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Floodplain mapping based on GIS techniques in Oued Fez watershed

Abdelkader EL GAROUANI[1], Astride ADJINACOU[2], Kamal AHARIK[1], Mohamed LASRI[3]

[1]Sidi Mohamed Ben Abdellah University, Route d'Imouzzer, BP. 2202, Fez 30060, Morocco

el_garouani@yahoo.fr

[2]Pan African University of Water and Energy Sciences, Tlemcen, B.P. 119, Pole Chetouane, Tlemcen 13000, Algeria

astrideadjinacou@gmail.com

[3]University Ibn Zohr, BP 29/S, Agadir, 80000, Morocco

simomed.lasri@hotmail.com

Abstract

The urban flood risk appears among the major environmental preoccupations of actors in resources management and land planning; and this issue is exacerbated by the climatic and the global change factors. Flood, considered as one of the worst weather-related natural disaster, cause severe damages to life, properties and environment. For the floodplain mapping, we adopted an approach based on modeling of flows processes. The main sources of information are maps, hydro-meteorological data, Digital Elevation Model (DEM), satellite images, field observation, etc. This research presents a straightforward approach for processing input and output of the HEC-RAS hydraulic model, to enable two and three dimensional floodplain mapping and analysis in the ArcGIS environment. The study area concerns Fez located in Saiss plain. The agglomeration of the city is actually being developed in the area of confluence of all the hydrologic network of Oued Fez watershed. This watershed, which is composed of several sub-basins, receives its water from six essential Oueds. The results of the study indicate furthermore that Geographic Information System is an effective environment for floodplain mapping and analysis. The resulting GIS maps, consisting of flood hazard, floodplain extension and risk maps. This helpful information can guide the local early warning system of flood and identify the areas facing flood risks.

Key Words: Floodplain mapping, Hydraulic modeling, Oued Fez, Morocco

Introduction

Floods are probably the worst weather-related natural disaster, widespread, disastrous and frequent natural hazards of the world, which cause severe damages to life, properties and environment [1]. Over the last 30 years (1981–2011), floods have been the most recurrent disasters recorded in [2] with at least 300 events (53 percent of the total number of disasters), indicating a strong need for early warning systems [3]. This large increase can be attributed to a growing concentration of assets at risk, particularly in urban areas, and insufficient structural and non-structural mitigation measures [4] [5].

Since five decades, the flooding risks have been intense in the Fez agglomeration. Their impacts were important either inside the urban area or in its immediate peripheries, where population densities are progressively high. The south-eastern Fez suburbs experienced episodic flooding risks since 1950 [6]. A severe flood disaster occurred in 1989, when Oued Boufekrane frightened the extending habitat in its valley bottom and engendered several human victims. In October the 12th, 2008 an abrupt rise of the Oued discharge caused considerable material loss in the area (Photos, 1-2).

The inundation due to punctual overflow is occasioned by hydraulics structures (bridges, drainage canal) not well or less dimensioned and/or clogged.

Besides that flooding occasioned by urban runoff in Fez is due to the impermeability of the urban surface of the city. Actually, impermeability help in the increase of quick runoff of the flood. [7] mentioned that the runoff volume could increase from 500% to 800%, according to the degree of impermeability. That led to small time of concentration and high peak

Corresponding author: Abdelkader EL GAROUANI

discharge. Therefore, the inundations amplified as it is the case sometimes in Fez agglomeration. For instance, on May 18th, 2010; the city received 52 mm of rainfall and all the neighborhoods of the city have been inundated [8].

Photo 1: Overflow of Oued Boufekrane drainage canal in Fez Medina, September 28th, 2008

Photo 2: Overflow of El Himmer drainage canal in Lala Soukaina district, March 13th, 2013

Those figures alone render consideration of flood risk management, a necessity, especially in this context of climate change, which according to [9] will increase the vulnerability and damages in the countries. . With respect to that, the prevention of the risk could be a positive point for the management of the disaster. Conjointly, according to [10], one of the cornerstones of flood risk management is the information of people at risk and of the authorities and agencies responsible for flood management. Only if the people and decision makers are aware of the flood risk, and only if they are able to evaluate the risk, they can then be expected to adequately respond to this thread. Additionally, owing to the fact that maps give a more direct and stronger impression of the spatial distribution of the flood risk than other forms of presentation such as diagrams or verbal description [10]. This work will focus on Flood Modelling and Flood plain Mapping based on Geographical Information System in Fez watershed in Morocco. Owing to that, the study sets out to achieve three specific goals:

- Assess factors controlling flood hazards in the study area
- Conduct the hydraulic simulation of flood in the watershed
- Develop the indicative maps of flood risk in the study area and recommend some mitigation and/or adaptation measures to reduce the impact on people and the environment.

To achieve these goals, the work will present Oued Fez watershed, its physiographic and climatic characteristics, the modeling and the mapping of the flood in the study area and the presentation and discussion of the results.

1. MATERIAL AND METHODS:

A. STUDY AREA:

Fez is the fourth largest city fin Morocco (Fig. 1). It is situated 33°58'N 04°59W, at 571 m above the sea level in a valley between the Atlas Mountains in the South and the Rif mountains in the North [11]. Fez consists of two contrasting parts: the traditional Arabic-Islamic, medieval city center, the Medina, and the modern city with its roots in the French colonization.

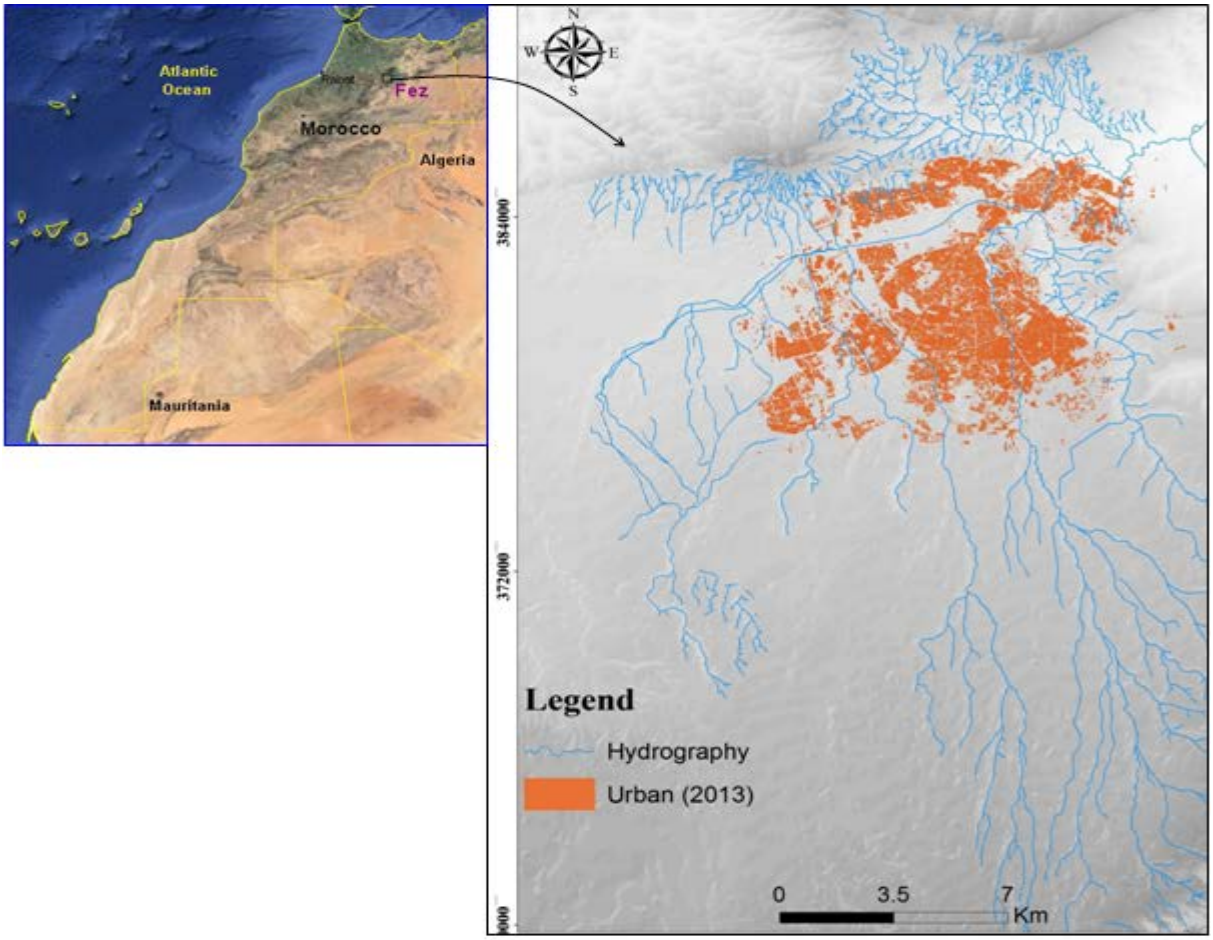

Figure 1: Study area

The city of Fez is situated at the convergence point of four major natural regions, and in the crossroads of two major parties of Morocco: the Middle Atlas in the south and the Saiss plain in the west. Its site is located in the foot of the Tghat Mountain (837 m) and that of Zalagh (900 m) where the course of Oued Fes, after crossing the plain of Saiss to join the Sebou River.

From the analysis of hydrographic characteristics of watersheds, we can say that the density of the hydrographic network as well as the slope of the main collectors can only favor a medium to low hydrological response. To quantify this hydrological response, we estimate the flood concentration time and calculate the peak flows using different methods. In general, a moderately dense hydrographic network characterizes the watershed of Oued Fez, but the flow of the latter is much disarticulated. Theoretically, this situation dampens the hydrological response of watersheds due to rainfall stresses because the interrupted flows between branches of the hydrographic network. However, in the case of the Oued Fez watershed, the impact of this situation on the flow concentration is complicated because the combination with other factors (morphometry, relief energy, soil permeability, etc.) influence of the routing of the hydrographic network on the genesis and concentration of floods.

B. DELIMITATION OF OUED BOUFEKRANE WATERSHED (AFFLUENT OF OUED FEZ)

With an area of 52 km^2 and a length of 29 km, the Oued Boufekrane takes his source from El Kanntra basin (Fig. 2). This watershed represents the eastern limit of the Oued Fez and the Saiss plateau. The Oued Boufekrane drains the Southeastern part of Fez, extending from El Gaâda plateau. It converges to Oued El Mehraz and form a braided bifurcating hydrologic system that, in downstream, influence the lowest part of the Aouinate El Hajjaj district. Boufekrane also converges with Oued Zitoune in the entry of the Rçif district (in the ancient Medina). Its outflow is weak, but the discharge becomes torrential in periods of strong rainfall causing the flooding risk along Oued Boufekrane, mainly in the Aouinate El Hajjaj district.

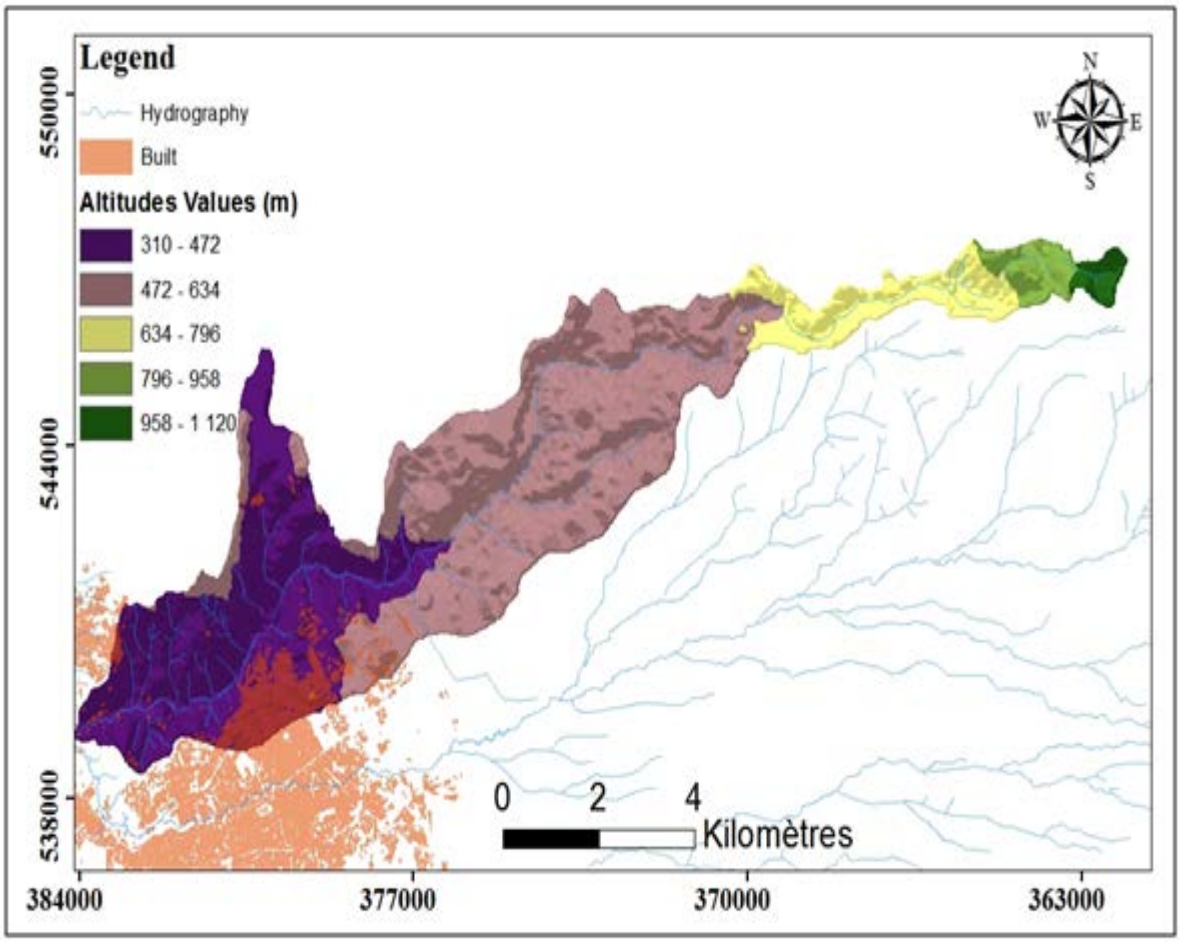

Figure 2: Oued Boufekrane Watershed

C. HYDRAULIC MODEL DEVELOPMENT

This section provides a detailed description of the methodology that was applied to obtain the hydraulic modeling results. The main objective of the hydraulic model was to estimate the flood hazard with return periods of 10, 50 and 100 years in the Boufekrane (the most important affluent of Oued Fez). In order to obtain results that could be incorporated into a flood hazard map, hydraulic models with different cross section configurations and additional geometric features were developed with HEC-GeoRAS and analyzed regarding the validity and accuracy of the simulation results [12]. The final modeling approach that was developed based on the preliminary simulations is described below.

For the floodplain mapping, we adopted an approach based on modeling of flows processes using US Army Corps of Engineers Hydrological Engineering Corporation's River Analysis System (HEC-RAS) model [13] and [14]. The main sources of information are maps, hydro-meteorological data, Digital Elevation Model (DEM), satellite images, field observation, etc. This research presents a straightforward approach for processing input and output of the HEC-RAS hydraulic model, to enable two and three dimensional floodplain mapping and analysis in the ArcGIS environment. The hydraulic modeling tool HEC-RAS is used to perform the steady flow simulations and the model input files are developed in the ArcMap environment by using the software extension HEC-GeoRAS.

The final hydraulic model was primarily used to define the locations of the channel, where bank overtopping can be expected to occur after a certain threshold flood discharge is exceeded. The chart below describes in detail the means used within the ArcGIS environment, HEC-GeoRAS and HEC-RAS (Fig. 3).

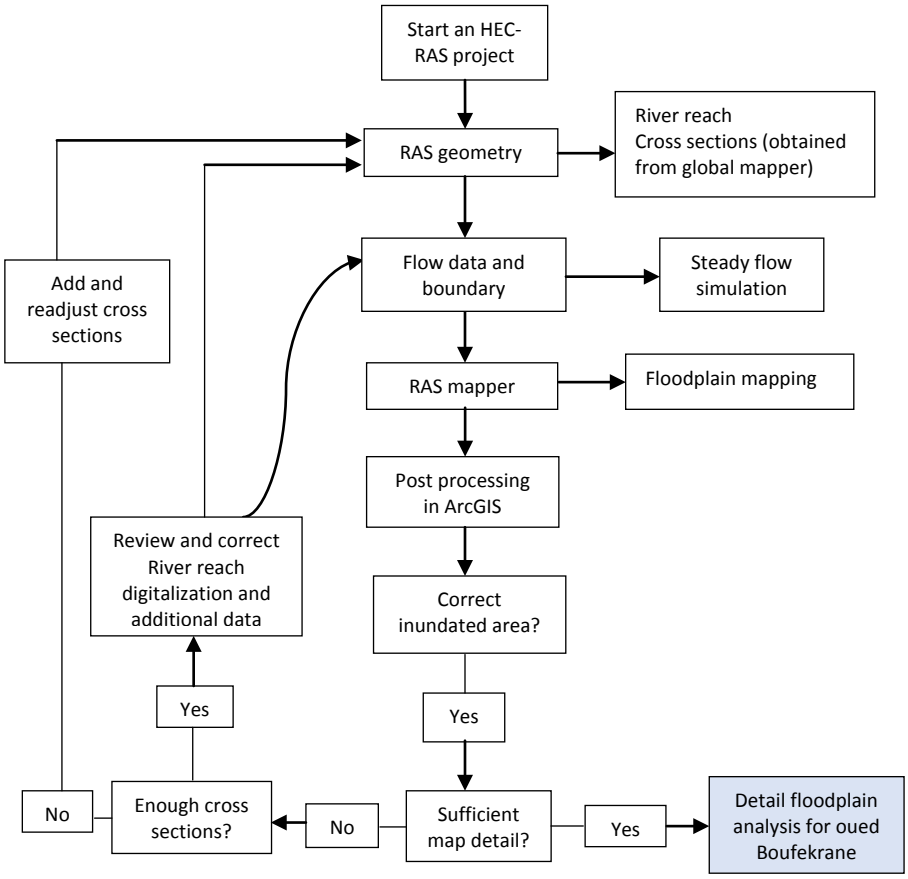

Figure 3: Hydraulic modeling process

D. HYDROLOGIC RESPONSE OF THE WATERSHED

Given the results obtained, it is clear the watersheds can generate exceptional flood, considering the analysis of the historical flood events, before and after the construction of some hydraulic structures. It is then obvious that the position of the city influence greatly the hydrological response of its watersheds; because it is located in the confluence zone of the completely hydrographic network of the basin.

Besides that, time of concentration is a fundamental watershed parameter. It is used to compute the peak discharge for a watershed. The peak discharge is a function of the rainfall intensity, which is based on the time of concentration. Time of concentration is the longest time required for a particle to travel from the watershed divide to the watershed outlet. According to the different time of concentration obtained, it is relevant to notice that they are relatively short. That implies that there is a relatively fast runoff within the watersheds. The next part will present and discuss the results obtained from the hydraulic modeling using ArcGIS, HEC-GeoRAS and HEC-RAS.

2. RESULTS AND DISCUSSIONS

The hydraulic modeling performed has allowed the simulation of the water levels, the velocity and the areas submersible by the decennial, the 50- years and the 100- years flood. The results are presented below (Fig. 4-5).

The flood depth map provides information about the water depth in a particular location for a given recurrence interval (or probability) of flood. Here, the results are given in meters (m). Oued Boufekrane has a hollow valley restricting its lateral overflow which generally do not exceed 70 meters. Actually, the flooding generated by Oued Boufekrane take the path of the entrance of the medina where the waters flow at a velocity exceeding 4 m/s. The water depth can reach and exceed 25 m. That represents a high hazard. In addition, as it was for the September 2008 event, the overflow of Oued Boufekrane occasioned flooding in Aouinat El Hajjaj district. The flood hazard map is presented below for Oued Boufekrane.

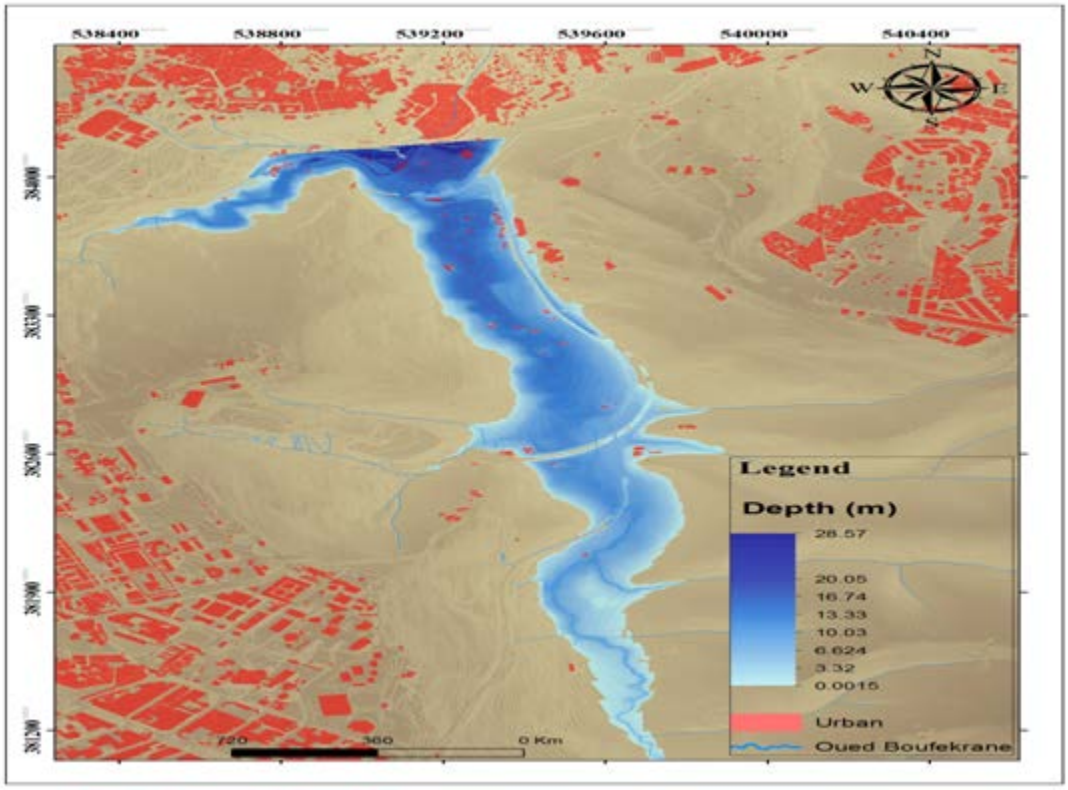

Figure 4: Flood hazard map of Oued Boufekrane

The floodplain map of Oued Boufekrane is shown in figure 5. In this figure, the damaged building can be clearly seen (in red).

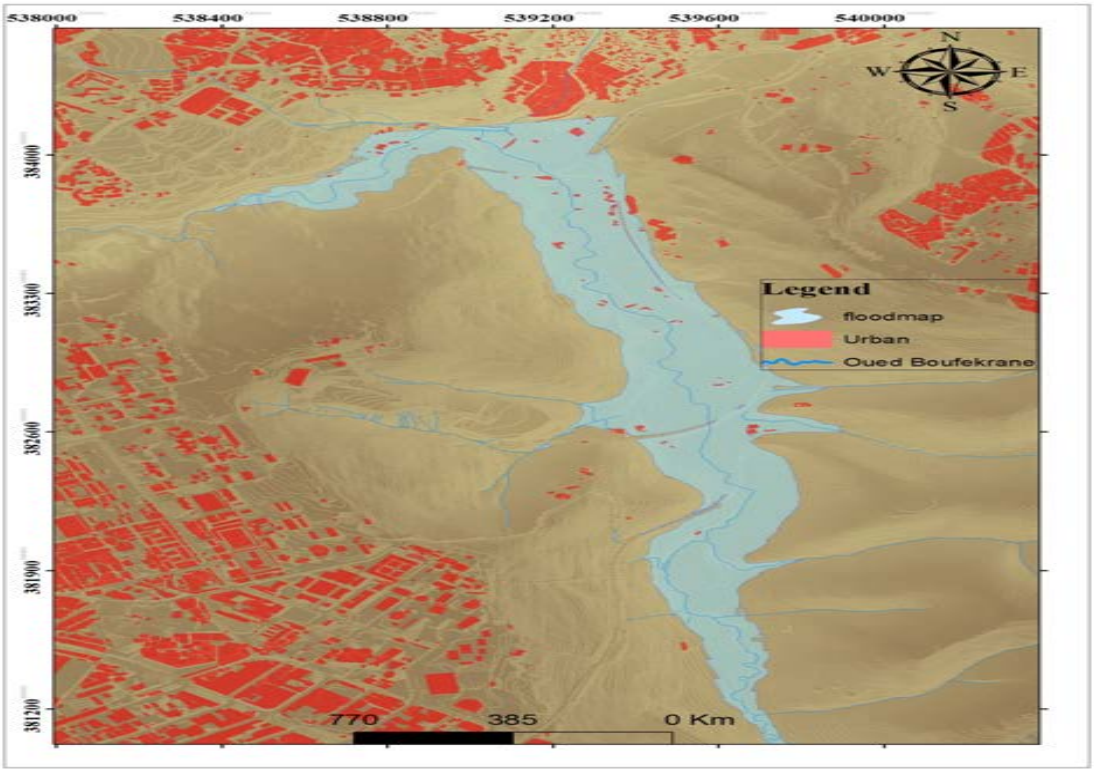

Figure 5: Oued Boufekrane floodplain map (10 years return period)

Besides that, it is important to notify that before the hydraulic modeling, this report analyses the factor affecting the flood risk in Oued Fez watershed in addition to the different behavior of its watersheds. The study performed a frequency analysis of the historical rainfall events as well as the hydrological response of the watershed.

With respect to the hydrological analysis of the watersheds, the morphometric and physiographic characteristics of the watershed denote a soft hydrological response. However, based on the analysis of the intensity of the rainfall events, it appears that the watersheds can generate exceptional flooding which are evidenced by the historical flooding events in Fez. The peak discharges estimated by the empirical formula also are important and can generate catastrophic damages in the future. This vulnerability induced by the hydrological hazard in Fez is alarming.

Moreover, Flood mapping heavily depends on data. Depending on the methods and techniques chosen, the need for accurate data is high. The task is not easy with some absence of data. Some remarques are expressed here to make that effortless:

- Production of a climatic, hydrologic and geologic database:

These types of data are extremely useful for hydrological modeling and forecasting. It could be judicious to centralize the data (discharges, rainfall, class and type of soil, etc.) at a watershed scale and make them available for work, study and research purpose.

- Enhance the accuracy and increase the location of hydrologic and climatic measurements:

The different stations of measurements need to be diverse and effective in order to ensure a better spatial and temporal homogeneity of the precipitation. It would also be beneficial to increase the number of the stations, especially in the rural areas where they are just fewer.

3. CONCLUSION:

The major goal of this study was to reach is to undertake a flood modeling based on Geographical Information System ArcGIS and HEC-RAS. The database of the GIS maps provides people, related agencies and organizations with a better view of the real situation. It serves as a guide map for stakeholders working in the study areas to implement disaster risk reduction projects and programs. Furthermore, by distinguishing between areas that are safe and those that are vulnerable to natural disasters, it is easier to ensure the emergency plans for evacuation or preparedness properly.

Many different stakeholders use flood maps. The maps serve at least one of the three purposes of flood risk management:

- Prevent the build-up of new risks (planning and construction),
- Reduce existing risks, and
- Adapt to changing risks factors.

The following recommendations could help in minimizing the flooding risk in Fez agglomeration:

- Cleaning and emptying the drainage canal at the end of summer or the dry season at least.
- Increase the dams' reservoirs capacity and ensure their good maintenance to avoid their filling or invasion.
- Ensure a good management of solid wastes to avoid the filling or the eutrophication of the Oueds.
- Create natural water retention by the realization of green space surrounding the Oueds.

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