Exercise 6F: Flood Risk Assessment.

ANSWERS

Expected time:	3 hours
Data:	data from subdirectory:/exercise06F
Objectives:	This exercise will demonstrate how to combine flood depth information, for example generated by a flood model, with building data, such a location, height and construction materials into a flood risk assessment. For three flood scenarios with different return periods (10, 50 and 100 years) the risk will be assessed. At the end of the exercise one should be able to understand and replicate the steps in the procedure.

Riskcity has experienced several severe flood events, which have caused damage. In order to evaluate the flood risk, flood depth maps have been generated with a hydraulic model for different return periods. Because of the limited amount of time, will only consider only three flood scenarios with return periods of 10, 50 and 100 years.

Figure Buildings in the confluence of the two rivers in RiskCity

Name	Type	Meaning
Flood data		
Flood_100y, Flood50y, Flood_10y	Raster map	Flood depth maps resulting from flood modeling study for scenarios with 100, 50 and 10 year return period.
Building data		
Building_map_1998	Raster map	Updated map of buildings for the situation after the disaster of 1998. For all buildings information is available on the urban landuse, number of floors, building area, and total floorspace.

PART 1

In this exercise we follow the quantitative risk assessment approach, which tries to quantify the risk according to the risk definition given in chapter 1 of the Guide Book. As explained in chapter 1 this equation has the basic form:

Risk = Hazard * Vulnerability * Amount of elements-at-risk

This equation is not only a conceptual one, but can be actually calculated with spatial data in a GIS to quantify risk from hazards. The way in which the amount of elements-at-risk are characterized (e.g. as number of buildings, number of people, economic value or the area of qualitative classes of importance) also defines the way in which the risk is presented. The hazard component in the equation actually refers to the probability of occurrence of a hazardous phenomenon with a given intensity within a specified period of time (e.g. annual probability). For calculating risk quantitatively using equation 1 the vulnerability is limited to physical vulnerability of the elements-at-risk considered, determined by the intensity of the hazard event and the characteristics of the elements-at-risk (e.g. building type). The equation can be modified in the following way:

$$R_S = P_T * P_L * V * A$$

in which:

P_T is the temporal (e.g. annual) probability of occurrence of a specific hazard scenario with a given return period in an area;
P_L is the locational or spatial probability of occurrence of a specific hazard scenario with a given return period in an area impacting the elements-at-risk;
V is the physical vulnerability, specified as the degree of damage to a specific element-at-risk given the local intensity caused due to the occurrence of the hazard scenario;
A is the quantification of the specific type of element at risk evaluated.

It is important here to indicate that the amount can be quantified in different ways, and that the way the amount is quantified also the risk is quantified. For instance the amount can be given in numbers, such as the number of buildings (the risk is then the number of buildings that might suffer damage), number of people (e.g. injuries/ casualties/affected), the number of pipeline breaks per kilometer network etc. The elements at risk can also be quantified in economic terms. It is then usually expressed as damage.
In order to be able to evaluate these components we need to have spatial information as all components vary spatially, as well as temporally. The temporal probability of occurrence of the hazard scenario (P_T) has also a spatial component. For example a flood with a given return period has a certain extension, and spatial variation of intensity. The term (P_L) indicating the spatial probability of occurrence and impact. This is not relevant for all types of hazards, and in many cases this probability can be indicated as 1, given a specific hazard scenario (e.g. the area that will be flooded given a return period of 50 years).

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- Open the raster map **Flood_100y** and add the raster map **building_map_1998.** Make this last map 50% transparent. Open the Pixel-Information window and explore the flooded areas and the water depths at these locations.
- Close the map window.

As you can see large parts of the center of the city are flooded, but also further North you will find buildings that are affected by the water. The water depths may reach up to 8 meters in certain locations!
In the following exercise we will analyse how many buildings are affected in the three flood scenarios.

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- Create a flood extent map by typing:

```
floodextent_010:=ifundef(flood_10y,0,1)
```

QUESTION 6F1:
What does this statement do?

This statement replaces all undefined values in the map flood_10y with the value 0, and the defined values with the value 1; The flooded area becomes 1, the not-flooded area, 0.

- Look at the result.
- Cross the map **buildings_map_1998** with the map **floodextent_010** and create a cross-table **building_flooded_010**.
- Open the cross-table and add a column with the surface area of the houses. Do this using the join operator in the column menu. The surface area information can be found in the histogram **building_map_1998**, and add the column "area", but name it **area_building**.

QUESTION 6F2:
Why is this newly added column different from the existing column "**area"**?
Are the values different for all rows?

The existing column "area" is the surface area for the cross: B_xxxxx * 0 or B_xxxxx * 1. Some buildings area partially flooded and partially not-flooded. The added column "area_building" is the surface area of the building, which equals {B_xxxxx * 0} + {B_xxxxx * 1}. Check this!

- Calculate the area percentage of the buildings affected by typing:

```
Perc_affected_010:= iff(floodextent_010=1,area/area_building,0)
```

- Calculate the number of buildings that are partially affected by the flood by typing:

```
affected_buildings_010 := iff(perc_affected_010>0,1,0)
```

- And calculate the number of buildings that are completely flooded:

```
completely_flooded_010 = iff(perc_affected_010=1,1,0)
```

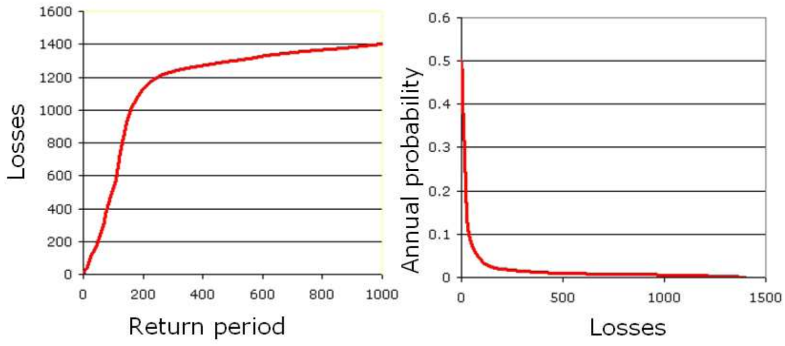
QUESTION 6F3:
How many houses are completely flooded, how many partially and how many buildings are affected in total?

	10y	**50y**	**100y**
Total	**307**	**588**	**1329**
Completely flooded	**156**	**371**	**1051**
Partially flooded	**151**	**217**	**278**

- Repeat this whole procedure for the other two flood maps (from the top of this box)
- Write down the number of buildings affected (total), and plot them in a risk graph See two examples below.

QUESTION 6F4
How is the risk quantified in this assessment?

In number of buildings



Two ways to represent a risk curve. Left: Plotting losses against return period. Right: plotting losses against annual probability.

There are several ways to express economic losses. The Probable Maximum Losses (PML) is the largest loss believed to be possible in a defined return period, such as 1 in 100 years, or 1 in 250 years. In the graphs shown above the PML for 1 in 1000 years is 1400. The risk can also be represented as a curve, in which all scenarios are plotted with their return periods or probability and associated losses. Such a risk curve is also called the Loss Exceedance Curve (LEC). The left graph has the advantage that it is better visible which return periods have the largest contribution to losses. The right curve can be used directly to calculate the Average Annual Losses (AAL). This is done by calculating the area under the curve (also Guide Book, session 6.5.5).

We will now add the calculated percentage of buildings affected to the table building_map_1998.

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- open the table: **Building_map_1998**
- **Join** to this table the table **buildings_flooded_010**, column **perc_affected_010**.
- Follow the steps through the join-wizard. Because the building_flooded_010 has more than one record for some buildings so you need to select an aggregation function.
- Select: MAXIMUM.

QUESTION 6F5:
Why are there more than one record for some buildings in the table **building_flooded_010**;
Why is the function "Maximum" the appropriate choice?

Some buildings are partially flooded and twice in table building_flooded_xxx: The part that is flooded and the part that is not flooded. The not-flooded part has received the value 0 in the column perc_affected_010, so the percentage of the flooded part is always higher for the partially flooded buildings

- Repeat this procedure (from the top of this box) for the other two flood scenarios (add columns **perc_affected_050** and **perc_affected_100** to the table **building_map_1998**)

PART 2

In the following part of this exercise we will make a link between the building properties (vulnerability of the elements-at-risk) and the characteristics of the hazard (in this case, flood depth). In order to do this we have to prepare the data to be able to make this link; The flood depth maps must be classified (sliced in ILWIS terminology) and the buildings must be characterized in a way that makes sense for flood risk. Based on experience of past flood events there are two major characteristics of buildings that define the vulnerability. These are: **construction material** and **number of floors.** We will create a new class based on a combination of these two parameters and we will link these with the classified flood depth maps.

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We will classify the three flood depth maps (flood_10y, flood_50y and flood_100y.

- Create a group domain **flooddepth** and insert the following class-boundaries:

Upper Boundary	Class Name	Code
0.5	< 0.5 m	1
1	0.5 – 1.0 m	2
3	1.0 – 3.0 m	3
6	3.0 – 6.0 m	4
99	> 6 m	5

- Slice the three flood depth maps and name the: flood_010_cla, flood_050_cla and flood_100_cla.

Now we prepare the building characteristics. Step 1 is to create a domain with the three main types of building materials:

- Create a class domain **building_mat** and insert the following three classes:

Class name	Code
Adobe and wood	a
Brick	b
Concrete	c

- Right-click on the domain **landuse** and select "create table". Name it **building_mat**
- Open the table **building_mat** and add a column **building_mat** and give it the domain **building_mat**
- Fill in the table as shown in the figure below.

	build_mat
Com_business	concrete
Com_hotel	concrete
Com_market	concrete
Com_shop	concrete
Ind_hazardous	concrete
Ind_industries	concrete
Ind_warehouse	concrete
Ins_fire	concrete
Ins_hospital	concrete
Ins_office	concrete
Ins_police	concrete
Ins_school	concrete
Pub_cemetery	brick
Pub_cultural	brick
Pub_electricity	concrete
Pub_religious	brick
Rec_flat_area	brick
Rec_park	brick
Rec_stadium	concrete
Res_large	concrete
Res_mod_single	brick
Res_multi	concrete
Res_small_singl	brick
Res_squatter	adobe and wood
River	adobe and wood
unknown	adobe and wood
Vac_car	brick
Vac_constructio	adobe and wood
vac_damaged	adobe and wood
Vac_shrubs	adobe and wood

Step 2 is to reclassify the building according to their number of floors. This was already done in the table building_map_1998, but this classification does not suit our purpose. We want to have the houses classified in three classes: 1 floor buildings, 2 floors and n floors. We do this because the floods usually affect the first (ground) floor, sometimes the second floor and only in exceptional cases it reaches the higher floors.

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- Create a group domain **Nr_floors** and insert the following classes:

Upper Boudary	Class name	Code
1.5	1 floor	1
2.5	2 floors	2
99	>2 floors	n

- Open the table **building_map_1998**
- In order to reclassify the number of floors type the following in the table command line:

```
Nr_floors_flood := CLFY(nr_floors,Nr_floors)
```

- Now we want to add the construction material to the table. We do this using the join option in the column menu.
- Select the table **Building_mat**, column **Building_mat** and go through the join-wizard accepting all defaults.

In the following step we will merge the building material with the number of floors so we have characterized the buildings as a function of these two parameters.

- Type the following instruction in the table command line:

```
Build_type:=code(build_mat)+code(nr_floors_flood)
```

A new column is added to the table with 9 codes: a1, a2, an, b1, b2, bn, c1, c2 and cn.

QUESTION 6F6:
What do these codes mean?

a1 = Adobe and wood, 1 floor
a2 = Adobe and wood, 2 floors
an = Adobe and wood, >2 floors

b1 = Brick, 1 floor
b2 = Brick, 2 floors
bn = Brick, >2 floors

c1 = Concrete, 1 floor
c2 = Concrete, 2 floors
cn = Concrete, >2 floors

The domain of these codes is "string" (check this!).

- Double-click on the column header and select the option "**create domain from strings in column**". Domain name is **Build_type**
- Close the table.

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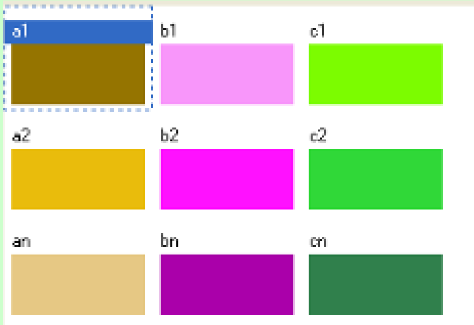
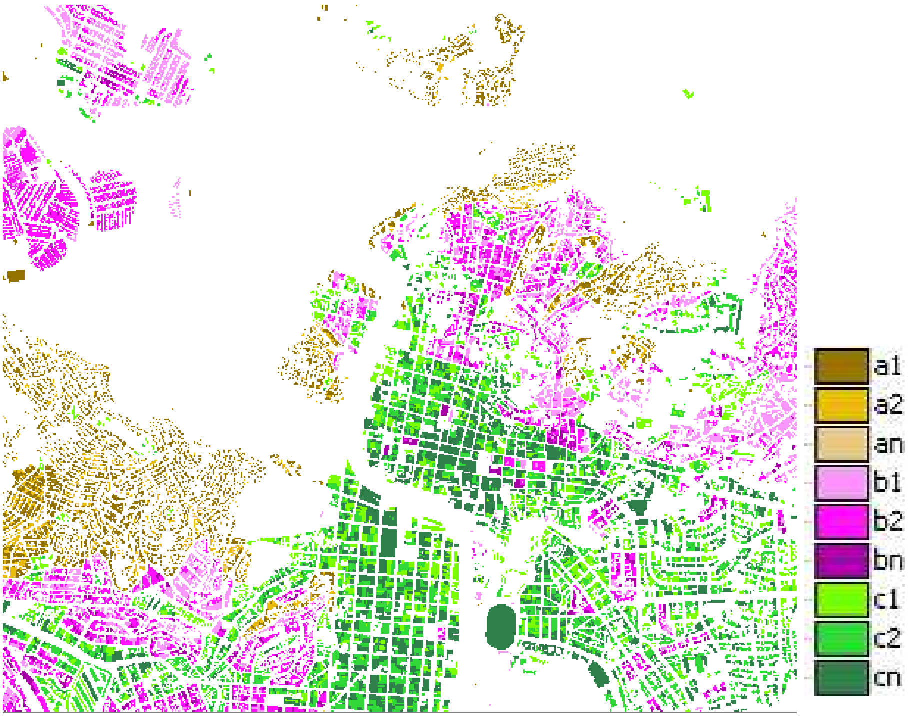
- Adjust the representation of build_type to the following colour scheme:



- Create an attribute map **build_type** from the raster map **building_map_1998** (select column **build_type**) and have a look at the resulting map.



We have now almost all the required data for the flood risk assessment: We have a map with a characterization of the buildings (**build_type**) and we have three maps for different flood hazard scenarios (**flood_010_cla**, **flood_050_cla** and **flood_100_cla**). The only thing lacking are the vulnerability curves like the ones you created in exercise 5a. In the following, final part of this exercise we will create a 2-dimensional table in which we insert the flood vulnerability curves for each of the 9 buildings types. With this table we will obtain the damage fraction to the buildings caused by the flood.

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- Create a new 2-dimensional table. Give it the name **flood_vuln;** Primary domain = **build_type,** secondary domain = **flooddepth.** The value range is: 0 to 1 and precision is 0.01
- Fill in the table as shown in the figure below.
- Close the table

2-Dimensional Table "flood_vuln" - ILWIS

	0 - 0.5 m	0.5 - 1.0 m	1.0 - 3.0 m	3.0 - 6.0 m	> 6 m
a1	0.40	0.70	1.00	1.00	1.00
a2	0.30	0.50	0.80	1.00	1.00
an	0.20	0.40	0.70	0.90	1.00
b1	0.20	0.30	0.70	1.00	1.00
b2	0.10	0.25	0.60	0.80	1.00
bn	0.10	0.20	0.50	0.70	0.90
c1	0.20	0.30	0.50	0.80	0.80
c2	0.15	0.20	0.40	0.70	0.80
cn	0.10	0.15	0.30	0.50	0.70

The 2-dimensional table is used to integrate the data from two different maps into one output map. We will compare the depth map with building type map and for each pixel the corresponding output value is read from the table, e.g. build_type = c2 and flood depth = 1.0 – 3.0 m, then the vulnerability value = 0.40.

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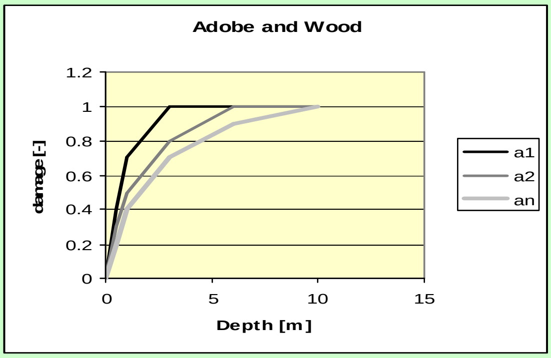
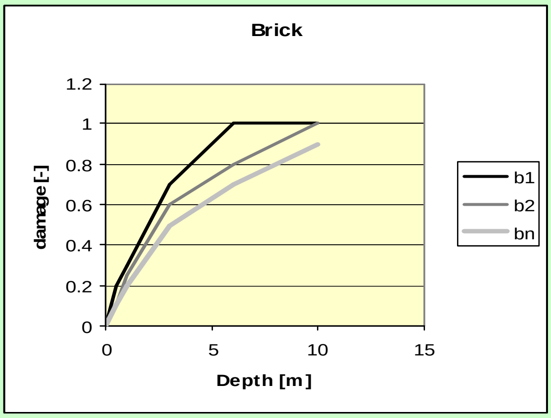
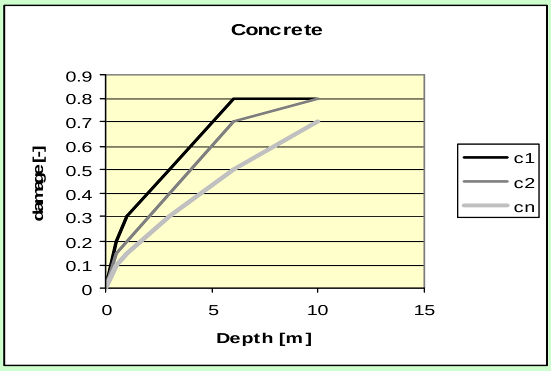
QUESTION 6F7:
The 2 dimensional table represents 9 vulnerability curves. Please draw the 9 curves in this space:







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- To use the 2-dimensional table, type the following statement in the command line of the ILWIS catalogue window:

```
build_damage_010:=flood_vuln[build_type,flood_010_cla]
```

Question 6F8:
What does the output map represent? How is the risk expressed in this map?

Degree of damage to buildings on a scale of 0 to 1

- Repeat the use of the 2-dimensional table for the other two flood scenarios.

Now the flood risk maps are finished. However, it is useful to be able to represent this map as an attribute map to the map **building_map_1998**. To do that we first cross the **build_damage** maps with the **building_map_1998** and then we join the resulting table to the table **building_map_1998**.

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- Cross the **building_map_1998** with the **build_damage_010** map and name the output table: **build_1998_damage_010.**
- Open the table **building_map_1998** and join it with the new table **build_1998_damage_010;** select column **build_damage_010.**
- Go through the join-wizard accepting the defaults but at the last window select as aggregation function **"maximum"** (There are some buildings that fall in two damage classes, and we select the worst case option).
- Create an attribute map from the map **building_map_1998**, table **building_map_1998**, column **build_damage_010** and give the map the name: **build_risk_010**.
- Compare the maps build_damage_010 and build_risk_010

QUESTION 6F9:
How do these maps differ and why?

Build_damage_100

Build_risk_100

The left-hand map shows a detail of the build_damage_100, the right-hand shows the same detail of the build_risk_100. On the left map, a single building can fall into more than one damage category, for instance part of a building can have 0.7 damage, another part 0.4 and a third part 0. In the right-hand map, a single damage category has been been assigned per building (the maximum damage). So for the example, the whole building now falls in damage category 0.7.

- Repeat this procedure for the other two flood scenarios.

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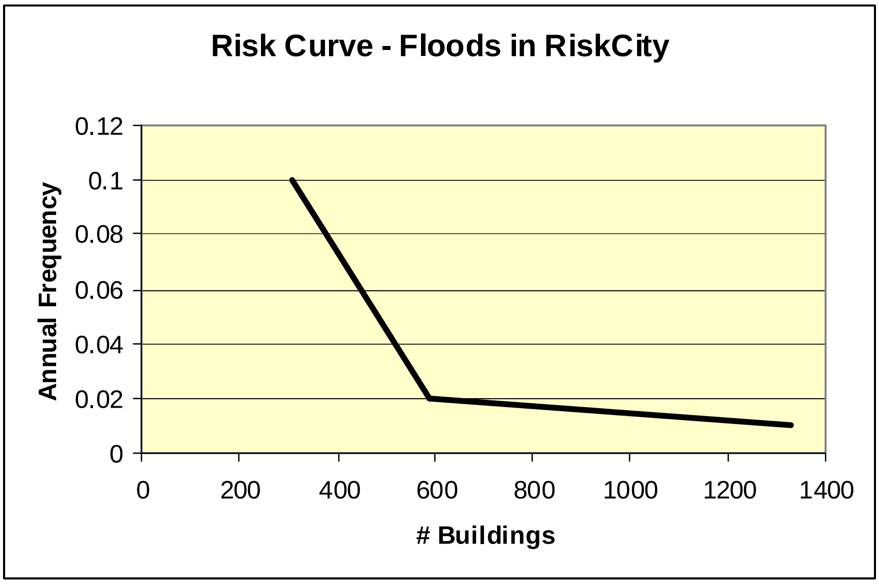
know the value of each building, the total damage of each flood scenario can be calculated and a risk curve can be constructed. This will be done in a later exercise.

To be handed in:

- **The risk curves of part 1**
- **The 3 build_risk_xxx maps of part 2 (screen-dumps or exported as bitmaps).**

Risk Curve:


Risk Curve - Floods in RiskCity
Annual Frequency
0.12
0.1
0.08
0.06
0.04
0.02
0
0
200
400
600
800
1000
1200
1400
Buildings

Build_Risk_010

Build_Risk_050

Build_Risk_100