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FLOOD HAZARD MAP IN THE CITY OF BATNA (ALGERIA) BY HYDRAULIC MODELING APPROCH

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Abstract: In the light of the global climatic changes that appear to influence the frequency and the intensity of floods, and whose damages are still growing; understanding the hydrological processes, their spatiotemporal setting and their extreme shape, became a paramount concern to local communities in forecasting terms. The aim of this study is to map the floods hazard using a hydraulic modeling method. In fact, using the operating Geographic Information System (GIS), would allow us to perform a more detailed spatial analysis about the extent of the flooding risk, through the approval of the hydraulic modeling programs in different frequencies. Based on the results of this analysis, decision makers can implement a strategy of risk management related to rivers overflowing through the city of Batna.

Key words: Analysis, Flood, GIS, Hazard, Hydraulic modeling

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INTRODUCTION

Flooding is serious natural disaster which has many socioeconomic and environmental for all activities and infrastructure within an affected floodplain (Shokoufeh et al., 2008, p. 660). They appeared during the two last decades in the forefront of the natural disasters in the world. Floods represent 34% of the catastrophes recorded on a worldwide scale between 1990 and 2007 (CRED, 2007). In 2011, they were reported to be the third most common disaster, after earthquake and tsunami, with 5202 deaths and adducing millions of people (CRED, 2012). In Algeria, they are defined as a frequent natural phenomenon inducing considerable economic damages and human life losses, where the majority of floods are caused by the overflow of the major bed of rivers. The most recent and fatal are those of Bâb El-Oued (733 dead) in November 2001 (Algeria) with very heavy economic damages and that of Ghardaïa, 40 dead in October 2008, also with a significant

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property damages and important economic losses. The province of Batna is not an exception since it knew rainy episodes which generated significant floods of which the effects remained alive in spirits, because of the level of vulnerability of this province. Flood occurred when the water overflowing onto dry land. Accurate and current floodplain maps can be the most valuable tools for avoiding severe social and economic losses from floods (Faghih et al., 2015, p. 1). The flood modeling is one of the engineering tools which provide accurate information of the flood profile (Sunil, 2014, p. 81). The aim of this work is to cartography the flood hazard due to the overflow of the river crossing the province of Batna, this analysis based on modeling within the framework of a data base GIS in ARC GIS and its extensions and hydraulic software of modeling HEC-RAS.

STUDY AREA

The city of Batna situated at 435 km in the South-East of the Algiers capital, between 6°7' to 6°13' east longitude and 35°34' to 35°31 north latitude, is located between two mountain ranges with an altitude ranging between 900 and 1040 meters and most of the space (40%) has a slope vrying between 0 and 3%, favoring the time submersion. The urban space is crossed by several streams (watercourses) and channels that empty into Oued El Gourzi River (figure 1, table 1).

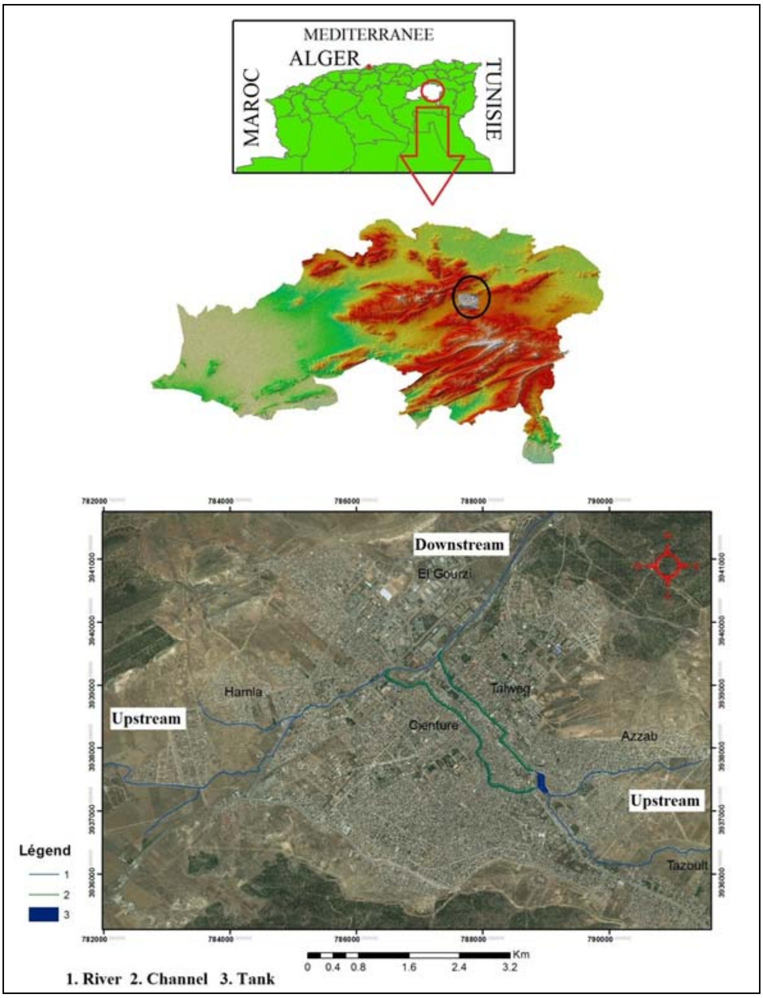

Figure 1. Study area
(Source: Guellouh Sami)

The climate is qualified as semi-arid characterized by irregular rainfall which torrential character explains the brutality of the flows and the risks which ensue from it in this city. Our study is based on the data of the annual maximum flow in m³/s for every river, from (NARH) the national agency for water resources.

Table 1. The maximum flow in m³/s

Sub basins	Return period	10-years	50-years	100-years	1000-years
Tazoult	Q max m³/s	39.4	184.96	211.85	309.06
Ben Tanoune (Azzab)		23.1	125.99	141.66	198.31
Hamla		20.39	86.67	98.87	143

MATERIALS AND METHODS

This study is based on hydraulic modeling by using the software HEC-RAS; it is numerical software for flow river hydraulics calculations (Darshan et al., 2014, p. 103-107).

It was developed by the Hydrologic Engineering Center, a research group for the U.S. Army Corp of Engineers (Robert et al., 2012, p. 1-15).

Hydrologic Engineering Centers River Analysis System HEC-RAS; it is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed. [1] We used the version 4.1.0. The hydraulic model HEC-RAS is based the one-dimensional Saint-Venant equation. The Saint Venant equation for one-dimensional river flow consists of the conservation equations for mass and momentum (Brunner, 2010).

Another principal tool was used is GIS through the software ARC GIS of ESRI institute (Environmental Systems Research Institute) with HEC-GEORAS extension for data preparation to export them towards HEC-RAS or to exploit the simulation results in GIS environment (Debiane et al., 2010, p. 162).

HEC-GEORAS is another program, developed by the USACE, for an ARC GIS environment which can be used to transfer data from ARC GIS to HEC-RAS for modeling simulations. Once the hydraulic modeling is complete, the output from HEC-RAS, in the form of georeferenced cross-sections with flood water elevations, can be imported into ARC GIS using HEC-GEORAS for floodplain delineation (Sagar, 2013, p. 68-79).

HEC-GeoRAS is a set of tools specifically designed to process geospatial data to support hydraulic model development and analysis of water surface profile results (HEC, 2005). The basic data requirements for simulation are included: geometric data, river system schematic, cross section geometry, reach lengths, Manning’s roughness coefficient, contraction and expansion coefficients, steady flow data, boundary condition, flow regime (Harman et al., 2008, p. 13-25).

The identification of river geometry is also necessary, in particular, the central flow, the minor bed, the major bed and transversely profiles (cross sections), which are represented by means of points representing the coordinates X-Y, where X is the distance compared to an arbitrary point of reference placed on bank and Y is the rise in the river bed (HEC-RAS support 2008).

Providing TIN model (Triangular Irregular Network) from a DEM (Digital Elevation Model). Cross sectional lines are created to extract the elevation data from the TIN (terrain data Cross sectional lines are the key inputs to the HEC-RAS simulations as the intersection of these lines with river centerline and flow paths carry crucial information such as location of bank stations, downstream reach lengths and manning values (land use codes) (Sudha Yerramilli, 2012, p. 7-16).

HEC-RAS simulations require each cross-sectional line to carry a manning ‘n’ value (land use type) in the geometric file (Sudha Yerramill, 2012, p. 7-16). A land use map, in the form Manning coefficient, forms to know the nature and type of soil.

[1] *http://www.hec.usace.army.mil/software/hec-ras/hecras-features.html*

Tabe 2. Manning ‘n’ value estimated.
(Data source: Manning)

Nature of soil	Manning ‘n’ value
Concreted	0.015
Naturel smooth	0.020
Naturel	0.030
naturel with vegetation	0.050

The developments on the river such as the bridges are modeled, but not presented on the map to avoid over filling it. The rivers sections, channels sections and the land use map are produced from obtained data in situ using GPS for the accessible zones and exploitation of data coming from a satellite image and topographic map for some inaccessible zones. HEC-RAS assures the hydraulic simulation so as to integrate flow data, and the boundary conditions.

The steady one-dimensional flow model can calculate subcritical, supercritical and mixed flow regime water surface profiles (Karney et al., 2010, p. 175-180). In a subcritical flow regime, boundary conditions are only required at the downstream ends of the river system. If a supercritical flow regime is going to be calculated, boundary conditions are only necessary at the upstream ends of the river system ((Karney et al., 2010; Sunil et al., 2014, p. 950-956). When flow regime is mixed, both downstream and upstream boundary conditions are required (Karim, 2009; Patrick, 2013, p. 950-956). There are three kinds of boundary conditions (critical depth, normal flow depth, or a given depth downstream of the channel), but only one is needed (Alemseged, 2005, p. 1-6).

Integration of technologies - HEC-RAS (Hydrologic Engineering Centers River Analysis System) and GIS (Geographic Information System) to obtain scientifically derived information has been specified as efficient in simulating, identifying and analyzing flood events in a geo-spatial environment (Sam et al., 2002, p. 8-12).

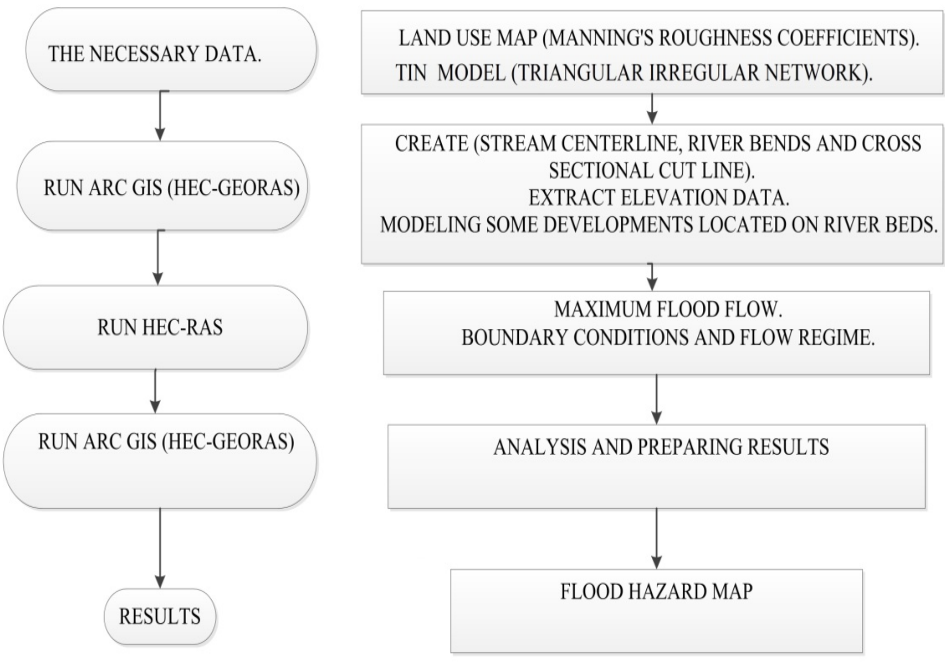

Figure 2. The hydraulic modeling steps
(Source: Guellouh Sami)

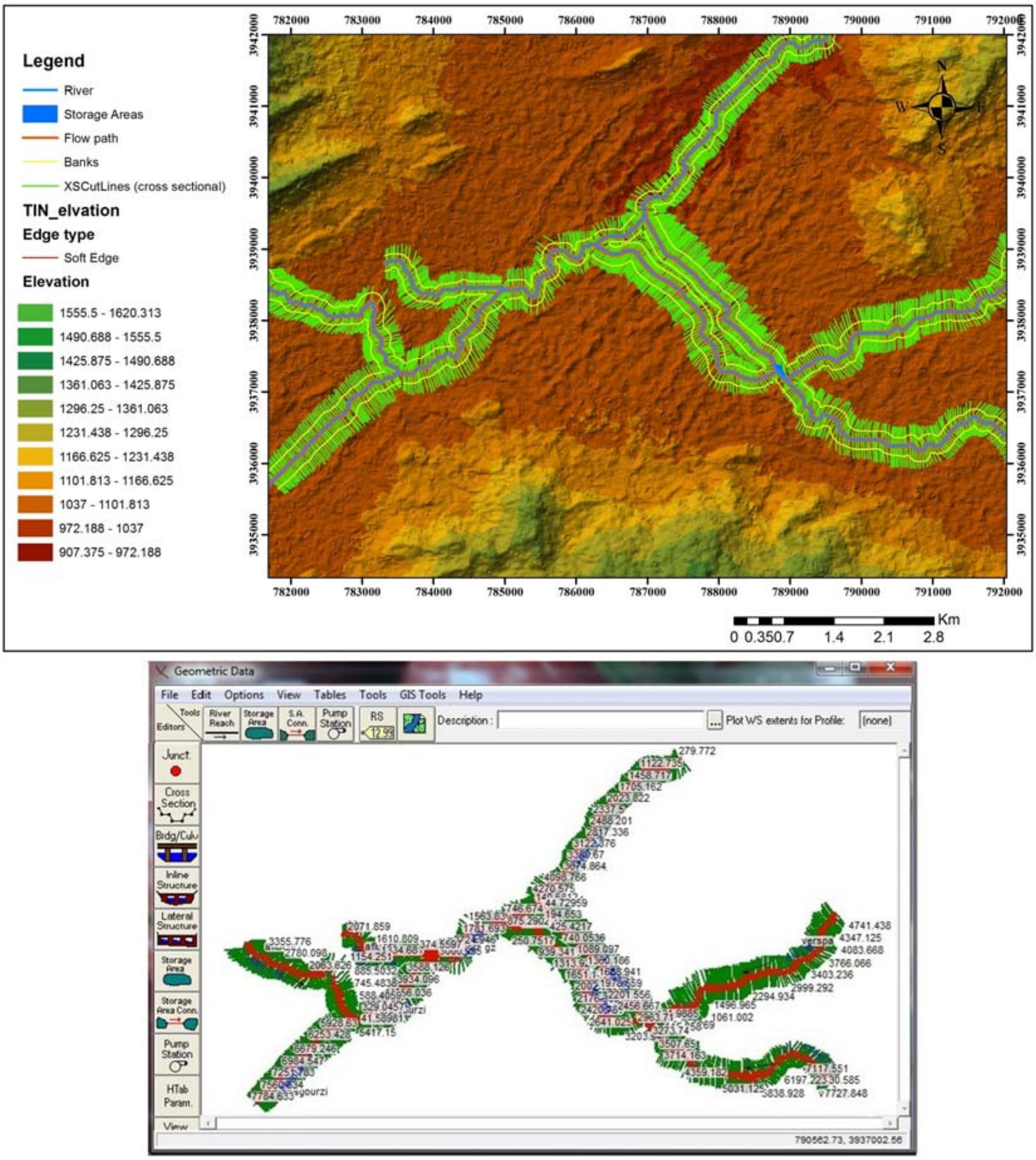

Figure 3. The modeling procedure
(Source: Guellouh Sami)

RESULTS AND DISCUSSIONS

Analysis and simulation show that the floods hazard areas expanded according to the recurrence of this phenomenon, to came between ten-year and 1000-year, touching a surface of 6.5038 km² and a water height 13, 2 m (figure 3 and table 2).

The map allows us to make a comparison between the hydraulic model results and the topography in situ, so facilitating an optimal visualization of floods areas contours and the involved socioeconomic stakes (Bachir et al., 2012, p. 25-31). Therefore, this model can intervene to implement effective to face actions fluvial dynamics processes. The hazard map described major floods (Mate, 2002).

In absence of historical extremes flow data, we adopted the 1000-year flood extent to develop the hazard map, where we found that several zones may be affected, particular areas A, B and C (figure 4), which we should give to a particular attention in the light of their strategic character and vulnerability.

Table 3. Simulation results by several scenarios
(Data source: hec-ras)

Simulation	water height (mettre)	Surface (km²)
10- years	6.7	1.8904
50- years	8.2	3.1535
100- years	10.2	4.4803
1000- years	13.2	6.5038

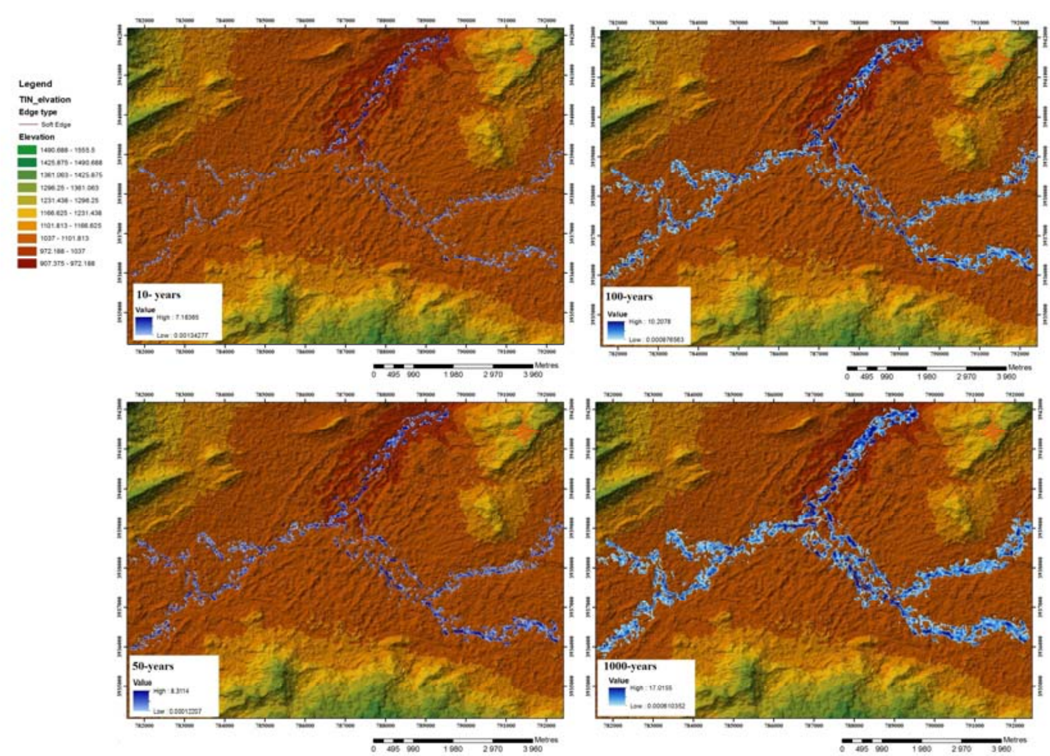

Figure 3. Simulation results
(Source: Hec-GEORAS)

The use of hydraulics models as decision support has become essential to better describe and knowledge the flow characteristics, particularly the water surface profiles (Seago et al., 2008, p. 57-66). On one hand, this technique showed a superior effectiveness in the diagnosis of flooding risk (overflowing streams).

On the other hand, a precise knowledge of socio economic information will contribute to apprehend this risk with more efficiency. Data availability has a very important role in the choice and the efficiency of the methodological approach used.

Based on the results of this study, the responsible of this city can have a pertinent data, which is necessary to now the level of risk assessment.

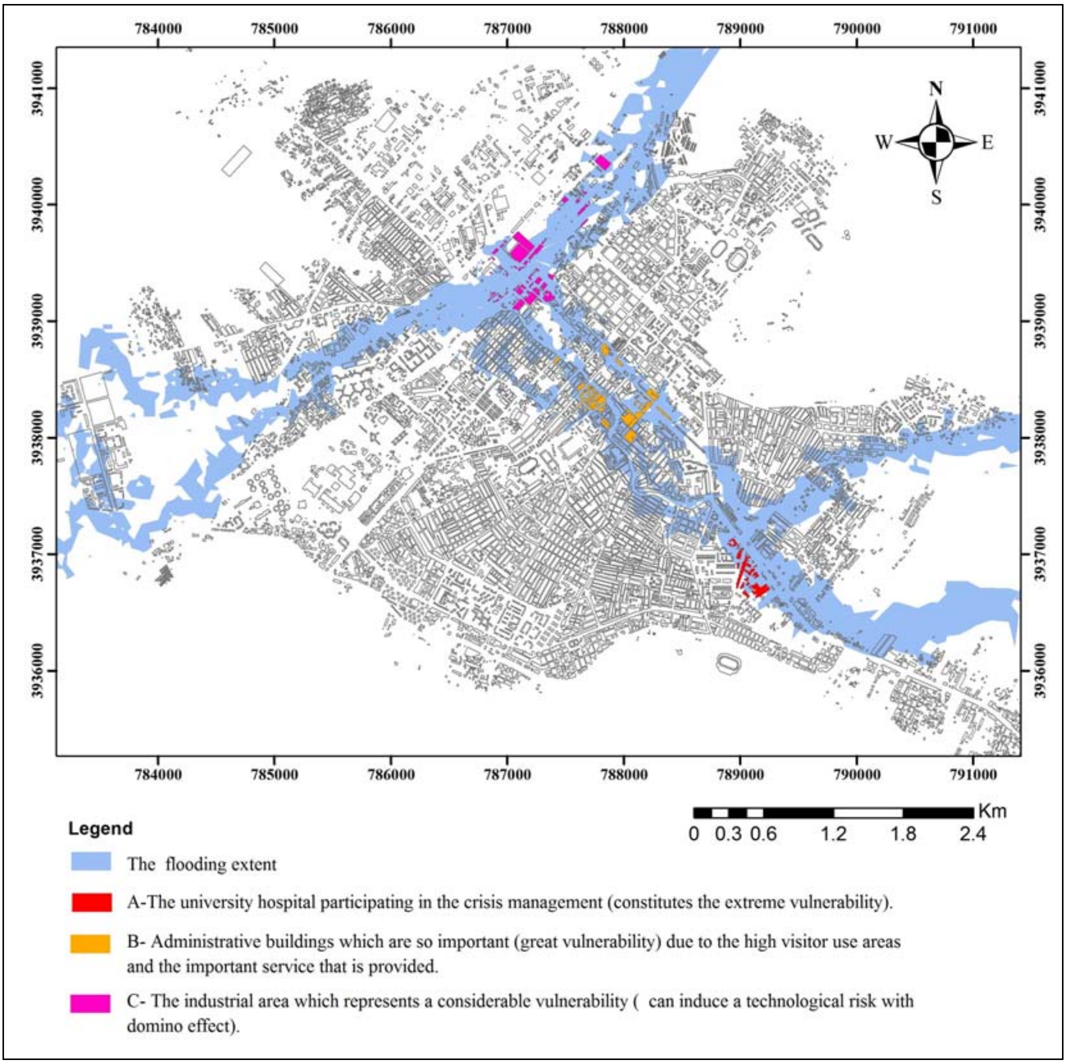

Figure 5. Flood hazard map
(Source: Guellouh Sami)

CONCLUSION

Developing scenario of flood hazard in the city of Batna can represent a decision support document in terms of protecting and crisis management. The use of Geographic Information System (GIS) and modeling software (simulation) which are pertinent tools in spatialization of floods, led us to deal with the fluvial dynamics and the damage that can ensue from it. A profound knowledge of flooding Processes facilitates the creation and development of prevention plans.

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