Revista Română de Inginerie Civilă, Volumul 11 (2020), Numărul 2

Flood risk mapping based on hydraulic model 2D and GIS, Case study in Draa Ben Khada, Tizi ouzou, Algeria

Abdelghani Leghouchi[1], Mohammad Djemai[2], Oussama Derdous[3], Jamila Tarhouni[4]

[1 2] Laboratory Geomaterial, Environment and Installation (L.G.E.A), University Mouloud Mammeri Tizi Ouzou Algeria,
ghanileghouchi@hotmail.fr ; mohdjemai54@gmail.com
[3] Department of Civil and Hydraulic Engineering, University Kasdi Merbah Ouargla Algeria.
oussamaderdous@hotmail.fr
[4] Laboratory Sciences and Technology of Water, National Institute of Agronomy Tunisia (I.N.A.T), Tunis, Tunisia
elmaainat@yahoo.fr

DOI:10.37789/rjce.2020.11.2.9

Abstract. *Floods caused by rivers are one of the serious, common and natural disasters that many countries are facing. It has caused an immense damage, and a huge proportion of such destruction is associated with the lack of knowledge, resources and coping mechanisms. Therefore, studies and researches on the nature of the rivers are inevitable. Computer models are an effective tool for studying and simulating river behavior with the least possible cost, and one of the measures for the risk reduction is the delineation of flood-prone areas. Flood risk mapping involves modeling the complex interaction of the river flow hydraulics with topographical and land use features of the floodplains. An integrated approach to river flood modeling is the use of GIS and hydraulic models.*

This paper presents the use of flood frequency analysis integrating with 2D Hydraulic model (HECRAS) and Geographic Information System (GIS) to prepare flood maps of different return periods: 10 years, 20 years, 50 years, and 100 years in Wadi Bougdoura; Wadi SEBAOU and Wadi Sbet at DraaBenKahada City in TiziOuzou.

The resulting hydraulic model provides a good representation of the general landscape and it contains additional details, the results indicate that GIS is an effective environment for mapping and analyzing floodplains, they clearly show that this new approach, based on 2D simulation results, allows the stakeholders to have a better appreciation of the consequences of a flood, a design of making a land use and infrastructure development decisions, and emergency measures.

Keywords: *Draa Ben Khada; Flood risk mapping; HEC-RAS 2D; GIS*

1. Introduction

There is a growing global concern about solutions to reduce many human and financial losses caused by floods (Shahiri, A.et al 2016), the complex behavior and detrimental consequences that are shown by natural hydraulic phenomena have led to considerable investments in the development of hydraulic models that are capable of predicting water flow in a large variety of situations(González B, R., 2017).In this context, researchers have been working to reduce this risk since few decades ago, where riverine flooding has received a considerable attention from researchers (Garg, P. K. 2015).Researchers considered the hydraulic modeling and the identification of floodplain prone zoning maps can be one of the key solutions in flood mitigation and important to nonstructural measures in planning and optimizing utilization (Linh, N. T. M., et al 2018; Shahiri, A.et al 2016). Also, they are certainly one of the most basic and important information needed in civil engineering projects and they should be taken into consideration before any investment or operational development in the projects of the areas around the river.

In the aforementioned mapping efforts, accurate identification and delineation of flood inundation requires hydraulic numerical modeling of the river system, where they would be considered one of the efficient tools in order to study and simulate the behavior of rivers. (Javadnejad, F. 2013).Developing flood inundation maps using hydraulic simulators and GIS are the least costly procedure in terms of data collection, design, computation, and professional costs. The use of GIS in conjunction with hydraulic modeling is relatively recent and widely implemented. Until the last few years, GIS applications to floodplain mapping and terrain modeling have been relatively limited. With the rapid advances in GIS in the 1980s, GIS began to be used to represent the flow of water on the land surface (Tate, E. C., et al 1999). Digital elevation models (DEM) grids of regularly spaced elevation data are commonly used in hydraulic analysis to represent flow paths of water over the land.

There are many existing tools available for computational hydraulic modeling, and they are very dependent on the type of hydraulic analysis performed. It is safe to say that at least there exists a program for each possible scenario related with water. There are three different ways to represent water flow in the case of flooding in a river. (González B, R., 2017).The water flow in such situations can be represented as a one-dimensional (1D) flow, a two-dimensional (2D) flow. Moreover, some of the existing software offer the possibility to combine a 1D flow model with a 2D flow model, commonly referred to in literature as quasi-2D and 1D models, to be mentioned: one dimensional (MIKE1, HEC-RAS, Iber,) and two dimensional (MIKE21, HEC-RAS 5.0, Telemac 2D, HEC-RAS, FLO-2D, TUFLOW's 2D, QUAL2K).(Penton, D. J., et al 2007). Hydraulic models require river cross-sections, accurate high-resolution digital elevation models (DEM) and extensive calibration. River hydraulic models such as HEC-RAS contain a wealth of detailed terrain data, typically developed from land surveys. (Tate, E. C., et al 2002)

River flood routing (flood propagation in rivers) can be described by one dimensional (1D) mathematical model. This solution is suitable for the modeling of inundation of open floodplains as well but in case of sophisticated morphological conditions application of quasi 2D or 2D models might be necessary. (Anonymus, A. 2007). Performance of traditional 1D model is questionable in very flat floodplains. Thus, many 1D hydraulic models are being replaced by 2D hydraulic models (Merwade et al. 2008). The latest version, HEC-RAS 5.0.5 offers the stand-alone capability to perform 2D hydraulic routing and capabilities of a detailed animation and mapping of flood within the RAS mapper in HEC-RAS itself. (Bhandari, M., et al 2017).This ability allows hydraulic engineers to analyze model results through the geospatial visualization to more readily identify the hydraulic model deficiencies and making model's improvements (Engineers 2002).

In many studies, HEC-RAS, two-dimensional (2D) software, which is used to simulate floodplain, dam break, etc. (Marko, K., et al 2019) developed a direct processing approach to flood inundation modeling in urban areas of Jeddah City, Saudi Arabia. The floodplain mapping was done by integrating geographic information system (GIS) with HEC-RAS 2D and WMS. A numerical modeling was carried out using HEC-RAS 2d version 5.03 on the vast plains of Llanos de Moxos in the Bolivian Amazon. The objective of this simulation was to compare the results of the numerical model with the satellite images of the flood event. (Quiroga, V. M., etal 2016). (Khattak .et al 2016) have carried out floodplain mapping study for part of Kabul river in Pakistan using HECRAS hydraulic model. They conducted conventional return period study of flood using log-normal, Log-Pearson type-III and Gumbel's methods to calculate the extreme flows in river for different return periods. The results obtained were exported to ArcGIS software and floodplain maps were prepared for different return periods and from the floodplain maps areas vulnerable for flood hazard were identified and they also identified that 400% of the area is likely to inundate in comparison to normal flow of river. (Kumar, S., et al 2017).(Derdous et al 2015) developed an approach for the prediction of the dam break flood hazard in Skikda, Algeria using HEC-RAS numerical model in combination with GIS tool. (Timbadiya et al. 2012) developed an integrated hydrodynamic model of the lower Tapi River, India. Firstly, the one-dimensional model, hydrodynamic model was calibrated for Manning's roughness of the river channel and subsequently one-dimensional and two-dimensional integrated 11 hydrodynamic model was used to ascertain the sensitivity of Manning's 'n' on coastal flood plain depth of the lower Tapi river.(Mehta et al., 2012) presented a preliminary design for the physical enhancement of the reach of the Tapi River located near the confluence of Arabian Sea and the Tapi River in Surat City, Gujarat.

In this context, the present study aims at straightforward approach for processing output of the HEC-RAS 2D hydraulic model, for the enhanced mapping of the floodplain in the region by using the historical flow data of the middle valley of watershed of Sebaou (Wadi Bougdoura; Wadi Sbaou; Wadi Sbet). Also, an analysis in the GIS, in order to predict the flood depth and wave propagation of flood in the Draa

Ben Khada city floodplain located in Algeria, due to its proximity to numerous school buildings, homes,vast agricultural areas, and businesses, the modeling of floodplain and analysis in the GIS has a great interest to city. After the model calibration and validation, flood mapping of the Draa Ben Khada city was accomplished in GIS environment by exporting the results from HEC-RAS using the RAS Mapper tools, an additional map layers from google earth imagery were added in the GIS for an enhanced visualization. This will help the decisionmakers, especially the involved government's department, and developers to make a proper plan for future development.

2. Materials and Method

2.1 Study area

This study focuses on the middle valley of watershed of Sebaou as it passes through Draa Ben Khada and its surroundings, as well as on a small tributary (wadi Sebt ;wadi Bougdoura) that pours its waters into the Sebaou river .The town of Draa Ben Khedda, in Tizi Ouzou state, Algeria (Figure. 1), is located between 3 rivers and it is crossed by Wadi Bougdoura, it is limited from the East by Wadi Sebt and from the north by the Wadi Sebaou which is the largest Wadi in the state of Tizi-Ouzou and which receives all the flows of the territory of the municipality; which increases the risk of flooding, This is due to the topographic nature of the area which is characterized by a decline in populated areas (Figure. 1). In particular, the area of study covers a floodplain area of approximately 8.75 Km2 which comprises vast agricultural areas and the urban areas with significant population density. Although, the most susceptible parts to flooding are the floodplains on the sides of the Draa Ben Khada in the Wadi Bougdoura mouth, also the fundamental to check flooding in Wadi Sebaou due to the potential losses. In this city the subsequent expansion along the alluvial plains of the Wadi Sebaou, which has been done without detailed flood studies, makes it a good case for the study of floods.

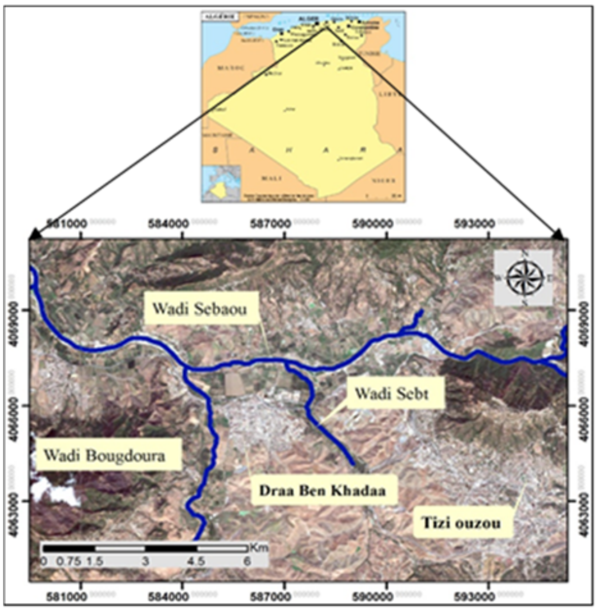


Figure 1: Study area: the town of Draa Ben Khadaa, in Tizi Ouzou, Algeria. source: own elaboration

Wadi Sebaou: it is the most important wadi that crosses the city, it is located at the North end of Draa Ben Khada city. This wadi is distinctly more sinuous with a width of 200 m, its path is relatively straight and its slope is 2 to 3% on average. The on-site visit identified several black spots that characterize this wadi, including the very small and insufficient section at the intersection with other wadis. At this level, the overflow of water is of concern to the local population, especially during heavy rains.

Wadi Bougdoura: This wadi is located at the west end of Draa Ben Khada city and presents a broad, relatively straight bed. It crosses a few dwellings located upstream but presents relatively greater danger than Wadi Sebaou.

Wadi Sebt: This wadi presents less danger for the city during heavy rains because it is located to the far east of the city. The houses reside at high elevations and are not exposed to floods.

2.2 Method

The development of the flood map is based on a two-dimensional (2D) flood modelling method applied across Draa Ben Khada to all three wadis. This method of flood modelling has the capability to estimate flood depths, extents and in turn a hazard score to estimate impacts on people, properties. This scenario has been simulated through model presented in figure 2;

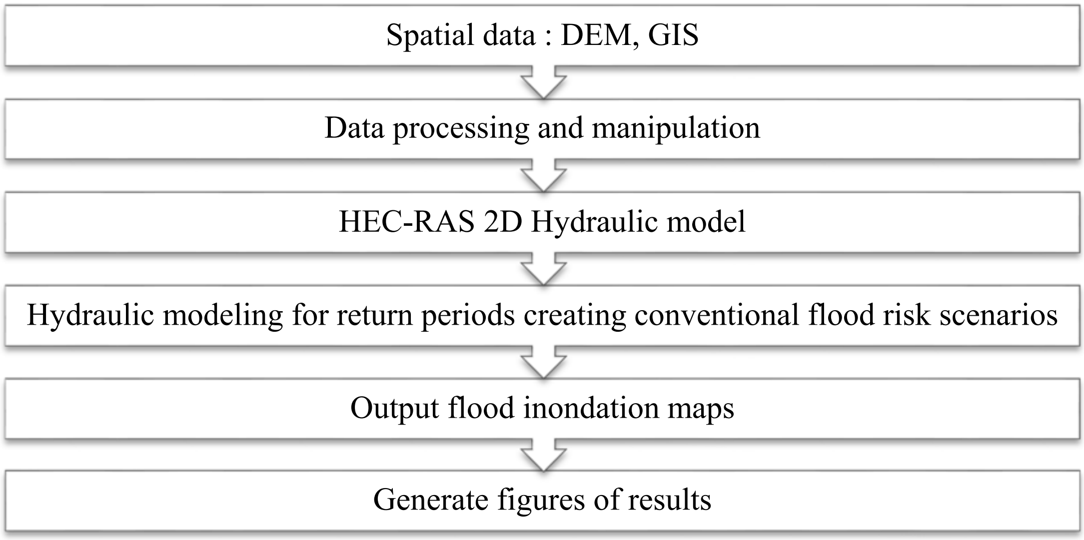


Figure 2. Developing a flood model using HEC-RAS and GIS

2.2.1 Topography, and DEM

In order to build a robust 2D model for the floodplain, detailed topographical data for the floodplain is essential. We chose HEC-RAS 2D as a modeling tool to undertake hydraulic simulations and in addition we used ArcGIS, more specifically ArcMap for the setting up of the geometry and the creation of all layers and sub-layers necessary before exporting the edited map on HEC-RAS for the hydraulic computation. To enable accuracy of inundation modeling two-dimensional HEC-RAS requires to secure the identification and accurate digital maps and digital elevation models (DEM) are required. The data used in this study include digital elevation model (DEM). Topography of the study area at a scale of 1/5000 was obtained from the National Institute of Cartography and Remote Sensing Agency of Constantine - Algeria. This DEM has a spatial resolution of around 30 m (SRTM-1s) and a vertical accuracy of ~10 m. It is available in the format of raster data, and it is used as main source of topographic data. In order to implement a two-dimensional simulation, HEC-RAS requires a terrain model for the study area so that the program can determine different heights of the analyzed surface. Once the terrain model is in raster format and has the resolution desired to work with, it is necessary to import from ArcGis into HEC-RAS, in this case the imported raster had tif extension. When importing the terrain model, HEC-RAS 2D requests a spatial reference system so that it is able to show the terrain accordingly. In this case, the same used for the pre-processing in Arc Gis will be selected the WGS84 UTM-Zone 31-N. Once the terrain map is successfully created in HEC-RAS, it is possible to visualize it in the RAS-Mapper. Figure 3 shows how RAS Mapper represents the terrain model used in this project.

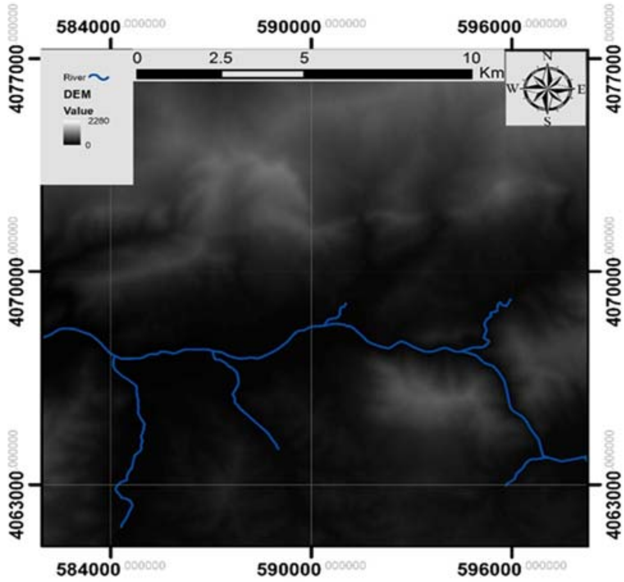


Figure 3. DEM generated from SRTM-1simages

2.2.2 HEC-RAS model

2D modeling features in HEC-RAS allow a user to create computational mesh. In the Geometric Data Editor, the modeler can define the limits of the computational mesh that envelopes the channel itself plus any adjacent floodplain areas. The pre-process calculates a detailed relationship between Elevation-Volume for each cell, and for each cell face computes the following relationships: Elevation-Wetted Perimeter, Elevation-Area, Elevation-Roughness and more hydraulic parameters. These detailed hydraulic property tables created by HEC-RAS allow the users to create bigger computational cells while preserving the terrain details. The valley at risk was modeled via a Structured Computational Mesh which was composed of 407013 cells with a grid size of 25x25 m with the computational time interval of 20 min with the output interval of 1 day. It is a process that was modified during calibration with two Structure computational mesh with a grid size of 50x50 m and 75x75m. A grid size of 25x25 m cell used in the computational mesh complies with two fundamental requirements. Firstly, the cells adapt to the terrain model as precisely as possible. Secondly, the cell size that allows it to interpret the water surfaces slope and it changes adequately. Small time interval and small cell size selection is better for getting good result though the simulation takes more time to complete. (Figure 4) shows the geometric data with computed cell meshing.

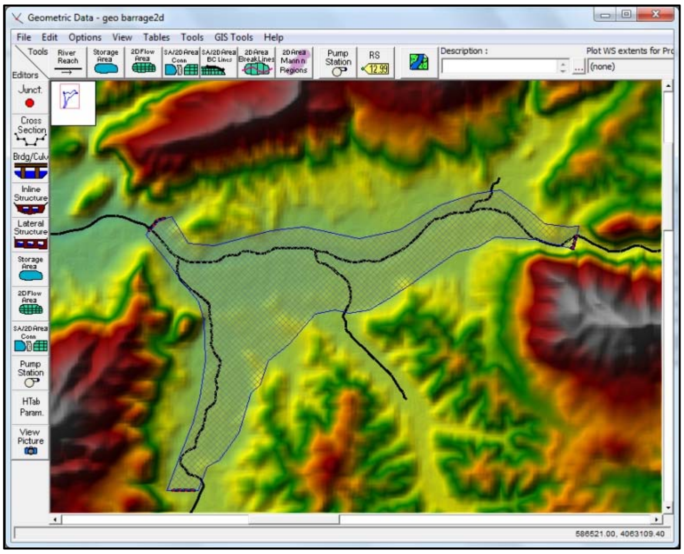


Figure 4. Geometric data with computed cell meshing. Source: own elaboration

HEC-RAS uses the Manning coefficient to measure flow resistance, and it has either the option of applying the continuous manning coefficient for the full-dimensional flow zone or dividing the region into different regions, each with its own n-manning value. For this simulations, one Manning's n value was assigned to the river and the floodplain respectively and set to 0.04. Because the study area is small there is not a broad variety in land cover classification, resulting in one Manning’s n values. The selected reference value for the representation of the channel and banks was obtained from a comparison between the characteristics of studied vascular valleys and tables published by (USACE 2016).This approach brings a more realistic simulation since the distribution of land usage is recognized.

2.2.3 Boundary conditions

The model requires boundary conditions, which will be based on discharge hydrograph and slope of the river and can be calculated by averaging the bed slope over the whole stream length. General Hydrograph from the central Sebaou basin are available by means of the carried out by the (National Agency of Hydraulic Resources -Algeria). For the unsteady flow simulation, daily discharge data for the periods of 28 March 1974 - 31 March 1974 was used. Over the period, maximum river flow occurred on 30 March 1974 with discharge value of 2888 m3/s. Consequently, it has been assumed that the alleged hydrograph corresponding to the point where the upstream boundary condition is set follow the hydrographs made by the (NAHR). The flood is supposed to occur under the solicitation of the return period flood event.

2.2.4 Two-dimensional unsteady flow hydrodynamics

The flow in unsteady flow conditions is governed by the conservation of mass and momentum. These conservations can be described by a set of two-dimensional equations commonly known as the Shallow Water Equations (SWE) or SaintVenant equations, which are the equations used in HEC-RAS. These are derived from the three-dimensional Navier-Stokes motion fluid equations by making a certain number of assumptions that are only applicable in case of open channel flow and flood modeling. The following derivations have been extracted from the HEC-RAS Hydraulic Reference Manual (USACE 2016).

Mass conservation:

$$\frac{\partial h}{\partial t}+\frac{\partial (hu)}{\partial x}+\frac{\partial (hv)}{\partial y}+q=0 \quad (1)$$

Momentum conservation:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-g\frac{\partial H}{\partial x}+\upsilon_t\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial^2 y}\right)-c_f u+f_v \quad (2)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-g\frac{\partial H}{\partial x}+\upsilon_t\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial^2 y}\right)-c_f v+f_u \quad (3)$$

Where: *h* = depth of water, *(m)*; u . v = are the averaged velocities in the x- and y-direction, *(m·s–1)*; *g* = gravity acceleration, (m·s–2); υ_t= velocity diffusion coefficient, m2·s–1; *H* = free surface elevation, *(m)*; t = time, s; *x, y* = direction respectively *(m)*; *q* = source or sink of fluid, *(m·s–1);* c_f =the bottom friction coefficient; f = the Coriolis parameter.

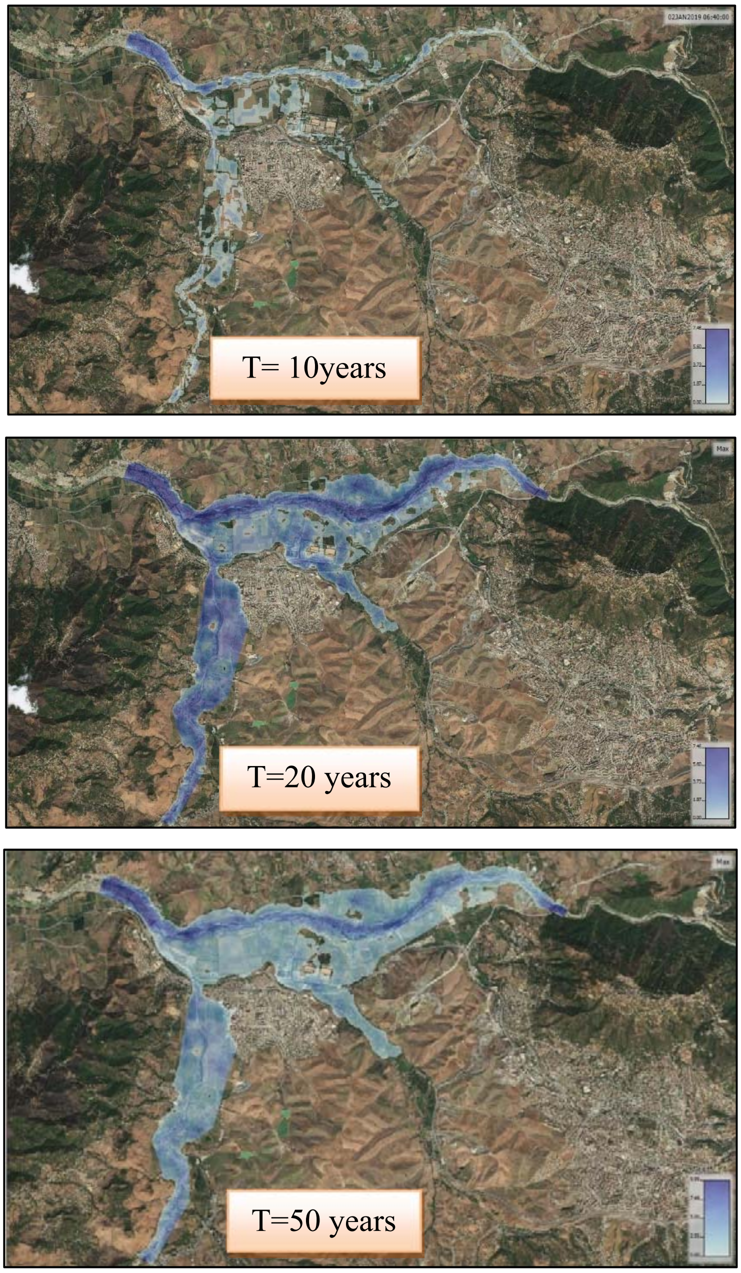
The solution of Saint Venant 2D model is given by an implicit finite volume algorithm, which allows longer time steps than explicit methods. The finite volume method gives the model an increase in the stability and robustness when compared to traditional finite difference methods. Additionally, the algorithm is able to solve subcritical, supercritical and mixed regimes (USACE, 2016).

3. Result and discussion

The risk map is projected on Google Earth imagery as shown in (Figure 5) to have a better view and understanding the nature of flood water. The flood risk map determined areas at risk of flooding in different parts of the study area, showing areas with risk. The most vulnerable neighborhoods are located on the trail of different wadis, according to the risk map of the study area, as shown in (Figure. 5).

The results obtained from the use of the two-dimensional unsteady flow analysis using the HEC RAS model shows that, to a great extent, the area lying on the right bank of the Wadi Bougdoura was found to be more vulnerable to get inundated than the left bank. Along the river valley, the most important city is Draa Ben Khada, a town of 30 889 people. The areas covered by the flows are mostly agriculture areas as there are few buildings covered by the water. Floods can threaten human life, in Draa

Ben Khada City around 40 families were identified at risk, from which 12 resulted at high risk and 28 at medium risk. The city of Draa Ben Khada can suffer losses both economically, damaging the environment and loss of life. HEC-RAS provided us with some insights of how the Wadi Bougdoura and wadi Sebaou might affect the urban developments in an event of the magnitude of outflow.Analysis of 100 years returns period flood plain map indicated that 6.88 km2 with the percentage of 20.50% is likely to be inundated. The predicted flood depth ranges vary from greater than 0 to 14 m in the flood plains and on the river. The range between 3 to 5 m were identified in the urban area of DBK, Marabou, the corresponding return flows that we estimated were inserted.



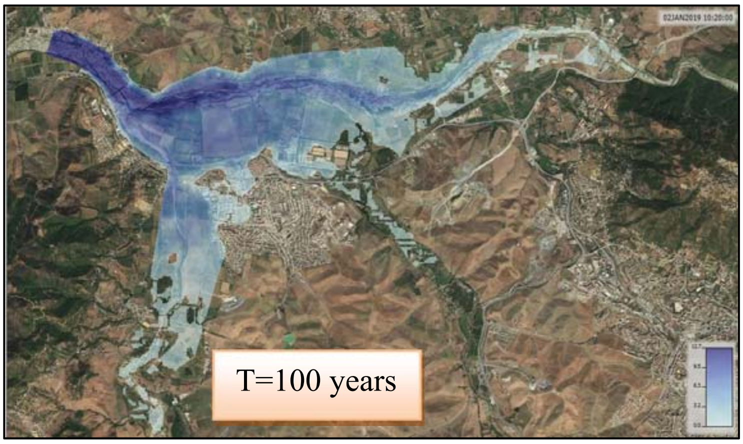


Figure 5. Floodplains obtained for events with return periods (T10; T25; T50; and T100 years) flow rate on the project area.source: own elaboration

The main flooded areas correspond in all cases with agricultural areas, mainly intended for irrigated crops. The areas that support buildings are also quite affected, with up to 100 Ha of urban land being impacted in an event of greater magnitude. Green areas, areas with riparian vegetation, and grasslands are also affected, while the rest of the land use types are only slightly affected. The generated river flood extent maps, rivers flood water depth distribution for Wadi Bougdoura, Wadi Sebaou and Wadi Aissi, are represented in Figure 5 for 10; 20; 50 and 100years return periods. The maps results provide the information of risk levels that can be used for solving flood problems alternatively. The urban zones do not pose a serious hazard, as the existing channel capacity can accommodate the simulated flood depths. Zones expand as the return period increases from 10 to 100 years due to the increase in the flood water depths in relation to the channel capacity. This result presented the locations of high, low and medium risks visually. The priority action plan is also evident for the decision.

4. Conclusion

The purpose of this study was to map the floodplains of the wadi Sebaou; wadi Bougdoura and wadi Sebt using Hec Ras 2D and GIS. From the analysis, it has been found that there are many land parcels in Draa Ben Khada city, there are many homes and a lot of infrastructure that could be exposed to floods because they are located in the floodplain of in these rivers. For this reason, the employed methodology provides the basis and criteria so that authorities and governments can regulate land use and limit human activity in the floodplains through proper territorial planning. Also, the existence of this risk cartography will allow a better management of those floodplain areas that are not affected by the risk of flooding. Due to HEC RAS and Arc Gis integration in the model, the resulting hydraulic model provides a good representation of the general landscape and it contains additional details, the results indicate that GIS is an effective environment for mapping and analyzing floodplains, very creative information could be generated regarding the flood episodes, in order to achieve a greater impact on the receiver, as well as very concrete and real recreations. Moreover, the quantification of expected damages or losses for future flood events in different scenarios will be possible, Thus, these zones need immediate attention during flooding situations and should be assigned high priority. The flood risk map developed can be used to develop early warning system and public awareness in this zone.

References

Abdulrazzak, M., Elfeki, A., Kamis, A., Kassab, M., Alamri, N., Chaabani, A., & Noor, K. (2019). Flash flood risk assessment in urban arid environment: case study of Taibah and Islamic universities' campuses, Medina, Kingdom of Saudi Arabia. Geomatics, Natural Hazards and Risk, 10(1), 780-796. https://doi.org/10.1080/19475705.2018.1545705

Anonymus, A. (2007). Handbook on good practices for flood mapping in Europe. Excimap (European exchange circle on flood mapping).

Bhandari, M., Nyaupane, N., Mote, S. R., Kalra, A., & Ahmad, S. (2017). 2D Unsteady Flow Routing and Flood Inundation Mapping for Lower Region of Brazos River Watershed. In *World Environmental and Water Resources Congress 2017* (pp. 292-303).

Criado, M., Martínez-Graña, A., San Román, J., & Santos-Francés, F. (2019). Flood risk evaluation in urban spaces: the study case of Tormes River (Salamanca, Spain). International journal of environmental research and public health, 16(1), 5.

Derdous O., Djemili L., Bouchehed H., Tachi S.E. A (2015b) GIS based approach for the prediction of the dam break flood hazard – A case study of Zardezas reservoir "Skikda, Algeria". Journal of Water and Land Development.No.27,p.15.20. https://doi.org/10.1515/jwld-2015-0020

Engineers, U.A.C.O. (2002) HEC RAS River Analysis System. Hydraulic Reference Manual. FEMA (2016) Federal Emergency Management Agency.

Garg, P. K. (2015). The role of satellite derived data for flood inundation mapping using GIs. The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 40(3), 235.

González blanch, Ricard. Effect of the sub-grid geometry on two-dimensional river flow models. 2017. Thèse de baccalauréat. Universitat Politècnica de Catalunya.

Javadnejad, F. (2013). Flood inundation mapping using HEC-RAS and GIS for Shelby County, Tennessee (Doctoral dissertation, University of Memphis).

Khattak, M. S., Anwar, F., Saeed, T. U., Sharif, M., Sheraz, K., & Ahmed, A. (2016). Floodplain mapping using HEC-RAS and ArcGIS: a case study of Kabul River. Arabian Journal for Science and Engineering, 41(4), 1375-1390.

Kumar, S., Jaswal, A., Pandey, A., & Sharma, N. (2017). Literature Review of Dam Break Studies and Inundation Mapping Using Hydraulic Models and GIS. International Research Journal of Engineering and Technology. P-ISSN, 2395-0072.

Linh, N. T. M., Tri, D. Q., Thai, T. H., & Don, N. C.(2018) Application of a two-dimensional model for flooding and floodplain simulation: Case study in Tra Khuc-Song Ve river in Viet Nam.

Marko, K., Elfeki, A., Alamri, N., & Chaabani, A. (2019). Two-Dimensional Flood Inundation Modelling in Urban Areas Using WMS, HEC-RAS and GIS (Case Study in Jeddah City, Saudi Arabia). In Advances in Remote Sensing and Geo Informatics Applications (pp. 265-267). Springer, Cham.https://doi:10.3390/ijerph16010005

Mehta, d., yadav, d., & waikhom, m. S. I. (2013). Hec-ras flow analysis in the river tapi. *Journal of global analysis*, *2*(4), 90-93.

Merwade, V., Olivera, F., Arabi, M., & Edleman, S. (2008). Uncertainty in flood inundation mapping: current issues and future directions. Journal of Hydrologic Engineering, 13(7), 608-620.

Naiji, Z., Mostafa, O., Amarjouf, N., & Rezqi, H. (2019). Application of two-dimensional hydraulic modelling in flood risk mapping. A case of the urban area of Zaio, Morocco. Geocarto International, 1-17. https://doi.org/10.1080/10106049.2019.1597389

Penton, D. J., & Overton, I. C. (2007, December). Spatial modelling of floodplain inundation combining satellite imagery and elevation models. In MODSIM 2007 International Congress on Modelling and Simulation, Modelling and Simulation Society of Australia and New Zealand CSIRO, Clayton south, Vic, Australia.

Quiroga, V. M., Kure, S., Udo, K., & Mano, A. (2016). Application of 2D numerical simulation for the analysis of the February 2014 Bolivian Amazonia flood: Application of the new HEC-RAS version 5.RIBAGUA-Revista Ibero americana del Agua, 3(1), 25-3 https://doi.org/10.1016/j.riba.2015.12.001

Rangari, V. A., Sridhar, V., Umamahesh, N. V., & Patel, A. K. (2019). Floodplain Mapping and Management of Urban Catchment Using HEC-RAS: A Case Study of Hyderabad City. Journal of The Institution of Engineers (India): Series A, 100(1), 49-63. https://doi.org/10.1007/s40030-018-0345-0

ShahiriParsa, A., Noori, M., Heydari, M., & Rashidi, M. (2016). Floodplain zoning simulation by using HEC-RAS and CCHE2D models in the Sungai Maka River. Air, Soil and Water Research, 9, ASWR-S36089.

Tate, E. C., Maidment, D. R., Olivera, F., & Anderson, D. J. (2002). Creating a terrain model for floodplain mapping. Journal of Hydrologic Engineering, 7(2), 100-108.

Tate, E. C., & Maidment, D. R. (1999). Floodplain mapping using HEC-RAS and ArcView GIS. Center for Research in Water Resources, University of Texas at Austin.

Timbadiya, P.V., Patel, P.L., and Porey. P.D. (2012). Caliberation of HEC-RAS model on prediction of flood for lower Tapi River, India, J. of Wat. Reso. And Prot., 3:805-811

USACE. (2016). HEC-RAS River Analysis System Hydraulic Reference Manual. Version 5.0.