences.
- v) **Modifies downstream river defences** – A flag which defines whether a defence reduces downstream river flooding. Valid only for river defences. In practise this works by increasing the downstream defences. Every downstream region's defence is increased by:

$$\text{DownstreamDefenceLevel} = \text{DownstreamDefenceLevel} + \text{DefenceLevelAtCard} / (\text{Numlinks}+3)$$

Where NumLinks is the number of regions away from the region with the card.

- vi) **Add full defence to downstream river regions** – A flag which sets full defences for downstream regions. If the defence level is higher where the card is located then each downstream region assumes the higher defence level. Valid only for river defences.
- vii) **Maintenance Cost** – The percentage cost (of the original cost) for maintaining a defence. To maintain a defence you must play the maintenance card. In effect playing this card returns the age of the defence to zero. Valid for river/sea defences only.

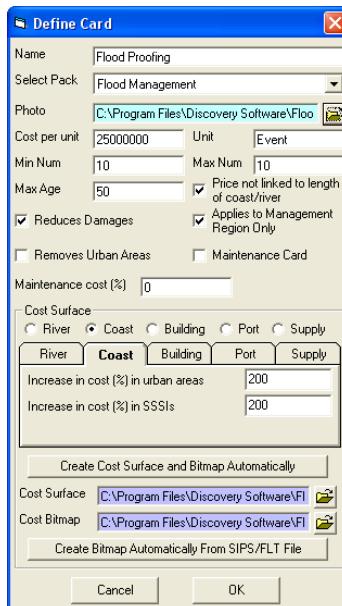


Figure 47 – Addition parameters for flood management cards

- viii) **Reduces Damages** – Reduces damages, in terms of the total area of urban flooding, for a flood event. The total area is reduced by 25%. If more than one card with this flag set is placed within a region then 25% of the new total is removed.
- ix) **Removes Urban Areas** – Specifies that the card should remove urban areas from the urban grid. All pixels in the urban grid are cleared that would have been flooded from the region in which the card is placed. This flag is set for the Land Management card in the TE2100 project.
- x) **Applies to Management Region Only** – Card only applies to the region in which it is placed – otherwise it applies to the entire study area, e.g. Flood Forecasting in the TE2100 project.
- xi) **Maintenance Card** – Specifies that the card is a maintenance card.

Appendix 1

The Discovery Software SIPS raster format explained.

The SIPS format is used in the STEMgis temporal GIS software created by Discovery Software. The format include a variable ASCII header section followed by an uncompressed chunk of binary data representing the pixel values.

The header consists of a number of essential and optional components which are listed below along with an example header.

SIPS
1
2
408
1568
8
0
3
27700
513600
169750
50
50
-9999
.

Table 1 – Example SIPS header

Line Number	Optional/Essential	Parameter	Explanation
1	Essential	File Header String	Must be the four characters 'SIPS' on its own line
2	Essential (can be blank)	Originator's name	Any length string (can be blank) on one line
3	Essential	Number of frames	Number of frames or bands in the raster grid
4	Essential	Date	A decimal number representing the date where a value of 1 is equivalent to 31/12/1899. This value is not used during the FloodRanger World program so can be set to 1
5	Essential	Number of rows	Integer value > 0
6	Essential	Number of columns	Integer value > 0
7	Essential	Number of bits per pixel	Not used in FloodRanger World – set to 8
8	Essential	Bit packing	Not used in FloodRanger World – set to 0
9	Essential	Pixel format	Value indicating data type for pixel values: 0 = Byte 1 = Short Integer 2 = Long Integer 3 = Double Decimal 4 = Single Decimal
10	Essential	Projection	Value indicating the map projection (e.g. 27700 for OSGB – UK National Grid). Values relate to the EPSG standard definitions. This value is not used within FloodRanger World. NB all co-

			ordinates within FloodRanger World should be of the same map projection but the actual projection does not matter.
11	Essential	Lower left X Co-ordinate	Double decimal
12	Essential	Lower left Y Co-ordinate	Double decimal
13	Essential	Pixel Size X	Double decimal
14	Essential	Pixel Size Y	Double decimal
15	Essential	No Data Value	A double decimal used to represent areas with no known data.
16	Essential	History	A number of lines of text describing the processing history of the file. For FloodRanger World this can just be a blank line.
17	Essential	End of header marker	The end of the header is indicated by a fullstop on a line by itself.
18	Essential	Binary array	The remaining file is a band sequential binary array of pixel values the size of which depends on the pixel format and the number of frames (bands), rows and columns. There are no new line characters required.

Appendix 2

The Discovery Software CSV vector format explained.

The CSV vector format is used in the STEMgis temporal GIS software created by Discovery Software. The format is an ASCII comma separated variable format that can be easily created in Microsoft Excel or a text editor. The format has a number of header rows best described by viewing an example.

A	B	C	D	E	F	G	H	I
1 TRANDATE	14/03/2007 10:07							
2 PROJECTION		27700						
COLTYPE	UCODE	FTYPE	FNAME	DATE	POLYGON	POLYGON	LINK	LENGTH
COLSUBTYPE	NAME	NAME	NAME	X	Y			
5 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	516904.0593	171510.2157	1	5000
6 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	516611.2571	171886.5328	1	5000
7 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	516443.9416	172388.289	1	5000
8 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	516527.5994	172722.7931	1	5000
9 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	517113.2037	172973.6712	1	5000
10 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	517824.2945	173308.1753	1	5000
11 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	518117.0967	173559.0534	1	5000
12 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	518158.9255	174102.6226	1	5000
13 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	517907.9523	174478.9398	1	5000
14 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	517531.4924	174813.4439	1	5000
15 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	517113.2037	174478.9398	1	5000
16 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	517364.1769	174311.6877	1	5000
17 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	517364.1769	173977.1836	1	5000
18 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	516862.2304	173726.3055	1	5000
19 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	516402.1128	173684.4925	1	5000
20 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	515941.9951	173182.7363	1	5000
21 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	515732.8508	172597.3541	1	5000
22 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	515816.5085	172095.5979	1	5000
23 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	516109.3106	171510.2157	1	5000
24 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	516402.1128	171175.7116	1	5000
25 VALUE	Unknown_0	FLUV	Richmond and Twickenham	01/01/2000	516904.0593	171510.2157	1	5000
26 VALUE	Unknown_1	FLUV	Kew and Isleworth	01/01/2000	517531.4924	174813.4439	2	3600
27 VALUE	Unknown_1	FLUV	Kew and Isleworth	01/01/2000	517155.0325	175273.387	2	3600
28 VALUE	Unknown_1	FLUV	Kew and Isleworth	01/01/2000	517113.2037	175649.7042	2	3600
29 VALUE	Unknown_1	FLUV	Kew and Isleworth	01/01/2000	517406.0058	175942.3953	2	3600
30 VALUE	Unknown_1	FLUV	Kew and Isleworth	01/01/2000	517782.4657	176151.4604	2	3600

Figure 48 – CSV file for fluvial management regions displayed in Excel

There are four header rows shown above. The TRANDATE row is for information purposes only and is not required (it is produced by STEMgis but not needed in FloodRanger World). The PROJECTION row signifies the projection of the co-ordinate data. It is not important within FloodRanger World, but is required if you wish to display the data within STEMgis. N.B. you must ensure that all spatial data are in the same projection within any one FloodRanger World project.

The third and fourth rows are used to define each column and should be replicated as above. Again these are used for STEMgis but the important columns for FloodRanger World are FNAME (the name of the region), POLYGON – X (the X co-ordinate of each vertex of the polygon), POLYGON – Y (the Y co-ordinate of each vertex of the polygon), LINK (the region to which this region links to in terms of downstream flow – region numbers start at zero and increment for each additional region in the CSV file), and LENGTH (the along stream length of the region in km).

The remaining rows define the regions. Rows 5 to 25 in the above example define the vertices of the Richmond and Twickenham region. Note that the last vertex is a repeat of the first vertex and that the LINK and LENGTH values are repeated for each row. Row 26 then starts the definition of the next region. Each region is repeated in this way. When the regions have been defined the last row should have EOF in the first cell.

It is usually best to create/edit these files in Excel and then export them as a CSV file.

	A	B	C	D	E	F	G
1	TRANDATE	02/01/2007 10:07					
2	PROJECTION	27700					
3	COLTYPE	UCODE	FTYPE	FNAME	DATE	LINE	LINE
4	COLSUBTYPE	NAME	NAME	NAME	X		Y
5	VALUE	road_0	ROAD	road_0	01/01/2000	387558.5041	344476.1435
6	VALUE	road_0	ROAD	road_0	01/01/2000	387610.9737	344581.2483
7	VALUE	road_0	ROAD	road_0	01/01/2000	387807.446	345594.1139
8	VALUE	road_1	ROAD	road_1	01/01/2000	387547.2472	344448.5895
9	VALUE	road_1	ROAD	road_1	01/01/2000	387558.5041	344476.1435
10	VALUE	road_2	ROAD	road_2	01/01/2000	507537.8489	345963.095
11	VALUE	road_2	ROAD	road_2	01/01/2000	507384.8046	345893.3329
12	VALUE	road_2	ROAD	road_2	01/01/2000	506371.3917	345595.8192
13	VALUE	road_2	ROAD	road_2	01/01/2000	506360.8447	345651.1984
14	VALUE	road_2	ROAD	road_2	01/01/2000	506255.3035	346208.3862
15	VALUE	road_3	ROAD	road_3	01/01/2000	376478.7524	344468.5181
16	VALUE	road_3	ROAD	road_3	01/01/2000	376703.2801	344634.1975

Figure 49 – CSV file for road lines displayed in Excel

Road lines are similar in their format apart from the change in row headers for the spatial data which change from POLYGON to LINE. Also there are no LINK and LENGTH columns required in this file.

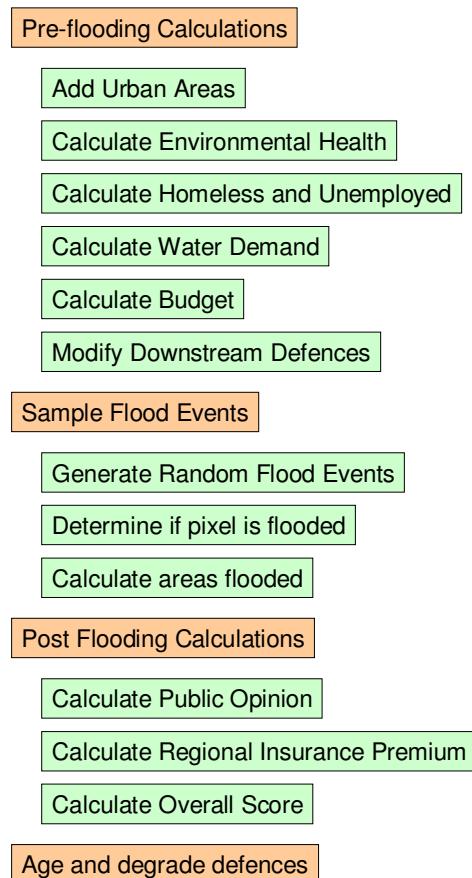
	A	B	C	D	E	F	G
1	TRANDATE	14/09/2006 17:10					
2	PROJECTION	27700					
3	COLTYPE	UCODE	FTYPE	FNAME	DATE	POINT	POINT
4	COLSUBTYPE	NAME	NAME	NAME	X		Y
5	VALUE	RiverPt_0	RIVP	RiverPt_0	01/01/2000	447456	246429
6	VALUE	RiverPt_1	RIVP	RiverPt_1	01/01/2000	424669	225661
7	VALUE	RiverPt_2	RIVP	RiverPt_2	01/01/2000	419307	215612
8	VALUE	RiverPt_3	RIVP	RiverPt_3	01/01/2000	402552	202549
9	VALUE	RiverPt_4	RIVP	RiverPt_4	01/01/2000	430701	191160
10	VALUE	RiverPt_5	RIVP	RiverPt_5	01/01/2000	428020	171732
11	VALUE	RiverPt_6	RIVP	RiverPt_6	01/01/2000	468567	160678
12	VALUE	RiverPt_7	RIVP	RiverPt_7	01/01/2000	485993	158668
13	VALUE	RiverPt_8	RIVP	RiverPt_8	01/01/2000	467562	221977
14	VALUE	RiverPt_9	RIVP	RiverPt_9	01/01/2000	481971	217287
15	VALUE	RiverPt_10	RIVP	RiverPt_10	01/01/2000	506769	204893
16	VALUE	RiverPt_11	RIVP	RiverPt_11	01/01/2000	512486	209248
17	VALUE	RiverPt_12	RIVP	RiverPt_12	01/01/2000	522854	217287
18	VALUE	RiverPt_13	RIVP	RiverPt_13	01/01/2000	548657	219297
19	VALUE	RiverPt_14	RIVP	RiverPt_14	01/01/2000	557370	207573
20	VALUE	RiverPt_15	RIVP	RiverPt_15	01/01/2000	479291	144265
21	VALUE	RiverPt_16	RIVP	RiverPt_16	01/01/2000	526540	144935
22	VALUE	RiverPt_17	RIVP	RiverPt_17	01/01/2000	552008	161348
23	VALUE	RiverPt_18	RIVP	RiverPt_18	01/01/2000	522184	188815
24	VALUE	RiverPt_19	RIVP	RiverPt_19	01/01/2000	530226	165702
25	EOF						

Figure 50 – CSV file for river points displayed in Excel

Again river points are similar in their format apart from the change in row headers for the spatial data which change from LINE to POINT. Also there are no LINK and LENGTH columns required in this file and each feature only has one spatial co-ordinate.

Appendix 3

Processing chain in FloodRanger World.



The above diagram illustrates the main areas of processing and calculation within FloodRanger when the user decides to proceed to the next decade. The order runs from top to bottom. The following sub-sections describe each of these processes in turn and identify the inputs and outputs, units and sub-processes involved. The next section will describe how these might need to be adapted for the Thames catchment.

Add Urban Areas

Data Input:	Map of urban areas at start of current decade Vector map of roads
User Parameters:	Number of people housed Number of industries added Location of urban cards placed on terrain
Scenario Values:	Area taken per person per housing type Area taken per industry type
Process:	1. Modify input map to add urban pixels 2. Add urban pixels to overlay maps, City-River, City-Forest-SSSI, City-River-Road, City-River-Soils, City, All 3. Calculate total distance of new urban areas to existing roads in km
Outputs:	Updated urban areas Overlays Distance of new roads (km)

Calculate Health of Environment

Data Input:	Map of current urban areas Map of National Parks, SSSIs and other environmentally protected areas Distance of new roads
User Parameters:	Passed from 'Add Urban Areas'
Scenario Values:	Weighting of importance of environmental land lost (%) Weighting of importance of amount of new roads (%)
Process:	1. Calculate area lost from environmental areas in km^2 2. Calculate health factor for environmental land lost = $\text{area_lost}/31.25$ with a maximum value of 1.0 3. Calculate health factor for new roads = $\text{length_roads}/125$ with a maximum value of 1.0
Outputs:	$\text{Health score} = 0.8 * (100 - \text{EnvironmentAreaLost} * \text{HealthHabitatWeighting} - \text{LengthNewRoads} * \text{HealthNewRoadsWeighting}) + 0.2 * \text{PreviousDecadeHealthScore}$

Notes:	Previous decade health score counts for 20% of current health score Loss of environmental land is more important in Local Stewardship scenario (see Appendix 1)
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Calculate Unemployment and Homeless Figures

Data Input:	Current population Current unemployment figures
User Parameters:	Number of people housed during decade Number of new industrial units added during decade
Scenario Values:	Population growth for scenario Required new employment for scenario
Process:	<ol style="list-style-type: none"> 1. Calculate new population 2. Calculate homeless figures 3. Calculate unemployment figures 4. Calculate number of people housed in eco-housing
Outputs:	Homeless numbers Unemployment numbers Number of eco-people

Notes: Housing and employment requirements for next decade are modified given performance during this month

Calculate Water Demand

Data Input:	Current Population, Large Industries and SMEs Current Eco-population
User Parameters:	Size of all reservoirs in litres
Scenario Values:	Summer temperatures for all scenarios for current decade Maximum number tourists for scenario Minimum number of tourists for scenario Water demand from large industries in litres Water demand from small/medium industries in litres Water demand from eco-population in litres Water demand from remaining population in litres Agricultural water demand related to climate scenario in litres Agricultural water demand related to world future scenario in litres
Process:	<ol style="list-style-type: none"> 1. Calculate number of tourists $\text{NumTourists} = \text{MinTourists} + (\text{MaxTourists}-\text{MinTourists}) * (CurrentDecade/10) * (CurrentScenarioSummerTemperature - \text{MinScenarioSummerTemperature}) / (\text{RangeScenarioSummerTemperatures})$ 2. Calculate agricultural water demand 3. Calculate water available by adding resource from reservoirs added by user 4. Calculate water demand
Outputs:	Water demand score which is a percentage of demand to that available

Notes: Resource is modified by summer rainfall figure for chosen climate change – multiplication factor is (SummerRainfall/200). N.B. there are no units here this is a relative figure which changes through the decades and between climate scenarios (see Appendix 1)

Calculate Budget for Next Decade

Data Input:	Current budget
User Parameters:	Current spend
Scenario Values:	Borrowing interest rate for scenario Income from normal rate taxes Income from eco-people taxes Income from industries Income from tourists Costs for unemployed Costs for homeless
Process:	1. Calculate new borrowing figures 2. Calculate interest for previous two decades 3. Calculate income and costs 4. Calculate new budget
Outputs:	New budget

Modify Downstream River Defences

Data Input:	Existing defence levels per river management region
User Parameters:	All defences added as cards
Scenario Values:	None
Process:	Each dyke, lock, weir or reservoir has an effect of downstream defences. If for example a large weir exists at the uppermost management region then the next downstream defence level will be raised by the following formula:
	$\text{NewDefenceLevel} = \text{OldDefenceLevel} + \frac{\text{LargeWeirDefenceLevel}}{\text{NumberOfRegionsDownstream}} + 2$

Outputs:	Modified defence levels
-----------------	-------------------------

Notes: FloodRanger does not perform on the fly modelling of river volumes so this is a gross approximation of the effects of upstream defences retaining flood water
As you travel further downstream the effect of the upstream defences becomes less

Sample Flooding for Decade

Data Input:	Current Urban Areas Map River Flood Event Map Coastal Flood Event map River Segment Source Map Coastal Segment Source Map
User Parameters:	Flood defences located in management segments
Scenario Values:	Borrowing interest rate for scenario Income from normal rate taxes Income from eco-people taxes Income from industries Income from tourists Costs for unemployed

Costs for homeless

Process:

1. Generate random flood events for each magnitude e.g. 1:5, 1:100 etc. and for coastal and fluvial origins
2. Check to see if 1:100 river and 1:200 coastal occurs at same time and whether tidal barrier is in place – if not then major disaster occurs.
3. Test each flood event at each pixel to see if pixel could be flooded for that event. If it could, then check all segment sources for that pixel. If any of the sources do not have sufficient defences for that flood event then the pixel is flooded.
4. Count number of pixels flooded in both urban and non-urban areas.
5. Count number of pixels that could be flooded and are not currently protected
6. If a coastal flood event is a 1:100 year event or greater and more than 10km² is flooded then a disaster occurs.

Outputs:

Raster map showing number of flood events per pixel for river events.	Raster map showing number of flood events per pixel for coastal events.
Accumulative map showing number of decades that pixel has been flooded	

Area at Risk Score in Flood Plain

Notes: The frequency of each level of flood event is increased each decade according to climate scenario parameters

The flood event maps contain values for each pixel representing the years between expected floods. Therefore for a value of 15 you would expect that pixel to be flooded every 15 years. These values are decimal numbers so might have the value 43.54, which wouldn't get flooded on a 1:20 event but would get flooded in a 1:50 event

The segment source maps contain values representing where the flooding may come from. If you imagine a point between two rivers, it might get flooded from either river. These two rivers may belong to separate management units labelled for example unit 12 and unit 65. The pixel in question would then have a value of 1265. The number is stored as a float number in the raster file but treated as a string in the program with every two characters representing a source segment. Therefore a management segment number of 3 needs to be represented as the string 03 in the stored pixel.

Defences degrade from decade to decade so that a defence that should protect against a 1:100 event when it is built will gradually decay so that it might only protect against 1:80 events and then smaller and smaller events until it eventually fails.

If pixel flooded for more than 3 decades then game prevents you from building at this site.

Calculate Public Opinion

Data Input:

Number of unemployed
Number of homeless
Health of Environment Score (%)
Regional Insurance Score (%)
Water Demand Score (%)

User Parameters: None

Scenario Values: None

Process:

1. Calculate current public opinion
2. Calculate final public opinion by combining with previous two decades of public opinion

Outputs: **Public Opinion Score**

Notes: Current public opinion is 35% unemployed, 30% homeless, 5% health of environment, 15% water demand unmet and 15% insurance premium.

Unemployed figure is calculated as fraction of NumUnemployed/300000, with a maximum of 1.

Homeless is calculated as fraction of NumHomeless/45000, with a maximum of 1.

Public opinion is modified according to previous decades 10% 20 years ago, 20% 10 years ago and 70% present, or 20:80 if only in first decade.

Calculate Regional Insurance Premium

Data Input:	Urban areas flooded (km ²)
User Parameters:	None
Scenario Values:	None
Process:	<ol style="list-style-type: none">Calculate regional insurance premiumCalculate final public opinion by combining with previous two decades of public opinion

Outputs: **Regional Insurance Premium Score**

Notes:	It is assumed that current insurance covers up to 6.25km ² of flooding in urban areas
	Flooding less than this decreases the previous decades premium and vice versa
	Maximum increase in premium per decade is 20% and the actual increase is calculated by $20 * (\text{UrbanAreaFlooded} - 6.25) / 31.25$

Calculate Overall Score for Decade

Data Input:	All other scores
User Parameters:	None
Scenario Values:	None
Process:	<ol style="list-style-type: none">Combine all scores

Outputs: **Overall Score = ((100 - WaterDemand50) + PublicOpinion + HealthEnvironment + (100 - RegionallInsurancePremium) + (100 - AreaAtRisk) / 2.0) / 450**
where the WaterDemand50 is the water demand above 50% doubled, i.e. a water demand figure below 50% will score maximum points while a figure of 100% will score zero.

Notes: **AreaAtRisk figure only has half the significance of the other scores in calculating the overall score.**