Flood risk management in Allala River (Algeria) using Flood frequency analysis and hydraulic modeling

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Abstract. The objective of flood frequency analysis (FFA) is to associate flood intensity with a probability of exceedance and for making probabilistic estimates of a future flood event in Allala basin based on the historical discharge record at Sidi Akkacha gauging station, the peak floods discharge of Allala river for 5, 10, 50, 100 years return period are estimated using exponential distribution and the stage at different position of river are calculated using HEC RAS model. Based on the modeling study carried out considering 62 cross sections for 8 km length of river, the Output HEC–RAS model show that the existing embankments system on the banks of Allala River is not sufficient to resist the peak flood discharge of 100 years return period, water level profile shows that a maximum of 1.25m in left bank (at 1.2 km downstream) is needed to protect the inundation of the low laying areas of Old tenes.

1. Introduction

Floods are natural disasters that afflict almost all regions in the world today. The threat of flooding is a natural disaster that most frequently cause loss of property and lives [1], estimates of the size and frequency of floods is important for infrastructure planning and design and in the management of water resources and riparian areas [2]. Research on flood frequency has focused on the estimation of extreme flood events, rather than the more frequent small to moderate magnitude flood events which dictate alluvial channel morphology [3,4]. Flood inundation models play a central role in both real time flood forecasting and in flood plain mapping [5], the HEC RAS is one of this models. Already many authors using this models for modeling flooding in various countries where the results were satisfactory [6,7]. The objective of this study is to forecast the flood water surface profile on a return period of 50 and 100 years.

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2. Methods

2.1. Site description

The hydrometric station of Sidi Akkacha is located at the outlet of Oued Allala watershed (fig.1) which has a surface of 296.34 km², a perimeter of 94.59 km, an average slope of 2.25%, a courtyard main water of 31.57 km. This station has been in operation since 1972. The highest flood event recorded at the station is reached at a discharge of 538 m³/s which corresponds to a water level of 6.1 m (March 1979).

![Fig.1. Location of the Allala river study reach and Sidi Akkacha hydrometric station. Hydrometric](image)

2.2. Hydrometric data

The present study based on a series of hydrometric data (water stage-discharge) where they are recorded at the Sidi Akkacha hydrometric station during the period from 1973 to 2017 and rating curve with gauging data, they were provided from National Agency of Water Resources (NAWR) of Blida, as showing figure 2.
2.3. Frequency Analysis of discharge data

Frequency analysis is used to predict how often certain values of a variable phenomenon may occur and to assess their liability of the prediction of an event. In the present study the statistical methods used to analyze the maximum discharge data reconstructed rating curve is the exponential distribution, Weibull and Gumbel. The result shows that distribution of discharge data in the gauging station of Sidi Akkacha follow the distribution of exponential with an Average of 129; Skewness coefficient (Cs) = 1.71; Standard Deviation (Sd) = 121; Kurtosis coefficient (Ck) = 4.72 and a coefficient of variation (Cv) = 0.936, the suitability of discharge data tested using the Chi–square test.

The value of the design flood discharge for different return period is presented in figure 3.

![Fig. 3. The predicted values of the peak flood discharges of Allala River using exponential’s method.](image)

2.4. HEC-RAS Model
Hydrologic Engineering Centers River Analysis System (HEC-RAS) developed by the US Army Corps of Engineers allows to perform one dimensional steady and 1D and 2D unsteady flow river hydraulics calculations. It’s an integrated system of software, designed for interactive use a multi-tasking, multi-user network environment [8].

HEC RAS is dependent on finite difference solutions of the Saint-Venant equations (Equations (1)-(2))

\[
\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = 0 \tag{1}
\]

\[
\frac{\partial Q}{\partial t} + \frac{\partial (QA)}{\partial x} + gA \frac{\partial H}{\partial x} + gA(S - S_f) = 0 \tag{2}
\]

where \(A\): cross-sectional area normal to the flow; \(Q\): discharge; \(g\): acceleration due to gravity; \(H\): elevation of the water surface above a specified datum, also called stage; \(S\): bed slope; \(S_f\) = energy slope; \(t\): temporal coordinate and \(x\): longitudinal coordinate.

Equations (1) and (2) are solved using the well-known four-point implicit box finite difference scheme [9].

**Topographic data of Allala River**

For the topographic data, there are 62 cross sections at an average distance of 120 m describing the geometry of a section of 7207 m. We presented in Figure 4 a part of the studies.
Fig. 4. Cross-sections at different points along Allala River used in the HEC-RAS model.

3. Result and discussion

Flood peak discharge will be used as input for the hydrodynamic model HEC–RAS. The design peak flood discharge will be modelled are 50 and 100 years. Model the calibration necessary and critical step in the model application for parameter evaluation and refinement [10]. In our simulation the model HEC RAS is calibrated by the calibration of manning’s roughness coefficient (n), this latter is calibrated for the main channel then for the over banks of the channel using the observed marks during the recent flood of January 2017 (fig
5), Thereafter, the HEC-RAS model was used to model the water surface for different locations (along about 8 km), and defining the flood-prone areas linked to 50 and 100 years (fig.6).

**Fig.5.** Calibration of HEC RAS Model using the observed water surface (flood of January 2017)

**Fig.6.** Simulated Water surface profile using HEC RAS for the peak discharge of 50 and 100 years
The above results (Fig. 7 and 8) show that the existing embankments system on the Right banks of Allala River is not sufficient to resist the floods of 50 and 100 years return period so the water level exceeded the bank river as shown in (Fig. 6, 7 and 8). Hence HEC-RAS
model for estimation of flood magnitude and corresponding water level profile shows that a maximum of 1.25m in left bank((at 1.2 km downstream) is needed to protect the inundation of the low laying areas of Old tenes (table 1).

Table.1 High and location of Embankment For Flood Plan Return Period 100 year

| Station | Right Embankment | Right Embankment |
|---------|------------------|------------------|
| 37      | 0.55             | -                |
| 35      | 0.1              | -                |
| 21      | 0.96             | -                |
| 9       | 1.25             | -                |

4. Discussion and Conclusion

Following conclusions have been derived from the present study:

1. The modelling results for a return period of 100 years, dikes should be built at the following positions: station 35 to 37 on the left embankment of the river, station 22 to 21 on the left embankment of the river, station 10 to 8 on the left embankment of the river. High levees ranging from 0.55 to 1.25 m.

2. The decision maker can use the output of the HEC–RAS program to develop programs of flood control on the Allala River. If the selected flood control efforts are the construction of embankments, the position and height of the embankments that will built to be adapted from the output of the HEC–RAS 5.0.3.

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