Blue and Green Spaces
Flood Control in Aveiro

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Velp, august 2012

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Blue and Green Spaces for Flood Control in Aveiro

The Benefits of Blue and Green Spaces

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Bachelor thesis of Land and Water Management
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August, 2012

Acknowledgements

Hereby I would like to thank Peter C. Roebeling for his guidance during the research process, for his input and comments. Also Peter Groenhuijzen for his supervision and comments. A special thanks to Joao Roche and Rita S. Freitas from the Municipality of Aveiro for their help with the Geographical Information System (GIS) data and the explanations of Aveiro's water system. I have very much enjoyed the months working at the University of Aveiro.

Rianne van Dorp

Summary

Aveiro is a city in the central coastal zone of Portugal with floods occurring approximately every six years, due to heavy rainfall and S/SW wind related surge storms. Since 2011, Aveiro is one of the eight partners involved in the project "Aqua-ADD", in which the partners work together in an integrated project to develop strategies for a better integration of water in spatial planning and spatial development projects. This research focuses on the reduction of floods caused by heavy rainfall events by using sustainable measures such as blue and green spaces, in the case I have studied a park. Besides water storage, other environmental, social and economic benefits of blue and green spaces are analysed through literature study.

The limited available space in Aveiro and the absence of long term planning make it difficult to implement blue and green spaces as a solution for peak flow reduction or extra storage capacity when needed. One location has been chosen for the implementation of the park with two detention basins with a total of 38451m^3. These days most of the rainfall water is discharged through the channel system of the city to the lagoon, which is connected to the Atlantic Ocean. The time the channel system can discharge onto the lagoon depends on the tidal schedule and can mainly be discharge during low tide. Design storms with return periods of 50, 100, 500 and 1000 years return period with a duration of six hours and one peak are designed to calculate if the storage capacity of the channel system is sufficient. The needed storage capacity is calculated with the peak at high tide and low tide, with a full and empty channel.

The results are:

- When the channel system is empty, with the peak during low tide, the channel system is sufficient for all four return period storms. With the peak during high tide, there is enough storage for the 50 and 100 year return period storms, but 17,715 and 26,807 m^3 additional water storage is needed for storms with return periods of 500 and 1000. Both amounts fit in the storage basins in the park.
- When the channel system is full, the system is not sufficient with the peak of the event at both high and low tide. 74% to 85% additional water storage is needed.
- The runoff coefficient before and after the implementation of the park has been calculated with the SCS curve number method. After the implementation of the park the runoff coefficient values have declined with circa 6% from 0.89 to 0.83 for a 50 year return period, 0.91 to 0.84 for a 100 year return period, from 0.92 to 0.86 for a 500 and 1000 year return period.

Parks play a role in flood reduction but they can also help reduce other environmental issues, such as urban heat islands and air pollutants. The temperature difference between the centre and the rural areas is maximum 7.5°C. Besides environmental issues my thesis shows that the economic benefits of green spaces in urban areas cannot be underestimated. The calculated estimation of property premiums due to the park in Aveiro is €8.5 million. Higher property prices, means more income for the municipality in the form of property taxes. The economic recreational value of the park is calculated according to the willingness to pay method and is almost € 1,8 million. This cannot be seen as direct income but it reflects the value people are willing to pay to make use of the park. Parks make cities attractive, which is positive for tourism. The economic tourism value of the park is €255,613.

Keywords: Green spaces, high intensity rainfall, flood control, Aveiro

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1. Introduction

1.1 Framework

In February 2012, the opportunity to conduct my bachelor thesis, to finalize my study Land and Water Management, arose at the University of Aveiro. Around the same time, a new project called "Aqua-ADD" started, in which the University of Aveiro is one of the eight partners. The research conducted in this report is based on the Aqua-ADD project. This project involves eight partners in eight cities in the world facing water related issues. They work together in an integrated project to develop strategies for a better integration of water in spatial planning and spatial development projects. This project follows on the Directive 2007/60/EC that the European Union has adopted on the assessment and management of flood risks (EU Flood Directive, 2007). Cities in flood risk areas should establish a framework for the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activities associated with floods. Cities have to deal with numerous issues related to water. If we want to deal with these problems, water should be integrated in spatial planning development and spatial policies.

Aveiro is a city located in the central coastal zone of Portugal (40°38'N, 08°45'W) and connected to the Atlantic Ocean by the lagoon "Ria de Aveiro". Aveiro is, due to its geological features, an attractive place to settle and underwent severe urbanization and industrialization, particular over the last decades. The pressure on the city is quite high since the urbanization is still continuing. The Aveiro region is considered a flood-prone urban region, with much of the flooding events occurring when heavy rainfall, causing high river flows, coincides with low pressure systems N/NW of Portugal or high pressure systems S/SW of Portugal, causing S/SW wind related storm surges" (Roebeling, 2011). The general idea is that with climate change and a subsequent sea level rise, the already existing water problems will increase and the municipality of Aveiro has to become more creative in finding solutions for their flood problems.

The planning of space for water into cities' spatial planning can be seen as blue spaces in cities to control floods. Beside blue spaces, also green spaces can be added. For example, parks that can act as water buffers in case of heavy rainfall. This research focusses on the integration of blue and green spaces in Aveiro as a relatively cheap and creative way to help control peak flows when heavy rainfall occurs. Since the municipality is responsible for their water management planning, the findings in this report will be shared with them in an attempt to convince them of blue and green spaces as a possible solution for their problems.

1.2 Problem analysis

Aveiro is involved in the Aqua-ADD project because approximately every six years, wind related storm surges and high river levels cause floods in the city (figure 1). This happens when the combination of heavy rainfall and a high lagoon level, due to wind related surge storms, occurs. More often returning problems are the high intensity rainfall events causing temporary water on the streets due to an insufficient drainage system. Due to climate change, there is a real possibility that the already existing water problems will grow, especially when rain intensities become higher and the sea level continues to rise. The need for more space for water is growing.

On the other hand, over the next decades continued urbanization in the Aveiro region will increase the pressure on the city as well. Problems increase when more space becomes occupied with buildings. The amount of paved surfaces increases, which will results in higher runoff amounts. Besides space issues, there is an economic facet as well. Since land in urban areas is expensive, there is an economic consideration to create more living space in urban regions, instead of keeping space open, for blue and green spaces. However, this is seen as expense while building houses for creating more living space is seen as income. The weak financial situation of the state of Portugal does not help getting the water problems higher on the agenda. Long-term planning is required for sustainable measures for water control, but decision makers these days only make it a priority when flooding occurs (Mirandela seminar, 2012). It is widely acknowledged that blue and green spaces can help control floods, but nowadays they are poorly integrated into Aveiro's urban design and spatial planning.

Figure 1. Flood in Aveiro, 2006

1.3 Research questions

This research focuses on the reduction of floods caused by heavy rainfall events by using sustainable measures such as blue and green spaces, in this case a park. The limited available space in Aveiro and the absence of long term planning make it difficult to implement blue and green spaces as a solution for peak flow reduction or extra storage capacity when needed. To counter the idea that open space "costs" money, other benefits such as economic and social ones are also included in this research.

The main question of this research is: *To what extent can blue and green spaces reduce the flood risk in Aveiro. And what are the environmental-economic and social benefits of the integration of blue and green spaces into Aveiro's urban design and spatial planning?*

To be able to answer the main question, several sub questions are formulated:

Analyses Aveiro region:

1. How often do floods occur in the current situation?
2. Which areas are affected by floods?
3. What are the current measures taken by the municipality of Aveiro to prevent floods?
4. To what extent does the municipality of Aveiro integrate blue and green spaces into their urban design and spatial planning?

Aveiro case study:

5. Which location should be chosen for the implementation of the park?
6. Has the channel system enough capacity for extreme rainfall events?
7. Does the implementation of the park decreases the amount of run-off compared to the original situation?

Environmental, social and economic benefits:

8. What are the environmental values associated with the creation of this green space?
   8.1 What is the effect of the park on property values?
   8.2 What are the recreational and tourism related values?
   8.3 Are there social benefits of creating a park?
   8.4 What are the economic costs of creating this green space?
   8.5 What are the environmental-economic benefits of this green space?

1.4 Purpose

The main aim of this report is to find out, to what extent a park can be a solution for floods caused by heavy rainfall events. Due to the complexity of the water problems in Aveiro, with many different variables (rainfall coincides with wind related surge storms), this report focuses on the rainfall related problems in the city. The park will most of the time acts as a park, but when needed it can be used for water storage. Since the financial aspects and space issues are possible barriers for keeping space open, the economic benefits versus the costs will be calculated to create support and to justifies the park’s inclusion.

1.5 Justification and relevance

Due to global climate change, city planners might adapt their vision on water management in urban areas. For cities as Aveiro, historical chosen strategic beneficial location due to the presents of water, are now threatened by the substantial sea level rise, increase of rainfall intensities. Giving the water more space in creative ways such as blue and green spaces, might be a solution for the future.

1.6 Data and methodology

	Methodology
Analyses Aveiro	Historical information with respect to the occurrence of inundation and present spatial planning in the Aveiro region has been obtained through interviews with the municipality of Aveiro.
Water system analyses	The water system analyses contains several aspects. Interviews with the municipality of Aveiro has provided information on the measures in respect to the water level regulations in the channel system and the lagoon and the water transportation system for rainfall water. All geographical information with respect to land use, soil specifications, elevation, channel system specifics and water streams has been obtained using ArcGIS. The catchment area of the channel system has been determined with the Terrain Pre-processing tool in ArcGIS 9.2.
Parks location	Three possible locations will be chosen by using the elevation and flood risk area maps in ArcGIS according to two criteria. The park has to be inside the flood risk area or located such that it can help reducing water problems elsewhere in the city, and the park should be located close to the centre of Aveiro for optimum use of the park.
Rainfall data and runoff	The rainfall data are received from the Bureau of Water Supply in Lisbon. They provided the variables to create the intensity duration frequency curve (IDF-curve). From the IDF-curve, design storms are created using the Alternating Block Method. The runoff from the catchment area of the channel system is calculated using the SCS-curve number method. More detailed description of these methods in chapter 3.
Storage capacity	The available storage capacity of the channel system is calculated by using ArcGIS. The rainfall data, water level in the lagoon, storage capacity of the channel are plotted in excel to calculate the required storage capacity for storms with four different return periods. The available and required storage capacity will tell if extra storage is needed and to what extent the park can contribute with additional storage to prevent flooding.
Run off	The decrease of runoff by changing the land use of the park from the current land use to nature will be calculated using the SCS-curve number method.
Additional benefits	Other environmental, social and economic benefits of blue and green spaces will be studied through literature study. The economic benefits found through literature study will be projected on Aveiro to find an estimation of the economic value of the park.

1.7 Structure

This report starts with an introduction into the Aveiro region chapter two. It provides background information of Aveiro's, demographical, history, the geographical importance of the Ria de Aveiro and the spatial planning of the city in respect to blue and green space. In this chapter the sub-questions 1 to 4 will be answered. Followed by chapter three, that starts with an analyses of the water system in Aveiro. It continues with the location of the park, the rainfall data and the storage capacity calculation. In this chapter the sub-questions 5 to 7 will be answered. Chapter four include the literature study on the environmental, social and economic benefits of blue and green spaces. In this chapter the sub-questions 8 to 8.5 will be answered. Finally, the conclusions, discussion and recommendations extracted from the results of this research.

1.8 Readers public

This report is written for everyone who is interested in rainfall water related issues in urban areas, but mainly for my supervisors Peter Groenhuijzen and Peter C. Roebeling. Also the findings in this thesis are of interest for the municipality of Aveiro.

2. Aveiro region

Aveiro is the main municipality of the Baixo Vouga sub-region, and is surrounded by small municipalities (figure 2), such as Ilhavo, Gafanha de Aquem and Gafanha da Nazaré. The total area of the Aveiro municipality is 199.7 km^2 and has a population of 73.626 inhabitants. Aveiro had a population growth rate of approximately 10% between 1991 and 2001 (Statistics Portugal). The land use maps visualize the urban growth of Aveiro from 1990 up to 2006 annex I. The red areas are industrial or commercial areas where the purple colour represents the urban areas. It is clear that the city has grown, mainly, due to the establishment of industrial and commercial areas- explained by the economic growth of the industrial sector (European Commission, 2010). The university of Aveiro, established in 1973, attracts around 14.000 students to Aveiro each year.

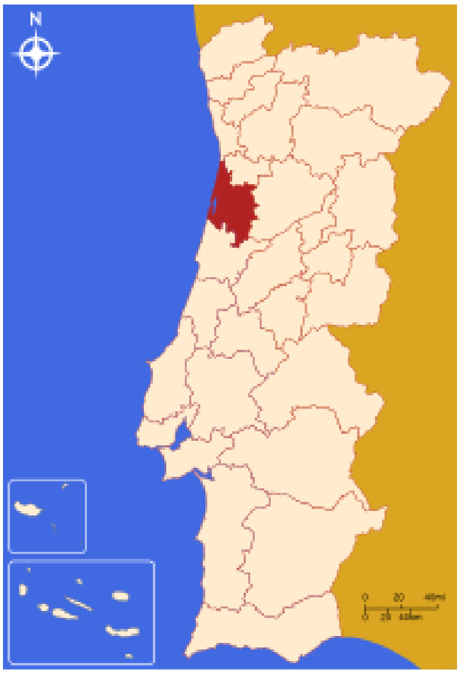

Figure 2, Aveiro Region

2.1 Ria de Aveiro

The Ria de Aveiro is a mesotidal estuarine system, with considerable regional and national economic importance (Lillebø et al., 2009). The lagoon has a maximum length of 45 km a maximum width of 8.5 km and an average depth of one meter (figure 3). Four rivers, (Vouga, Antua, Caster and Boco) enter the lagoon with variable flows, depending on the season (Pombo et al., 2005). Important economic activities in the region are: salt-production, fishing, port facilities, aquaculture and industries. The lagoon is influenced by tides and displays vast salt marches, which provide very good conditions for the construction of marshes (Rodriques et al., 2011). Ria de Aveiro has the largest area of salt marsh in Portugal and is, together with the fishing industry, one of the older economic activities in the region. The fishing industry in Aveiro represents the region's most important heritage. The harbour provides ample economic activities and possibilities for the region to be part of the European transport network. Nowadays aquaculture, and the technology and knowledge into the biology of several important commercial fish species, are of economic importance. Recreation activities such as fishing, canoeing and private harbours with recreational boats are also important economic activities. Especially small businesses depend on it (European Commission, 2010).

Figure 3, Ria de Aveiro

2.2 Climate change

The debate on whether our climate is changing due to human activities or not, is an ongoing debate with proponents and opponents, but we can´t ignore the signs of actual changes in our climate. There is a general consensus amongst experts that temperatures will increase, there will be more extreme events such as floods and storms, summers will be warmer and drier, winters will be warmer and wetter, and sea levels will rise (Lindley, 2010). Aveiro is located close to the Ocean. A rise in sea levels, heavier storms and an increase in rainfall, due to climate change, could increase the occurrence and area affected areas by inundations. High intensity rainfall events are usual in Aveiro. The annual rainfall in the northern part of Portugal is approximately 1250-1500 mm with most rainfall events taking place during the winter months, which means a lot of rain in a relatively short period of time. An increase of these intensities, will cause a lot of problems in especially lower parts of the city.

2.3 Green spaces in Aveiro

The European floods directive 2007/60/EC on the assessment and management of flood risks, aims to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. The directive shall be carried out in coordination with the Water Framework Directive (2000/60/ED; 2006/118/EDREF). The municipality of Aveiro has made a plan to increase green spaces in the city, which was called 'the five finger plan'. The idea was to create five strips with place for blue and green spaces and was included in the urban planning design from 1995. Unfortunately only one 'finger' was implemented completely and for the other four fingers, a few blue or green islands were created. The rest of the plan is not going to be implemented due to lack of financial resources, and the urbanization pressure on the city. In the urban planning design of 2009, the finger plan was re-established but with only four fingers (figure 4). Another plan was the legislation to increase the minimum height of the first floor in flood risks areas. While this has been implemented over the past seven years, this law does not longer exists, due to many complaints.

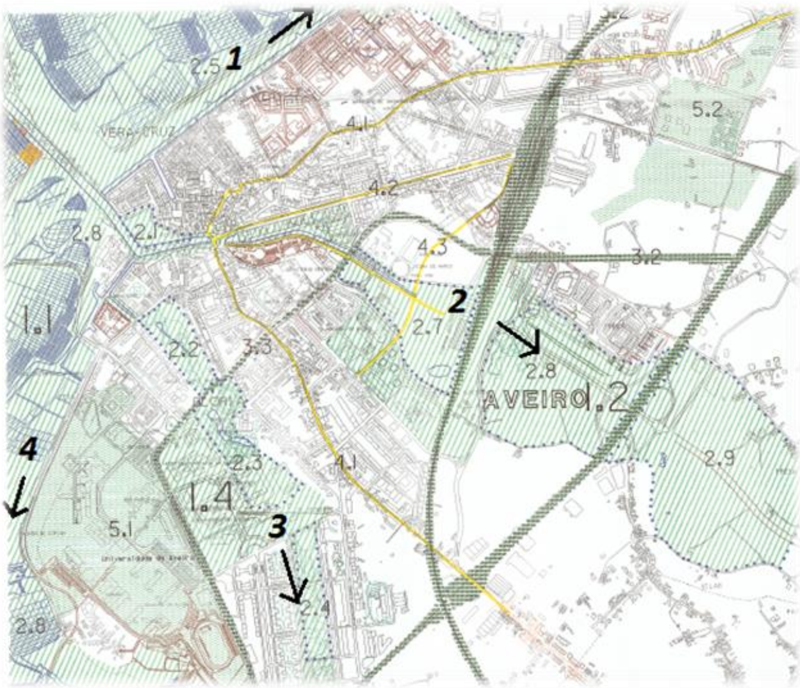

Figure 4, Four finger plan Aveiro

3. Aveiro case study

3.1 Analysis water system

These days Aveiro has two main water problems. The first problem is the water that stays on the streets after heavy rainfall events. In most parts of Aveiro, rainwater is collected in underground pipes and transported directly to the lagoon. The rain water transportations system is poorly maintained and new building constructions have little respect for this system. Also the system is not dimensioned for high intensity rainfall events. Moreover, in the old city centre, this system doesn't exists at all. There the water needs to find its way over the streets to the channels or small streams (Municipality of Aveiro, 2012). The second problem is the location of Aveiro close to the lagoon The wind related surge storms in combination with heavy rainfall cause low parts of Aveiro to flood circa every six years (figure 5).

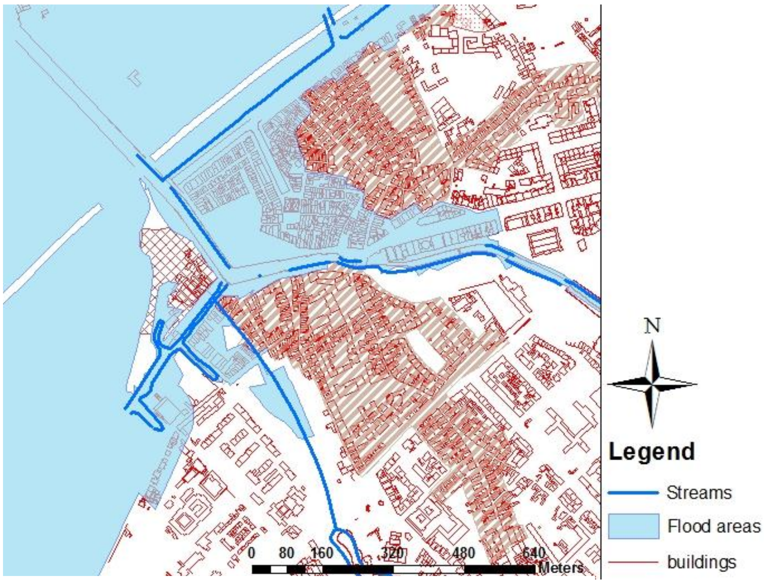

Figure 5. Flood area Aveiro

Since 1985 several measures have been taken by the municipality to prevent floods. In 1985 a hydraulic security system was implemented to protect Aveiro from inundations. A total of seven floodgates were installed and one canal lock at five locations at the border with the lagoon (MiSRaR, 2012). In 1995 the current highway was built which also acts as a barrier between the lagoon and the city in case of high water levels. In 2001, the system was found no longer effective due to a rise in water levels and deterioration of the gates. The gates heights were increased with 0,4 meters. In 2009 a command and monitoring centre was implemented with the main tasks to combine the operation of the gates to the tides table, wind and meteorological information. With the forecast of heavy rainfall, they take advantage of the low tide to empty the channel system to a minimum water level of 0,66 meter (-1.34 mean see level), and use the system as a detention basin (figure 6 explains this system).

The amount of storage capacity of the channel system depends on the tide schedule and the amount of rainfall. Since there is a limited amount of time to discharge on the lagoon: only during low tide. To be able to discharge, the level in the lagoon needs to be lower than the level in the channel.

3.1.1 Channel system

The channel system in Aveiro has a maximum storage capacity of approximately 336,000 m^3. The walls are 4.04 meter high (+2.04 mean see level (msl)), while the flood gates are 3.94 meter. The water level in the channels varies between 2.26m (+0.26 msl) and 3.26m (+1.26 msl). In case of forecasted rainfall, the channel will be emptied during low tide, to a minimum water level of 0.66 meter (-1.34 msl) to increase the storage capacity of the channel system. This minimum water level needs to remain for the boats to be able to navigate through the channels. The storage capacity is then 279,672 m^3.

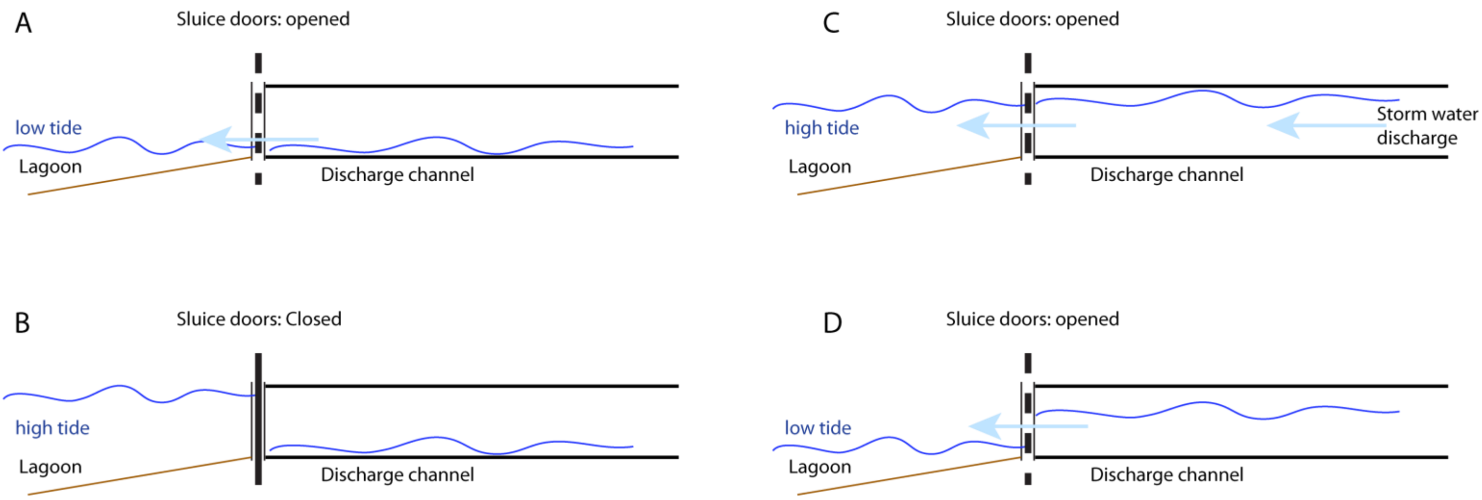

Figure 6. Emptying channel system

3.1.2 Lagoon Ria de Aveiro

The lagoon is connected to the Atlantic Ocean which means that the level is influenced by the tidal cycle. The tidal amplitude ranges from -1 m to 1,4 m above mean sea level (figure 7). In case of a higher sea level due to climate change, the tidal amplitude is expected to increase (Figueiredo & Duck, 2001). It is estimated that the water level in the lagoon with increase with 1.7 mm per year, which means an increase of 85 mm by 2060.

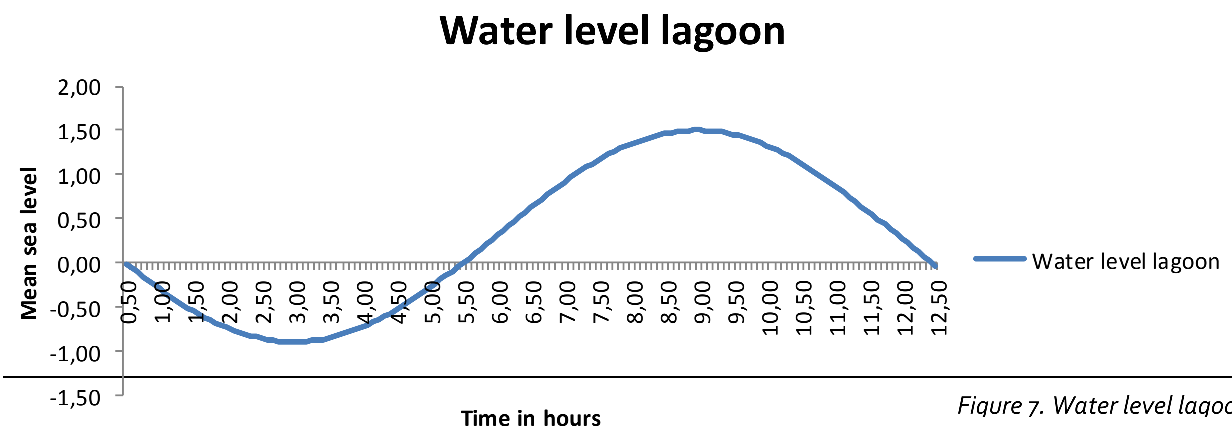

Figure 7. Water level lagoon

3.2 Methodology

The park will be tested to what extent it can contribute to runoff reduction, as a solution for the flood water that stays on the street, and the water storage capacity of the channel system will be tested for more common and extreme rain events. Also the park can function as a water storage basin. The value of the additional storage is analysed. Firstly, a location for a park will be chosen. Three locations will be selected according to two criteria. First, the location should either inside the flood risk area, or located such that it can help reduce water problems elsewhere in the city. And second, it should be located close to the city centre for optimal use of the park by citizens. Out of the three options, one will be chosen for the implementation of a park.

A storm will be created with the alternating block method. This is a method to create duration- and return-period-specific hyetographs using the intensity duration frequency relationship (Chow et al., 1988). Four return periods are selected, 50, 100, 500 and 1000 year. The duration of the storm is set at six hours, since the channel system is emptied after that interval according to the tidal schedule of the lagoon. The needed storage capacity is calculated for two water levels at the start of the rainfall event, and two start periods of the storm. In the first storm, the rainfall peak and high tide coincide, which means the channel cannot discharge on the lagoon. The second storm has its peak at low tide. The actual runoff from the catchment area will be calculated using the SCS curve number method. The catchment area is determined using ArcGIS. Finally, the design storms, the water level in the lagoon, the available storage capacity and the overflow into the lagoon are plotted in excel to calculate the needed storage capacity, and possible needed additional storage in the park.

Green spaces can reduce runoff in urban areas. The effect of the park on the runoff will be calculated using the SCS curve number method. The runoff is calculated with the original land use in the park and calculated again with the land use "park".

3.3 Parks location

The location for the park has been chosen by using two criteria. First, the location should either inside the flood risk area, or located such that it can help reduce water problems elsewhere in the city. Second, it should be located close to the city centre for optimal use of the park. Three locations were selected from which one is chosen for the implementation of the park (figure 8).

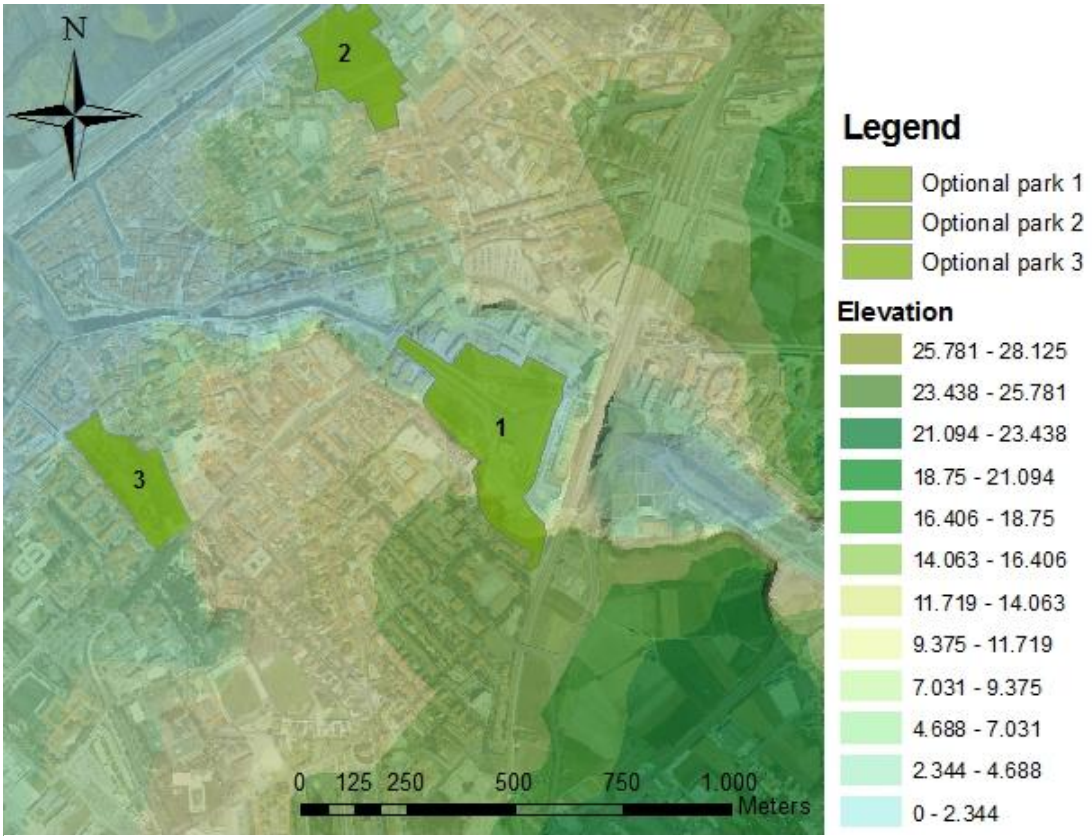

Figure 8. Optional parks in Aveiro

Park 1 became the final choice for the following reasons. The park is located in a green environment. Parts of the park are already suitable for recreation purposes, but other parts have no purpose yet and are now mainly used for car parking. The park is located at the lower parts of the city, with an artificial pond which is connected to the channel system. The final decision is also based on preferences from several small organisations involved in the project to use optional park one for the implementation of the park. To increase the storage capacity in the park, two detention basins are created in the park, by basically lower the ground level with one meter than its surrounding area (figure 9). Basin 1 has a volume of 20892m^3 and basin 2 has a volume of 17559m^3, which gives a total of 38451m^3. During heavy rainfall events, this 38451m^3 can if needed, be used to increase the storage capacity of the channel system.

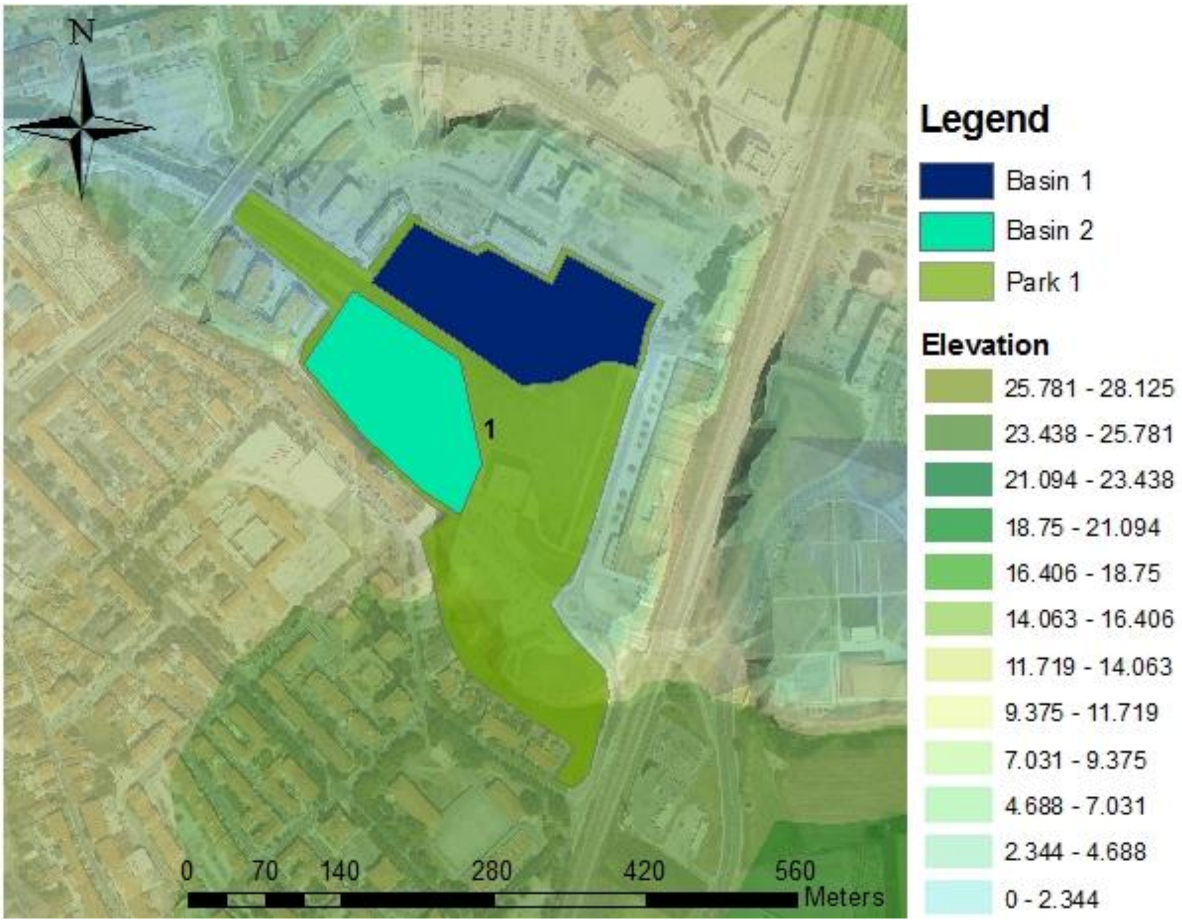

Figure 9. Detention basins in park

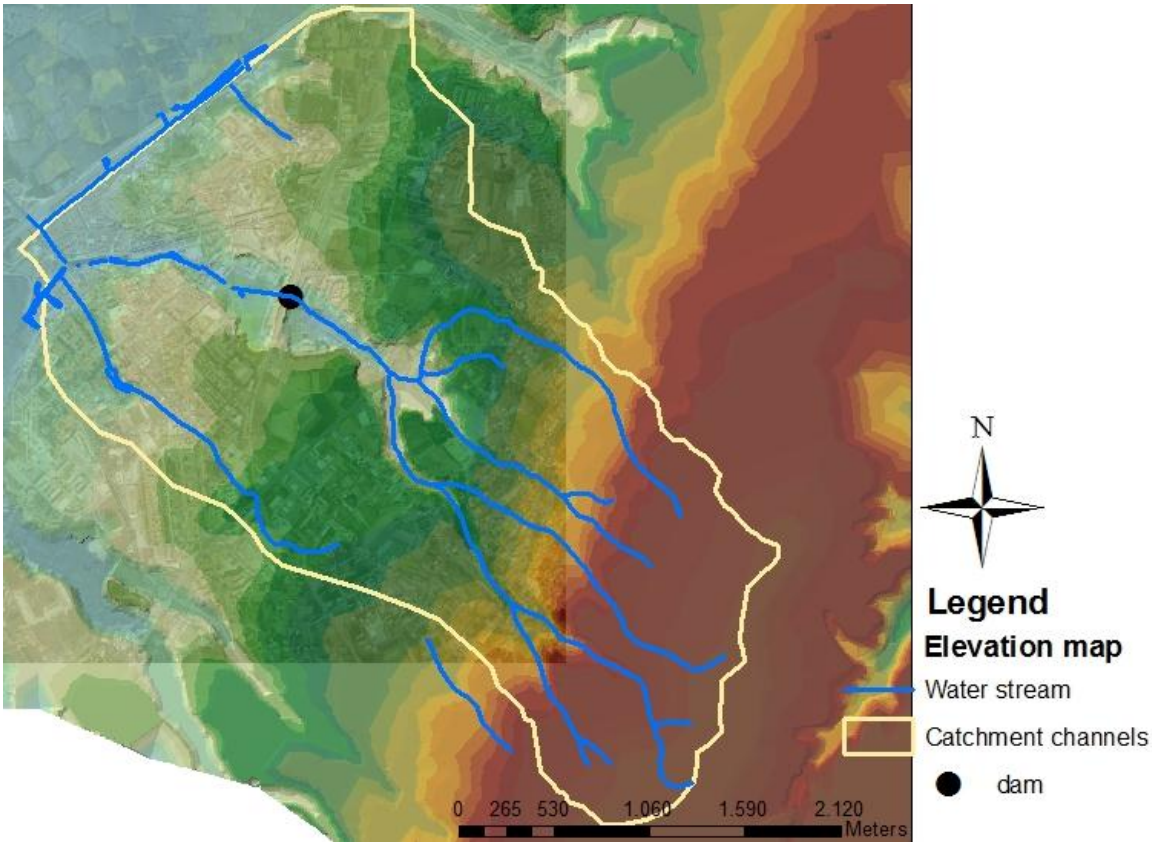

Figure 10. Catchment area channel system

3.4 Catchment area

The channel system is determined by using terrain processing tools in ArcGIS. The catchment area (A in figure 11) of the channel system has a surface of 9.3 km^2. The catchment is approximately 4.5 kilometres long and 2 kilometres wide and the elevation difference is about 50 meters to the park which is located at 0 m. Through the park (B) the water enters the channel system, before it will be discharged to the lagoon. A dam is located between the park (B) and the catchment area (A). A pipeline through the dam (black spot in figure 10) connects the catchment area (A) to the channel system.

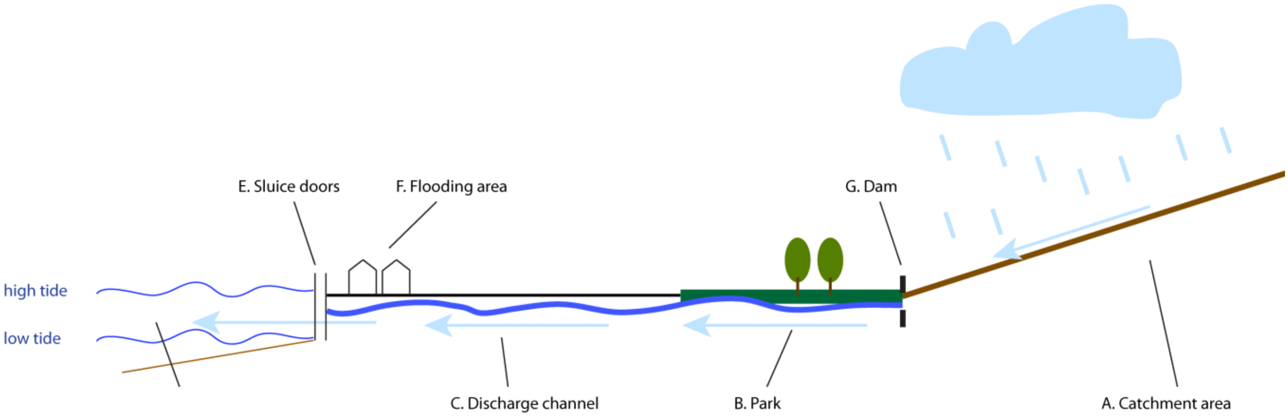

Figure 11. Cross section water system

3.5 SCS-curve number method

The SCS curve number method has been used for the determination of the run off coefficient *C*, for each land use. The runoff curve number (CN) is an empirical parameter used in hydrology for prediction direct runoff or infiltration from rainfall excess. First the different types of land use and types of soils are determined since the major factors that determine the CN are the hydrologic soil group (HSG), cover type, treatment and hydrologic condition (Dorsey, 2009). The soils are divided into four groups depending on their characteristics (figure 12).

Soil groups	
A	A soils have low runoff potential and high infiltration rates, even when thoroughly wetted. They consist of chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission.
B	B soils have moderate infiltration rate when thoroughly wetted and consist chiefly of moderately deep to deep and moderately well to well drained soils with moderately fine to moderately coarse texture. These soils have a moderate rate of water transmission.
C	C soils have low infiltration rates when thoroughly wetted and consists chiefly of soils with a layer that impedes downward movement of water and soils with moderate fine, to fine texture. These soils have a low rate of water transmission.
D	D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission.

Figure 12. Soil groups defined by the Soil Conservation Service (SCS) soil scientists

The main soil type in the catchment area is Cambisol, and is classified as a group B soil (green in figure 13). The pink colour in figure 13, is a Solonchak soil. It is a soil with high contains of salt, which is logic since it is located close to the lagoon and is also classified as a group B soil. The last soil type in the catchment area is a Podzols soil, which are typical soils for inter alia, eucalypt forests, which are very common in the region. This soil type is classified as a group C soil.

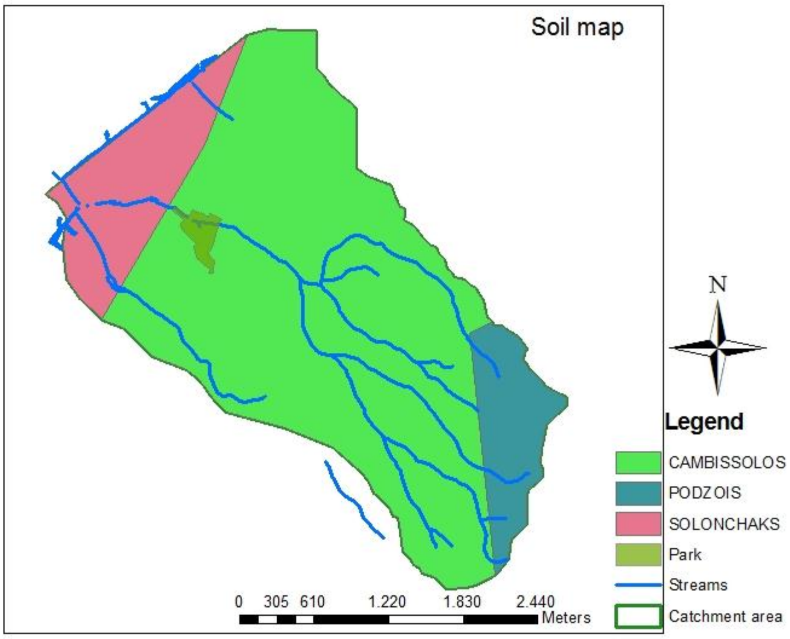

Figure 13. Soil map of the catchment area

The curve-numbers (CN) can now be determined. High CNs cause most of the rainfall to appear as runoff, with minimal losses. Lower numbers indicate a more able soil and groundcover to retain rainfall and have much less runoff. The land use maps available in ArcGIS are from 2007 and are not very detailed. Figure 14 shows the different types of land use in the catchment area. Next, the CNs for each land use type can be selected using the table in annex II. Some values differ from the values in the table, this is because of the difference between the land use maps and the reality. The areas are not as homogeneous therefore different values has been chosen. Figure 15, presents the values for the catchment area. The different types of land uses are combined with the soil classifications. The third column gives the CNs for each land use type. Urban areas and industrial show higher numbers due to the higher amount of paved surfaces compared to agricultural areas.

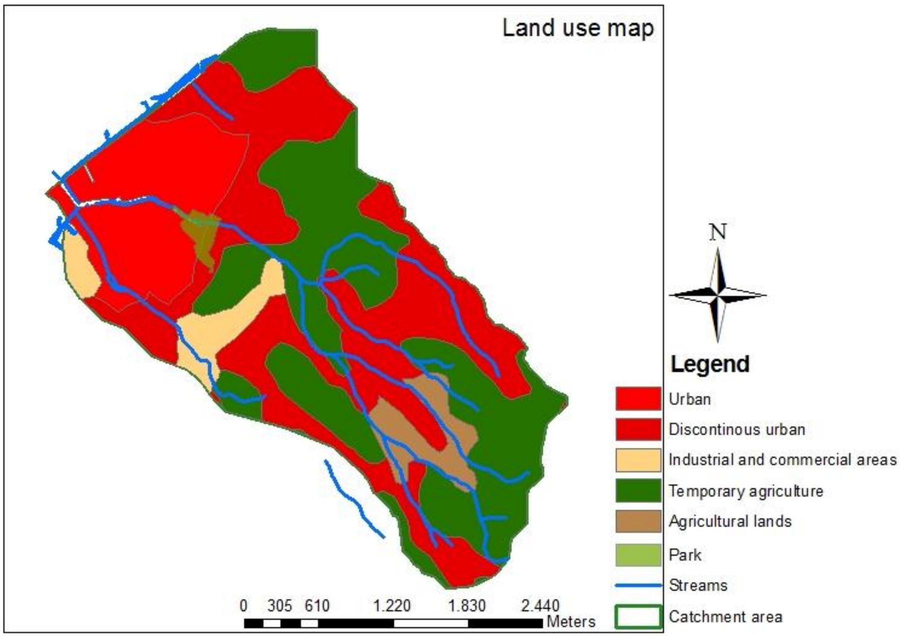

Figure 14. Land use map of the catchment area

Land use	Hydrological classification	CN
Temporary agriculture	Solonchaks **B**	20
Industrial, commercial areas	Solonchaks **B**	91
Urban areas	Solonchaks **B**	85
Agricultural areas	Cambisol **B**	20
Temporary agriculture	Cambisol **B**	20
Industrial, commercial areas	Cambisol **B**	91
Urban areas	Cambisol **B**	85
Temporary agriculture	Podzols **C**	13
Urban areas	Podzols **C**	90

Figure 15. Curve numbers of the catchment area

Knowing the CN for each land use, potential maximum retention in the soil after runoff begins, is calculated with the equation:

$$S = \frac{1000}{CN} - 10$$

S is the maximum potential retention of water in the soil in millimetres, which means all loses before runoff begins, such as evaporation, infiltration or water that remains in lower surface areas. This value is highly variable but generally is correlated with soil and cover parameters. Now the effective precipitation, the precipitation that actually runs-off can be calculated with the following equation:

$$Pe = \frac{(P-0.2S)^2}{P+0.8S}$$

Followed by:

$$C = \frac{Pe}{P}$$

Pe is the effective precipitation in millimetres, P is the total daily rainfall in millimetres, C is the runoff-coefficient, S is the potential maximum retention after runoff begins in millimetres and 0.2S is the initial abstraction in millimetres (Po in figure 16).

Land use	CN	S	Po	Pe50	Pe100	Pe500	Pe1000	C50	C100	C500	C1000
Temp. Agri.	20	40	8	52.37	58.48	72.60	79.04	0.60	0.62	0.66	0.68
Industrial Com.	91	0.99	0.20	85.73	92.59	108.09	115.06	0.99	0.99	0.99	0.99
Urban areas	85	1.76	0.35	84.83	91.68	107.18	114.15	0.98	0.98	0.98	0.98
Agri. areas	20	40	8	52.37	58.48	72.60	79.04	0.60	0.62	0.66	0.68
Temp. Agri.	20	40	8	52.37	58.48	72.60	79.04	0.60	0.62	0.66	0.68
Industrial Com.	91	0.99	0.20	85.73	92.59	108.09	115.06	0.99	0.99	0.99	0.99
Urban areas	85	1.76	0.35	84.83	91.68	107.18	114.15	0.98	0.98	0.98	0.98
Temp. Agri.	13	66.92	13.38	38.49	43.86	56.47	62.31	0.44	0.47	0.52	0.54
Urban areas	90	1.11	0.22	85.59	92.44	107.95	114.92	0.98	0.98	0.99	0.99
Average runoff coefficient								**0.80**	**0.80**	**0.81**	**0.83**

Figure 16. Runoff-coefficient calculations

3.6 Design storms

The alternating block method is used to create design storms with different return periods. The duration of the storm is set at 6 hours, since the time to empty the channels depends on the tidal amplitude of the lagoon. The event created by the method is hypothetical and involves intensity duration frequency relationship to derive duration and return period specific hyetographs (Chow et al., 1988). The intensity durations frequency curve for the Aveiro region is extracted from variables studied by the Bureau of Water Supply in Lisbon (Brandao et al., 2001). The lines in the IDF-curve represents the probability of occurrence of the return period. A one in five year rainfall event has a higher probability to occur than a one in ten year event. The IDF-curve can be used by water storage calculations in urban areas. Different parameters are used for different rain event durations and different return periods. The first period is from 5 minutes to 30 minutes, the second period from 30 minutes up to 6 hours. And the last period from 6 hours to 48 hours. From the parameters the intensity per hour can be calculated with the formula:

$I\ (mm/h) = a\ D(min)^{b}$

I is the rainfall intensity in millimetre per hour, a and b are parameters and D is the duration in minutes. The rain intensities per ten minutes up to six hours for the Aveiro region are visible annex III.

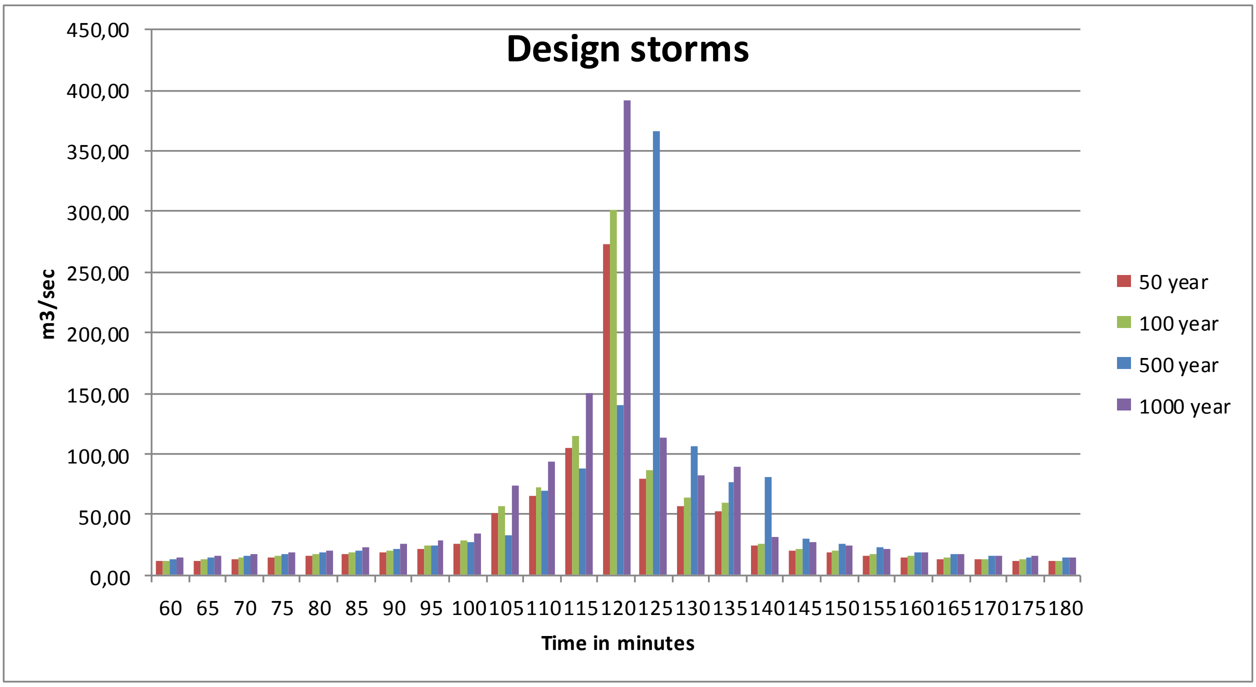

Figure 17. Design storms with return periods 50, 100, 500 and 1000 years

The return periods selected are 50, 100, 500 and 1000 years. Figure 17 shows the peak of the design storms for the different return periods. The storm starts at t=60 min and ends at t=180 min in order to put the focus on the peak of the event, but the actual duration of the storm is 360 minutes with one peak after 120 minutes.

3.7 Storage

The available water storage in the channel system depends on when it starts raining in combination with the tide schedule of the lagoon. It also depends on if the monitoring system has monitored the weather forecast and emptied the channel in advance, at low tide, to increase the available storage capacity in the channel system. The system is tested for four return periods, 50, 100, 500 and 1000 year rainfall events with a 6 hour duration. During high tide, little water can be discharged on to the lagoon, which means it has to be retained in the system until low tide. Therefore the storage capacity is calculated when the storm occurs during high tide, and during low tide. Also the storage capacity is calculated for different water levels in the channel system, the available storage capacity "empty" and "full".

"Empty" means, the monitoring system has forecasted heavy rainfall so the water level in the channel is the minimum water level of 0.66 meter which give a storage capacity of 279672 m^3, while "full" means the rainfall event comes unexpected, or for any other reason of discharge failure, and the water level in the channel system is 3.26 meter which is the usual water level and gives a storage capacity of 57981 m^3.

Another aspect that has been taken into account is that when the water level in the channel is higher than the (lowering) water level in the lagoon, the lock gates are opened to discharge the channel system. The flow of the discharge depends on the water level difference between the channel and the lagoon. The bigger the difference, caused by a larger runoff from the catchment area, the bigger the discharge flow into the lagoon. This has been calculated with the formula: Q = L*C*H^(3/2) where Q is the discharge into the lagoon, L=30 meters (the width of the channel), C=1.704, h= the water level difference between the channel and the lagoon. (figure 18).

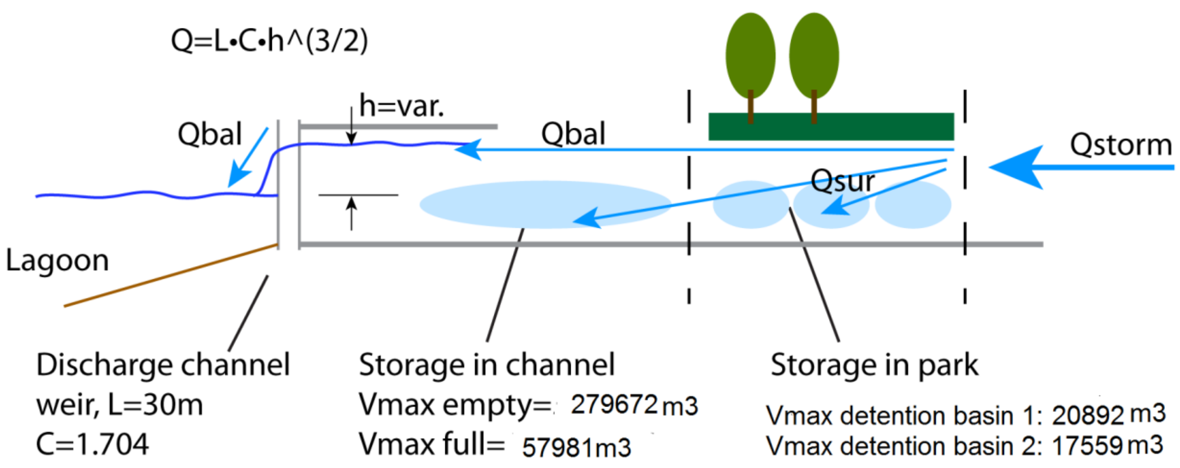

Figure 18. Overflow into the lagoon

The graphs in annex IV, show the results of the calculations. First the fifty years return period with the event at high tide with an empty and a full channel (annex IV.a). Second the fifty years return period with the event at low tide with an empty and a full channel (annex IV.b). This has been repeated for the three other return periods. The results are visible in figures 19 and 20.

Return period [years]	Available storage empty [m^3]	Max. needed storage high tide [m^3]	Δ storage [m^3]	Max. needed storage low tide [m^3]	Δ storage [m^3]
50	279672	246853	32819	203851	75821
100	279672	262118	17554	221511	58161
500	279672	297387	-17715	252438	27234
1000	279672	306479	-26807	266343	13329

Figure 19. Storage capacity with a water level in the channel of 0.66 meter

The channel system provides enough storage capacity for six hour rainfall events with the peak of the event during low tide, with an empty channel, for all four return periods. When the peak of the storm occurs during high tide, there is still enough storage capacity in the channel system for the fifty and hundred year return period. However, with a five-hundred and thousand year return period, respectively 17715 and 26807 m^3 extra storage capacity is needed in the peak of the event. The two detention basins in the park have a volume of 20892 and 17559 m^3 which gives a total of 38451 m^3. The extra storage needed during 500 and 1000 year rainfall events fits in the detention basins in the park, and will prevent the lower parts in the cities from flooding. 500 and 1000 year storms seem not to occur to often. But due to climate change, the rainfall events are said to become more intense, this does not necessarily mean more water in quantities, but it means the same amount of water in a shorter period of time. The peak of the event than becomes higher, and when there is no discharge possible, more storage capacity is needed.

Return period [years]	Available storage full [m^3]	Max. needed storage high tide [m^3]	Δ storage [m^3]	Max. needed storage low tide [m^3]	Δ storage [m^3]
50	57981	246853	-188872	203851	-145870
100	57981	260350	-202369	219311	-161330
500	57981	297387	-239406	252438	-194458
1000	57981	306479	-248498	266343	-208362

Figure 20. Storage capacity with a water level in the channel of 3.26 meter

With a full channel, the channel contains 277967 m^3 of water, which leaves an additional water storage of 57987 m^3. In this case, for all four return period rainfall events, additional water storage is needed. The additional storage in the park of 38451 m^3 is a fraction of the required storage – 15% to 26% - in the peak of the event, to prevent flooding. With the peak of the event during high tide, 80% to 85% additional storage is needed and 74% to 81% during low tide.

3.8 Peak flow reduction

Heavy rainfall events cause temporary water on the streets of Aveiro. The water transportations system, if present, cannot handle this huge amounts of water. Although the water stays on the streets for only a few hours, it is enough to damage buildings or/and cars. In the original situation, the water travels over the streets to the channels. The park is located in a low part of the city just next to the channel. This means the park at this location cannot do much to prevent the streets from flooding because to reduce the runoff, the location of the park should be in higher parts of the city where it can catch the water before it travels to lower parts where it will collect and cause problems. The park however, can reduce the runoff by only changing impervious areas to parks. Impervious areas have nearly no infiltration possibilities, while parks with vegetation have higher infiltration possibilities. The catchment area of the park is determined with ArcGIS and is visible in figure 21.

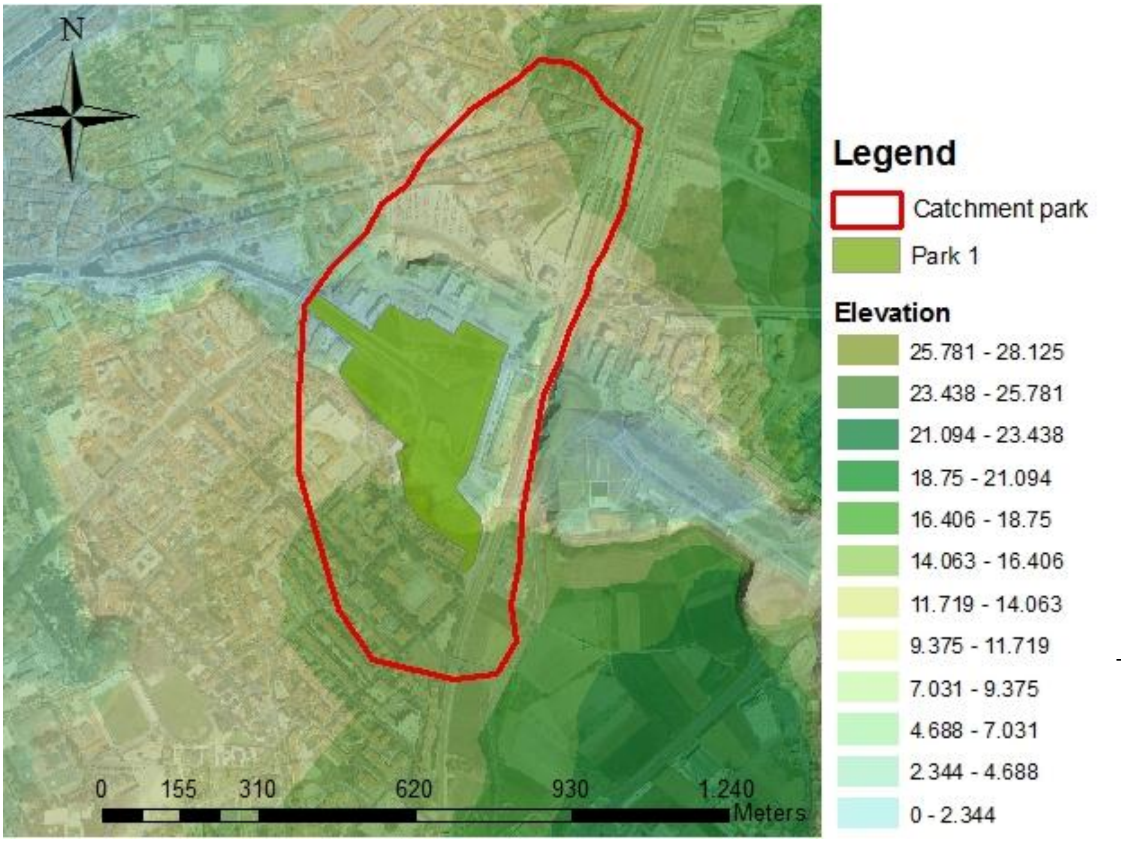

Figure 21. Catchment area park

With the SCS-curve method explained and used earlier, the runoff before and after the park is calculated. Figure 22 shows the results of the runoff coefficient calculations for the catchment area of the park before the park was created. The runoff coefficient means, the percentage of the rainfall that runs-off and thus not infiltrate into the soil. The CN is extracted from the table in annex II, the S is the potential maximum retention after runoff begins in millimetres, Po is the initial abstraction in millimetres, Pe is the effective precipitation in millimetres for different return periods.

The runoff coefficient for the different return periods are 0.89 for 50 year return period, 0.91 for 100 year return period, 0.92 for 500 and 1000 year return period.

Land use	CN	S	Po	Pe50	Pe100	Pe500	Pe1000	C50	C100	C500	C1000
Urban areas	85	1.76	0.35	84.8	91.7	107.2	114.2	0.98	0.98	0.98	0.98
Industrial and commercial areas	91	0.99	0.2	85.7	92.6	108.1	115.1	0.99	0.99	0.99	0.99
Open forest and plantations	79	2.66	0.53	83.8	90.6	106.1	113.1	0.96	0.97	0.97	0.97
Forest	66	5.15	1.03	81.0	87.9	103.3	110.3	0.93	0.94	0.95	0.95
Urban green space	61	6.39	1.28	79.7	86.5	102.0	108.9	0.92	0.92	0.93	0.94
Temp. Agri.	20	40.0	8.0	52.4	58.5	72.6	79.0	0.60	0.62	0.66	0.68
Light industrial lands	69	4.49	0.9	81.7	88.6	104.1	111.0	0.94	0.94	0.95	0.96
Average runoff coefficient								**0.89**	**0.91**	**0.92**	**0.92**

Figure 22. Runoff-coefficient calculations before the implementation of the park

Figure 23 shows the same figures, but after the implementation of a park. What changes is the land use for the park. The main land use in the park is industrial and commercial purposes and urban green space. After the implementation of the park nearly the whole park is a green space, with a curve number of ten. What this means for the runoff coefficient is visible in figure 23. The runoff coefficient values have declined with circa 6% from 0.89 to 0.83 for a 50 year return period, 0.91 to 0.84 for a 100 year return period, from 0.92 to 0.86 for a 500 and 1000 year return period.

Land use	CN	S	Po	Pe50	Pe100	Pe500	Pe1000	C50	C100	C500	C1000
Urban areas	85	1.76	0.35	84.8	91.7	107.2	114.2	0.98	0.98	0.98	0.98
Industrial and commercial areas	91	0.99	0.2	85.7	92.6	108.1	115.1	0.99	0.99	0.99	0.99
Open forest and plantations	79	2.66	0.53	83.8	90.6	106.1	113.1	0.96	0.97	0.97	0.97
Forest	66	5.15	1.03	81.0	87.9	103.3	110.3	0.93	0.94	0.95	0.95
Urban green space	61	6.39	1.28	79.7	86.5	102.0	108.9	0.92	0.92	0.93	0.94
Temp. Agri.	20	40.0	8.0	52.4	58.5	72.6	79.0	0.60	0.62	0.66	0.68
Light industrial lands	69	4.49	0.9	81.7	88.6	104.1	111.0	0.94	0.94	0.95	0.96
Park	10	90	18.0	29.9	34.6	46.0	51.3	0.34	0.37	0.42	0.44
Average runoff coefficient								**0.83**	**0.84**	**0.86**	**0.86**

Figure 23. Runoff-coefficient calculations after the implementation of the park

4. Environmental, economic and social benefits of blue and green spaces

4.1 Environmental benefits

The replacement of natural areas by buildings, roads and houses is probably the most obvious cause for several environmental problems in cities. Increased urban temperatures and air pollution are two examples of resultant environmental problems cities face. With a changing climate, increases in temperature, especially in summer, and higher rain intensities, these problems will become more severe. Blue and green spaces can help reduce these problems but the pressure on land in cities is high as well as the price of land. This results in that many cities, including Aveiro, find the reintroduction of blue and green spaces not valuable enough and they keep investing in built capital rather than natural capital. In the following, several environmental problems are pointed out and in addition it is discussed how blue and green spaces can help reduce these problems.

4.1.1 The urban heat island

The term "urban heat island" refers to urban air and surface temperatures that are higher than the nearby rural and natural areas. These climatic differences are primarily caused by the change of land use by human constructions and the release of artificially created energy into the environment (Valsson & Bharat, 2009).

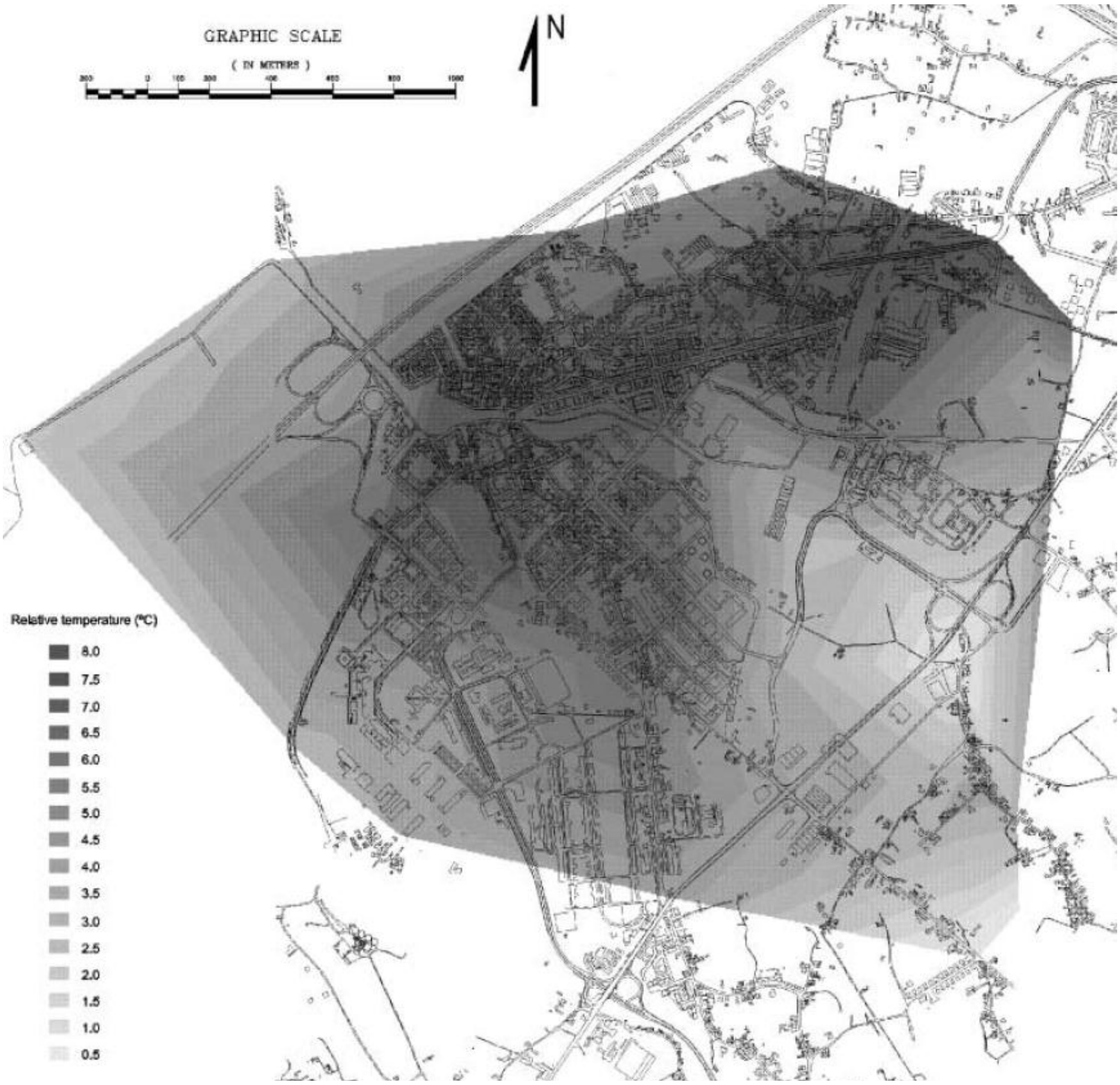

Figure 24. Urban heat island in Aveiro

Buildings and paved surfaces tend to absorb incoming solar radiation, which increases the ambient air temperatures in urban areas. The elimination of green space through urbanization is an important cause for increasing urban heat islands even in small cities such as Aveiro (figure 24, Pinho and Manso-Orgaz, 2000). Green spaces provide shading, evaporation cooling, rain water interception, storage and infiltration functions (Gill et al., 2007). A study conducted by Pinho et at., 2000, found an maximum increase of 7.5°C in the city of Aveiro compared to its surrounding rural areas. They state: "The more extensive the construction, the traffic and the lack of green space, the greater the intensity of the heat island". Thus, the implementation of a park can help reduce air temperatures, however, how much this specific park will help reduce the heat island depends on the type of vegetation cover. Further study must therefore be conducted.

4.1.2 Air pollutants

Urban heat islands and air pollution are related in the sense that urban heat islands can lead to reduced air quality (Currie & Bass, 2008). Higher temperatures accelerate the photochemical ozone production and the increase in temperature-sensitive emission of ozone precursors (Taha et al., 2000). Cities are key contributors to both low-level atmospheric pollution greenhouse gas emissions such as carbon dioxide.

Air pollution in cities has a negative effect on people's health. Exposure to high concentration of pollutants can lead so serious illness (Hunt et al., 2000; Morris, 2003). Levels of air pollution peak especially in hot summer. As stated above, trees, shrubs and other natural vegetation in urban areas affect air contaminant levels in several ways (Nowak et al., 1998; Currie & Bass, 2008). Temperature reduction due to vegetation can reduce the emission of many pollutants because they are temperature depended (Nowak et al., 2005). Green spaces can act as carbon sinks. Threes take in carbon dioxide during photosynthesis and store carbon until they are burnt or die. Urban sinks cannot be seen as the solution to the billions of tonnes of carbon globally, but they can help mitigation their impact. Increasing the amount and size of well-vegetated parks can help reduce the amount of pollutants in the atmosphere. In addition to the obvious health benefits for humans, the pollutant-reducing capabilities of vegetation also bode well for climate change management, particularly with respect to the greenhouse effect.

Specific values of air pollutant for the Aveiro region are not available. Therefore further study must be carried out find the contribution of the park to the reduction of air pollutants in Aveiro

4.1.3 Land and biodiversity

The European commission has created an EU biodiversity strategy to 2020 to halt the biodiversity loss in Europe. Several targets are stated with actions to reach each target. The strategy includes to maintain and restore ecosystems and their services by establishing green infrastructure and restoring of at least 15% of degraded ecosystems. One action is to promote the deployment of green infrastructure in the EU in urban and rural areas (European commission (2011) Cities are difficult places for flora and fauna to survive. The ecosystem is finely tuned with plant and animal species highly interdependent on each other for survival. Green spaces can act as links between other natural areas, which makes it possible for vegetation and animals to pass through cities. In turn, diverse vegetation plays an important role in water quality, soil nutrients and shade (Philiph Roetman, 2008). Urban green spaces provide valuable habitats for animals and plants but species can respond strongly to environmental change. There is a need for wildlife corridors within towns and cities to help plants and animals move in response to climate change. Urban areas need to be permeable to wildlife; private gardens as well as parks and other urban green spaces (including verges) can help with this.

4.2 Social benefits

4.2.1 Physical activities

The increase of people involved in physical activities leads directly to an increase in need for access to places suitable for physical activities such as parks (Kruger, 2008). Parks are a relatively low-cost option to provide spaces for physical activties (Shores et al., 2008). Brownson et al., 2001 states "to help achieving public health goals related to physical activity, environmental and policy strategies are aimed at changing the physical and social political environment". Several studies also conducted in Portugal, found that the presence of public spaces for physical activities, such as walking and biking trails are positively associated with physical activities. A study by Giles-Corti et al., (2005), found circa 30% that of the respondents of a survey in Perth had used a public open space for physical activities in the previous 2 weeks. They also looked at the association between access to public open space and achieving the recommended levels of physical activities. Those with very good access to attractive public open space were 50% more likely to achieve high levels of activity. People can be encouraged to become more physical active if green space is available. Having a public open space close by is important because the use of it is sensitive to place (Giles-Corti et al., 2005). The study conducted in Portugal draw the same conclusions from their survey. They found that 57% of the respondents used parks weekly and the use of green spaces is strongly associated with the proximity to open space (Santana et al., (2009).

4.2.2 Health and nature

The importance of using public policy to create supportive environments for health has increased. Research has proven that contact with green spaces has a positive influence on people's health. Ulrich argued that the benefits of viewing green space or other nature goes beyond aesthetic enjoyment to include enhanced emotional well-being and stress related health problems. Some scientists suggest that people have never lived further away from nature than ever before, mostly due to the fact that these days, the largest part of the world's population lives in cities. The only contact with nature then is urban green spaces.

People prefer to work in spaces with a view on nature. In one of his studies, Ulrich (1984) compared medical records of gall bladder surgery patients who had a window view of either trees or a brick wall. The results showed that patients with a view on green space had shorter post-operative stays, required less pain drugs and evaluated their stay better than those with a view on a brick wall. When this is a direct example how nature can stimulate people's health, there are other, less directly recognized health benefits. Mental health and especially depressive disorder, is becoming an increasing burden of the world's health problems. The Mental Health Priority Area predicts that depressive disorders will take the largest share of the burden of disease in the developed world by 2020. Also because of the high social and financial costs on society (Commonwealth Department of Health and Aged Care, 1999). One study on the mental benefits of exercise activities and green care found that, amongst other positive experiences, the participants were less stressed, less depressed, more positive and more active (Peacock et al., 2007).

4.2.3 Recreation and leisure

As our work becomes more sedentary and stressful, leisure and recreation opportunities gain importance. Time for leisure and recreational activities such as, family bonding, interaction with natural environment and exercising could get peoples mind of their daily stress and activities. Leisure activities have been linked to peoples' identity, social interactions and personal development. Leisure as "the state of mind", a physiological definition of leisure, includes the free choice of spending time, which many see as beneficial. A person's assessments of the "quality of life" and opportunities for leisure activities both depend on his/her immediate environment as well as awareness of that environment. Although many people are unaware of leisure opportunities (Howard & Crompton, 1984; Spotts & Stynes, 1985), the amount of information people have about recreation areas influences leisure choices (Stynes, 1990, Spotts & Strunk, 1985). People learn about leisure opportunities and develop perceptions of the environment not only from personal observation and experience but also from the mass media and interpersonal communication (Jeffers et al., 1993). The idea of spending time in nature with friends and family is attractive, but actually doing it is highly dependent on the distance people have to travel to reach suitable areas. Urban parks provide these opportunities close to home.

4.2.4 Social capital

Urban parks encourages contact between people and community development. The acts of maintaining, renewing or saving a park could build social capital and cohesion. Social capital can be defined as: "a focus on networks between people that lead to cooperation and beneficial outcomes" (Baum et al., 2002). Working together on keeping green space beautiful and safer gives a sense of "owning the place" which helps co-ordination activities and reduce conflicts between users. Interactions in public places such as parks, can stimulate social interactions, the basis on which social capital can be build (Whyte et al, 2006). The design of parks can influence its use of different age groups. Involving neighbourhoods in the design can contribute to social cohesion. At the same time, the chance that the park will be looked after and suits to the requirements of the people increases.

Figure 25: Recreation and leisure

4.3 Economic benefits

4.3.1 Property values

Well maintained green spaces in urban areas, such as parks, schoolyards, golf courses, greenbelts and boulevards, contribute to an increase in property values of adjacent properties (Crompton, 2005; Miller, 2001; Phillips,). The relation between property values and parks was already studied over a hundred years ago. Frederick Law Olmsted conducted a study between 1856 and 1873 on the economic benefits of Central Parks to justify the huge costs for the creation of Central park, New York. He used two principles of which the proximate principle became the wisdom for park advocates and later also for city planners (Crompton, 2005). "The *proximate principle* states that the market value of properties located proximate to a park or open space are frequently higher than comparable properties located elsewhere". The higher value of these properties implies that their owners pay more property taxes. The tax revenues that are attributable to a park or open space can be used for the development and maintenance of these spaces.

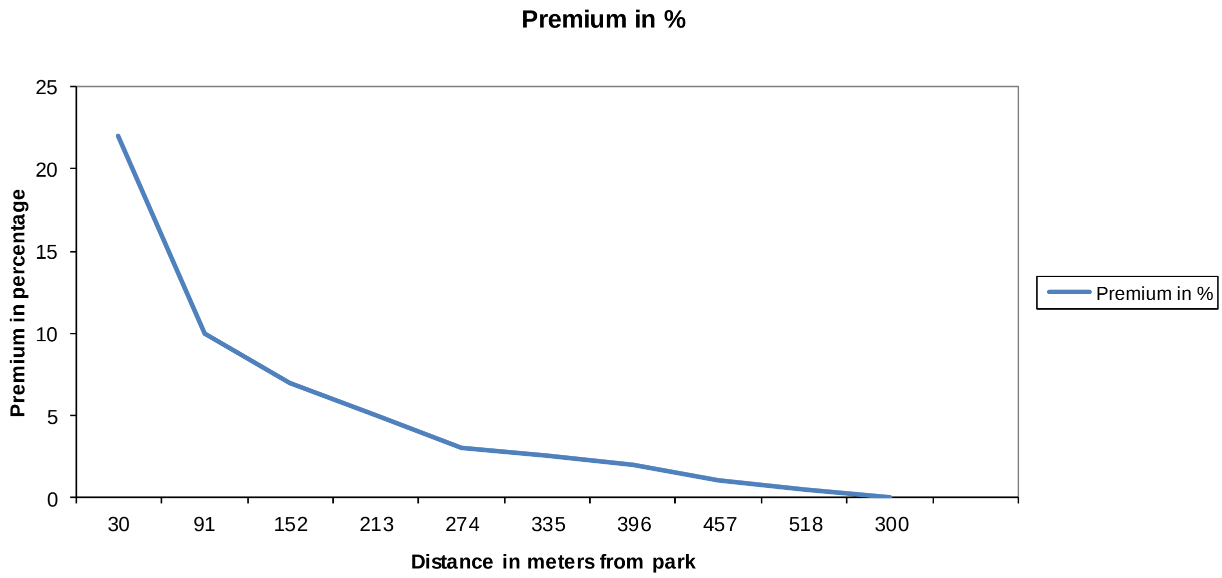

Figure 26. Real estate premiums in percentage. The percentages ranged from 22% adjacent to the parks to 0.5% at circa 500 meters from the park. (Miller, 2001)

World wide a lot of studies have been conducted to look at the effect of blue and green spaces on house prices. J. Luttik, (2000) studied nearly 3000 house transactions in eight towns or regions in the Netherlands. They found an increase in house price of 8-10% for houses overlooking water and an 6-12% increase for houses with a view on open space. Miller (2001) confirmed the proximate principle in relation to property values with his study at 14 neighbourhood parks. The park sizes differed from 0.08 hectare to 3 hectare. The percentages ranged from 22% adjacent to the parks to 0.5% at circa 500 meters from the park.

An example closer to Portugal, a study in Spain in the city Castellón, found a decrease of €1,800 in property values for every 100 meters away from a park (Morancho, 2003). With the above, it is justified to say that the park in Aveiro will have some influence on the property values of the properties around the park. To do an estimation of the additional values the numbers from Miller's study (2001) regarding fourteen neighbourhood parks will be projected on Aveiro. These numbers (figure 26) has been chosen for several reasons. First, the premiums of 22% to 0.5% are based on observations of fourteen random neighbourhood parks instead of just one, which makes the data more reliable. Second, the parks vary in size, but are all relatively small. A lot of research on property values in relation to urban parks are based on very large and often well know parks. Since the park in Aveiro is a neighbourhood park of nine hectare, the parks fits into type of parks used in Miller's study.

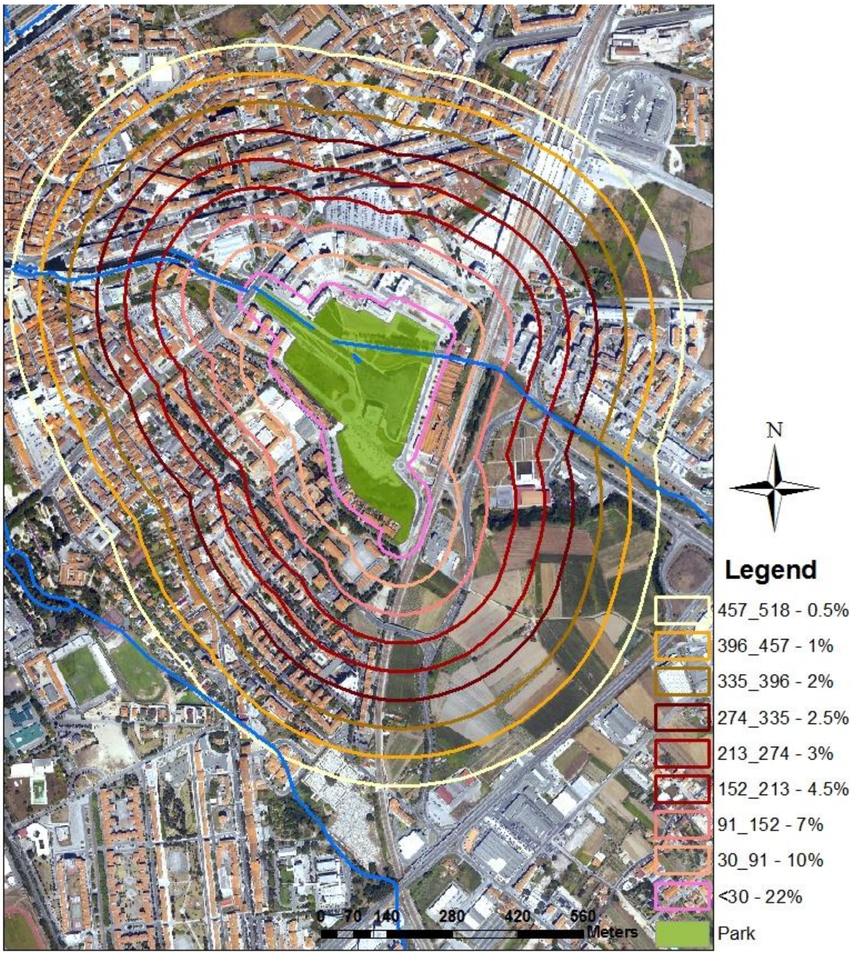

Figure 27. Circles with the different premium percentages around the park in Aveiro

To calculate the increase in property values, three variables must be known. First, the surface areas with the increase in property values in percentages (figure 27). Second, the "living area" or the amount of space occupied by houses in m^2 for each ring and third, the current property price per m^2. The "living area" in m2 for each ring is calculated by using the population and the area of habitation of the Vera Cruz neighbourhood, a comparable neighbourhood in the centre of Aveiro. This neighbourhood is used since the numbers of the parks neighbourhood are unknown. Vera Cruz has 9,657 inhabitants with an area size of 1,598,339 m^2, which gives an average population density of 0.00604 persons per m^2 of land. The living space is calculated by multiplying the average space per person, which is 20 m^2 for Aveiro (statistics Portugal), with the average population density. This gives 0.121 m^2 of living space per m^2 of land. The total living space within each ring has been calculated by multiplying the land area in m^2 with 0.121 (table 28).

The premiums are calculated by using the living space value per m^2, which is €1,148 for Aveiro. This value has been multiplied with the premium percentage from each circle from which follows the new living space value per m^2. The column "Old" in figure 28, shows the total real estate values for the current situation, while the column "New" shows the total real estate values including the premiums generated by the park. The last column shows that the premiums generated by the parks presence is € 8.5 million. Given a 5% discount rate and a time horizon of 30 years, the annuity real estate premium for the park has been calculated at € 465,137 per year. Annual benefits in the form of real estate taxes are calculated at € 110,390, with a tax rate of 1.3% (Statistics Portugal, 2012).

Circles	Area	Living space	Real estate price	Premium	Real estate price	Old price	New price	Premium
[m]	[m^2]	[m]	[€/m^2]	[%]	New [€/m^2]	[€ million]	[€ million]	[€ million]
<30	53199	6428	1145	22.0	1400.56	7.4	9.0	1.6
30-91	120504	14561		10.0	1262.80	16.7	18.4	1.7
91-152	141042	17043		7.0	1228.36	19.6	20.9	1.4
152-213	163337	19737		4.5	1205.40	22.7	23.8	1.1
213-274	186208	22501		3.0	1182.44	25.8	26.6	0.8
274-335	209301	25292		2.5	1176.70	29.0	29.8	0.7
335-396	232427	28086		2.0	1170.96	32.2	32.9	0.6
396-457	255657	30893		1.0	1159.48	35.5	35.8	0.4
457-518	278897	33701		1	1153.74	38.7	38.9	0.2
						227.6	**236.1**	**8.5**

Figure 28. Real estate premiums

4.3.2 Recreational value

Well known and attractive parks such as Central Park in New York or Millennium Park in Chicago, are tourism attractions by themselves. Other parks can be used for sport events, picnicking or festivals. The economic benefits of recreation is difficult to calculate. Calculation of the parks contribution requires knowing the number of park visitors and their spending. The recreational value has been calculated with the willingness to pay method. This method tries to determine the price that people are willing to pay for a certain good. It can be explained as when we buy something, we are evaluation the specific characteristics of that good. When there is a market for the good, that price reflects the willingness to pay. To find the recreational value for the park the value of activities in the park as well as the amount of residents that will make use of the park has to be determined.

The U.S. Army Corps of Engineers has developed a model to calculate the unit day values. The unit day values are based on the recreational opportunities a park provides and the quality of the park. Hundred points can be given to a park that has many general and specific activities, such as picnicking and running trails but also hunting and fishing. The higher score, the more opportunities there are. Several aspects are evaluate to find the score for the park in Aveiro (annex V). The evaluated aspects are: the number of activities in the park, the availability of opportunity, the carrying facilities, the accessibility of the park and the environmental quality.

The park in Aveiro has only basic activities such as picnicking, walking and running. The availability of opportunity can be explained as the travel time people are willing to spend to reach the park. A neighbourhood park serves it's neighbourhood, therefore 30 minutes to 1 hour walking distance has been chosen. The optimum facilities to conduct activity at the site potential is pretty high since the park is located in the centre of Aveiro. The accessibility of the park is therefore also high. The environment in cities is often not as good as in the surrounding rural areas. There are existing factors that lower the environmental quality. Therefore the environmental scores are quite low. The total score of the park lays between 24 and 40 points. The points can now be translated into a value in euro. This value is the value for each activity in the park. The unit day value of the park lays between €3.37 and €4.56 (U.S army. Corps of Engineers, 2010).

	Distance in km		
Days of use	**0.4 km**	**0.8 km**	**1.6 km**
365	13% - 57	9% - 77	10% - 282
182	55% - 240	31% - 266	49% - 1382
48	22% - 96	19% - 163	17% - 479
6	3% - 13	6% - 52	6% - 170
1	0% - 0	4% - 34	2% - 56
0	7% - 31	31% - 266	16% - 451
Total	**100% - 437**	**100% - 858**	**100% - 2820**

Figure 29. Park use in relation to distance

The number of residents that will make use of the park has been calculated according to a previous study by the RAND corporation in Los Angeles. A research on the use of 12 neighbourhood parks in days per year in relation to the walking distance from the park (figure 29). Aveiro has a population density of 0.00039 persons per m^2. Figure 31 shows three circles with the distances around the park. The surface of each circle multiplied with the population density of Aveiro gives an estimated number of residents living in each circle. The first circle has a radius of 0.4 km, and a surface of 1122071 m^2 which gives a population of 438 residents. The second circle has a radius of 0.8 km, has a surface of 3323278 m^2 minus the first circle gives 2201207 m^2 which gives a population of 858 residents. The third circle has a radius of 1.6 km and has a surface of 7230323 m2 which gives a population of 2820 residents. The residents have been multiplied with the days of using the park and with the unit day value of € 3.37. This gives an estimation of the recreational values of approximately €1,8 million annually. However, this cannot be seen as direct income since park visitors don't actually pay to make use of the park (figure 30).

	Distance in km		
Days of use	**0.4 km**	**0.8 km**	**1.6 km**
365	€ 70,793.53	€ 94,853.74	€ 347,386.43
182	€ 147,419.02	€ 163,389.41	€ 855,033.03
48	€ 15,551.90	€ 26,405.82	€ 78,235.81
6	€ 263.25	€ 1,052.99	€ 3,451.58
1	€ 104.62	€ 144.75	€ 191.75
0	€ 0	€ 0	€ 0
Sum	€ 234,132.31	€ 276,475.00	€ 1,286,864.02
Total		**€1,797,471.33**	

Figure 30. Recreational value of the park in Aveiro

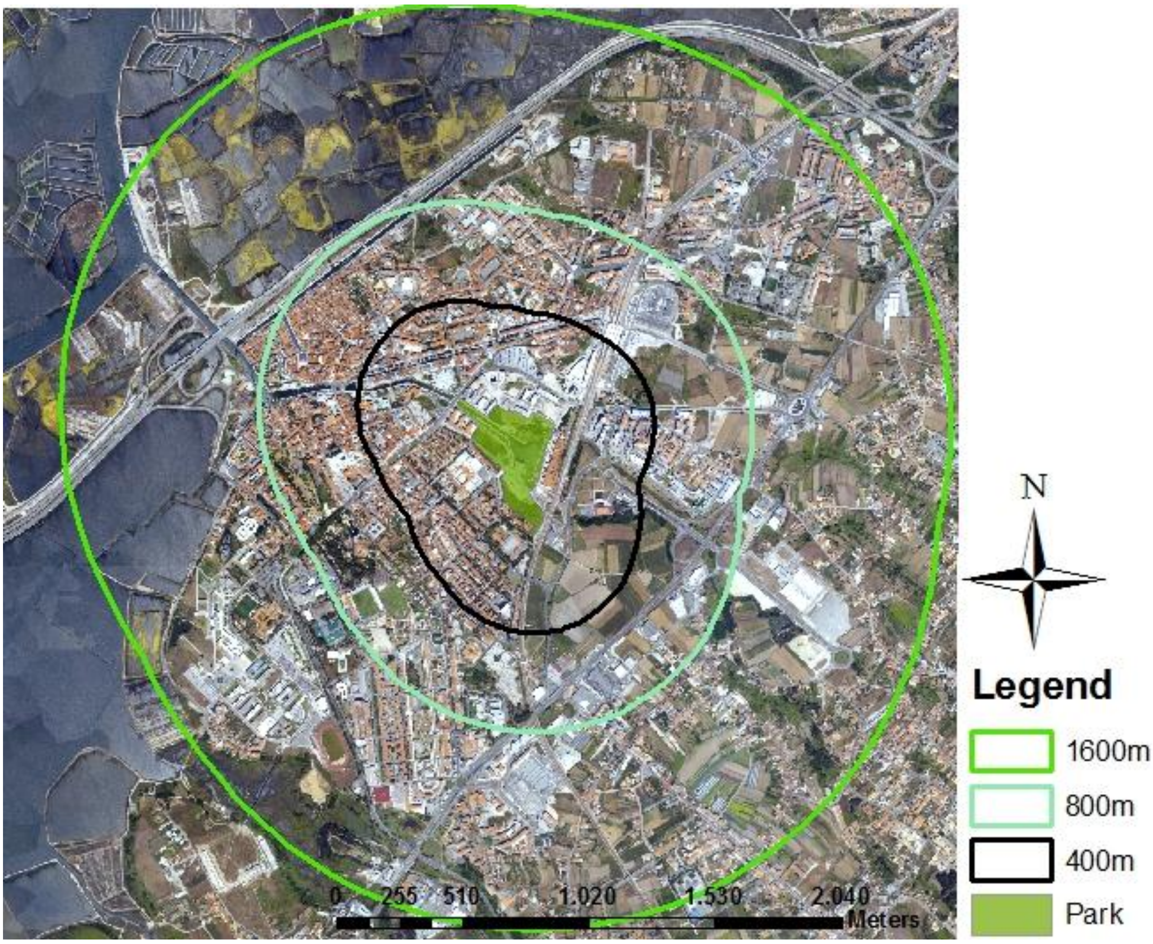

Figure 31. Recreational use circles from the park

4.3.3 Tourism

The economic benefits of blue and green spaces in relation to tourism requires knowing the number of park visitors and their spending. The prediction of how many tourists are going to use the park is difficult to make. The number of tourists visiting Aveiro in 2008 was 192,976 of which 67,541 were categorized as urban tourists (Costa Martins, 2010). The park is located in the centre of the city, and is easy accessible. Therefore the prediction is that urban tourists will visit the park during their city tour. The amount of money spend in the park depends on the facilities of the park. The park has only general activities such as walking trails, and is not an attraction on itself. To give an indication of the tourism value of the park, the urban tourist number is multiplied with the unit day value of € 3.37 which gives €227,613.

4.3.4 Investment and maintenance costs

The investment costs of the park are the costs of acquiring and developing the park. This includes fencing, trails, planting and landscaping. The costs per hectare is based on a hypothetical park of twenty hectare located in a suburban area in the United States, where a price per hectare of € 37,847 was found (Crompton, 2007). In the case of Aveiro, the proposed

Investment costs park	
Price per hectare	€ 37,846.67
Park size (hectare)	9.0708
Total costs	**€ 343,999.57**
Years	30
%	5
R	0.05
Annual debt charges	**€ 22,332.13**

Figure 32: Investment costs park

park size is 9.07 hectare, which gives a total investment cost of circa €344,000 (figure 32). The total annuity investment costs for a period of 30 years and a discount rate of 5%, are estimated at about €22,332 per year.

	€ per hectare	Park size	€
Routine maintenance	635.33	9.0708	5762.92
Mowing	159.46		1446.40
Pruning	61.57		558.46
Irrigation	113.62		1030.65
Garbage collection	55.91		507.15
Leaf removal	76.92		697.77
Lights	115.72		1049.67
General facility maint.	57.62		522.62
Total			**11575.64**

Figure 33. Estimation of maintenance costs in 2010 euros

The maintenance costs are based on observations of maintenance costs for several neighbourhood parks in Salem, United States. Figure 33 shows the different operations that need to be performed in a park. The annual costs of the different operations for several neighbourhood parks have been compared and an average of each service per hectare has been calculated. The total annual maintenance costs are calculated by multiplying the costs per hectare with the size of the park, and are estimated at about € 11,500 per year (figure 33). Consequently, the total annual costs for the park is given the sum of the annual investment and maintenance costs, and are estimated at € 33,900. The reliability of the numbers are questionable since they are extracted from previous studies in the United States and projected on Aveiro. However they do give an indication.

4.3.5 Costs- benefit analysis

The economic benefits generated by the park, versus the investment and maintenance costs is the justification for the parks inclusion. Figure 34 gives an overview over the earlier calculated benefits and costs.

Costs		**Benefits**	
Annual investment	€ 22,332.13	Property premiums	€ 110,390
Maintenance	€ 11,575.64	Recreational values	€ 1,797,471.33
		Tourism values	€ 227,613
Total	**€ 33,908**	**Total**	**€ 2,135,474.33**

Figure 34: Annual costs and benefits in 2010 euros

Annually, the benefits are higher than the costs in figure U. The premiums of the property prices are circa € 8.5 million, but this cannot be seen as income for the municipality. They only gain from the real estate taxes, and higher property prices means higher tax income. What has not been taken into account is the benefits for the municipality if investors would built houses instead of creating a park. Investors have to pay construction fees to the municipality which allows them to start building. The prices of the construction fees were not available and are therefore not present in this analysis.

5. Conclusion

This research focuses on the reduction of floods caused by heavy rainfall events by using sustainable measures such as blue and green spaces, in this case, a park. Floods occur approximately every six years in Aveiro. The flood risk areas are lower parts of Aveiro, in particular the historical centre "the old town". Over the years, the Municipality of Aveiro has taken several measures in an attempt to reduce these floods. The flood gates are increased and a monitoring system was implemented to monitor coming rainfall events. The storage capacity of the channel system is tested for storms with four different return periods (50, 100, 500 and 1000). The channel system provides enough storage capacity for 6 hour rainfall events with the peak of the event during low tide, with an empty channel, for all four return periods. When the peak of the storm occurs during high tide, there is still enough storage capacity in the channel system for the 50 and 100 year return period, however, with a 500 and 1000 year return period, 17715 and 26807 m^3 extra storage capacity is needed in the peak of the event. The detention basins in the park have a volume of 20892 and 17559 m^3 which gives a total of 38451 m^3. The extra storage needed during 500 and 1000 year rainfall events fits in the detention basins in the park, and will prevent the lower parts in the cities from flooding. With a full channel, the channel contains 277967 m^3 of water, which leaves an additional water storage of 57987 m^3. In this case, for all four return period rainfall events, occurring both during high and low tide, additional water storage is needed. The additional storage in the park of 38451 m^3 is only a fraction, 15% to 26%, of the needed storage in the peak of the event, to prevent flooding. 80% to 85% additional storage is needed with the peak of the event at high tide and 74% to 81% during low tide. The channel system is quite sufficient for heavy rainfall events with a duration of six hours when the monitoring system has prepared the channels by emptying them in advance. If not, the lower parts of the city will flood. 500 and 1000 year storms seem not to occur to often. But due to climate change, the rainfall events are said to become more intense, this does not necessarily mean more water in quantities, but it means the same amount of water in a shorter period of time. The peak of the event than becomes higher, and more storage capacity is needed (when there is no discharge possible).

The combination of heavy rainfall with S/SW wind related surge storms, the problems are expected to be more severe. The surge storms cause a rise of the water level in the lagoon, which means that the discharge from the channel system into the lagoon might not be possible even during low tide. In this case the water has no other way to go and the lower parts of the city will flood. The size of the flood area depends on the time no discharge is possible. The additional storage in the park would probably have very little effect on the size of the flood area, and other measures are needed to protect the city from flooding, such as dikes.

The park does decreases the runoff by changing the land use by circa 6%. However, the park should be located in higher parts of the city, to be able to reduce the nuisance of the water on the streets. In that case, the peak of the event can be stored in the park, to reduce flooding.

Several plans has been made by the Municipality of Aveiro to implement more green spaces, the five and four finger plan. Unfortunately, only a small part of this project is created, because several times, green has to give

way for other plans. But beside flood control, blue and green spaces have other benefits. They can help reduce environmental problems in cities, increase social cohesion and have actual economic benefits.
The maximum temperature difference between the city centre and the rural areas in Aveiro is 7.5°C. Higher temperatures can lead to reduced air quality because they accelerate chemical reaction, cities are key contributors to greenhouse gas emissions such as carbon dioxide. Green spaces on the other hand can store these emissions. To what extent the 9 hectare park can help reducing both problems island is unknown at this point.

Most people experience nature as something positive, but what a green environment really means for peoples health it difficult to measure. The availability of parks or other green spaces have a positive effect on activity such as walking and running. The times people make use parks is strongly related to the proximity of parks.

Probably the most studied economic benefit of blue and green spaces is the increase in property values. The calculated estimation of premiums due to the park in Aveiro is €8.5 million. Higher property prices, means more income for the municipality in the form of property taxes. The economic recreational value of the park is calculate according to the willingness to pay method and is almost € 1,8 million. This cannot be seen as direct income but it reflects the value people are willing to pay to make use of the park. Parks make cities attractive, which is positive for tourism. To economic tourism value of the park is €255,613. The annual investments costs of the park are estimated at€22,332 and the annual maintenance costs at € 11,500. Comparing the costs versus the benefits, the benefits are higher but, not all economic aspects has been taken into account. The benefits for the municipality if investors would built houses instead of creating a park are not calculated. Investors have to pay construction fees to the municipality which allows them to start building. The prices of the construction fees were not available and are therefore not present in this analysis.

5.1 Recommendations

The storage capacity of the channel for the designed storms with a return period of 500 and 1000 years should be increased with 80% to 85% with the peak of the event during high tide and 74% to 81% during low tide. This are very large quantities of water and creating more parks in Aveiro is not the recommended solution for it. There is already a lot of pressure on space in the city due to urbanization therefore other measures must be taken to prevent floods. The water transportation system in the city should be directly connected to the lagoon, maintained and modelled for larger water quantities. That way the channel system can be spared from large amounts of water, and leaves more storage capacity for the runoff from the rest of the catchment area. More drastic measures such as the construction of dikes can be a solution for the wind related surge storms in combination with heavy rainfall events. Especially if they can assure a constant discharge onto the lagoon, the flood risks in Aveiro will be reduced to a minimum. To reduce the runoff in Aveiro, it is recommended to locate parks in the higher parts of the city. There it can catch the water before it flows to lower parts of the city to prevent flooding in those areas.

5.2 Discussion

The economic benefits have been calculated using numbers found in previous studies elsewhere in the world and projected on Aveiro. This method has been used since there are no previous studies conducted in this subject in Portugal. This makes the calculated values less reliable, but they give an indication of the economic values of the park. The recreational and tourism values depends heavily on the facilities the park provides.

The available maps in ArcGIS are not very accurate and very detailed. Compared to aerial photos of Google maps, they show some differences in particularly the land use maps. This could give small differences in particular for the calculations of the runoff coefficient.

6. Reflection

The months I worked on this thesis have been very interesting. This topic is very up to date, and involves more and more cities. This research is conducted in Portugal, where things go rather differently than I am used to in the Netherlands. A lot of information is not as available and the language difference was something a barrier. The first weeks, I spend a lot of time gather all needed information. Shape files for ArcGIS and rainfall data are available, but you need to find the right person to ask for this information. Fortunately the municipality of Aveiro was very helpful and tried to provide me with all information. Although, I had to change the planning completely, to not waste time waiting for the right documents. Working on a thesis alone, I had to make a lot of decisions by myself, which makes me question what is the right decision, a lot. This is probably the reason I changed the direction of this thesis a couple of times, without really noticing. Meetings with Peter Roebeling helped me back on the right track.

The research proposal I wrote in February and the final thesis have quite some differences. The research question formulated in the proposal seemed during the process to broad and has therefore been changed to focus more on water management. Some of the sub questions where not sufficient anymore, and are replaced for others. The water problems in Aveiro are very clear but also very complex. I had to force myself to only concentrate on the rainfall water problems, and how my park could be a solution to those problems, and not try to solve the whole problem.

The literature study on other benefits (environmental, social and economic), was a challenged because there are so many research papers, with information. It was difficult to find comparable situations to the situation in Aveiro, and I had to choose the one that fits the best. A lot of studies are conducted in the United States, which might not be very comparable to Portugal, but those studies are usually based on a wider range of input data.

Sustainable solution for water management in cities, is a very actual item. Fighting against floods has always be a challenge in Aveiro. With this thesis I hopefully have put some focus on the importance of creating space for water in Aveiro to control flooding due to high intensity rainfall events.

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