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Flood risk assessment in Saharan regions. A case study (Bechar region, Algeria)

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Abstract

Intensive storm rainfall induced flooding is one of the most severe and devastating natural disasters in arid regions. In recent years, urban expansion and consolidation, changing demographic features within floodplains makes the urban environment transformed dramatically and results in additional flood risks. In this research, Gumbel's distribution was used to analyze maximum daily precipitation data from 1963 to 2012 (49 year) and calculate maximum instantaneous flows with different return periods, namely, 2-, 5-, 10-, 20-, 50-, 100-, and 1000-year. The peak flows from precipitation frequency analysis were input into the hydraulic models (HEC-RAS) to find the corresponding flood extents in a study area located in the upstream of Bechar basin. The results from HEC-RAS model were then used in integration with ArcGIS to compile a floodplain maps. Flood extents through floodplain maps, areas that are vulnerable to flooding hazards have been identified. Floodplain map analysis indicated that 2.679km^2 with the percentage of 23% is likely to be flooded under 100 year return period flood. In addition, show that the traffic roads and buildings surroundings Ephemeral river are more susceptible to flooding. Based on the results of this analysis, assist planners and policy makers can develop an effective strategy of flood management related to Ephemeral River overflowing through Bechar city.

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Introduction

Saharan regions defined as areas where water is limited and most scarce. The term arid region in a geomorphology and natural vegetation context is applied to the area where rainfall will not be sufficient for regular rain-fed farming (FAO, 1981). Moreover, on climatologically data (e.g., precipitation, evapotranspiration, temperature and radiation) has taken the ratio of annual potential evapotranspiration to annual precipitation (UNESCO, 1979). In arid region, the floods are extremely beneficial event, because they are the main source of groundwater recharge along drainage basins, where there are no human settlement or urban area exposed to flood danger (Şen, 2018). However, floods are the most hazardous natural disasters; they are governed by various factors, including rainfall characteristics, drainage systems, land-use and water management in river basins (Chang *et al.*, 2013). The societies in arid regions suffers from floods that are responsible for the loss of their life and property. Floods in these regions are an abnormal and infrequently recurrent phenomenon not only due to the extreme and highly variable of hydrological regime, but more significant due to human settlement along flood dangerous areas. Algeria's Sahara regions are not protect from the risk of such events. The most common types of floods in Algeria's Sahara regions include flash floods from the overflowing ephemeral rivers, rain floods due to poor drainage system. Furthermore, Flash floods is characterized by short duration, small areal extent, high flood peaks and rapid flows (UNESCO, 1999); can be caused important economic damage, a severe blow to regional development and the main source of erosion and accidental pollution. In other words, flash floods are a poorly understood phenomenon (Lin, 1999). More recently, Algeria's Sahara regions witnessed disastrous floods, among these regions, Adrar (October 2004, January 2009 and August 2013), Ghardaïa (October 2008 and January 2009), Biskra (September 2009), Bechar (October 2008), El Bayadh (October 2011), Tamanrasset (March 2015) and Tindouf (October 2015), were marked by an extent of human and material damage (Hafnaoui *et al.,* 2009; Hachemi and Benkhaled, 2016). Property damage and human injury caused by flooding have growing in recent decades worldwide, and it expected that flood risks increase continuously because of climate change and population growth, as well as increase of economic wealth (Te Linde *et al.*, 2010). How to assess future flood risk quantitatively and how to reduce flood danger and hazard are the key questions of the research on flood risks. Risks are the potential or possibilities that something bad will happen because of the hazards (Shroder, 2014), indexed by the average annual flood loss and calculated by combining the probability density function of flood magnitudes with a function relating flood magnitude to flood loss (Arnell and Gosling, 2014). The study on risk assessment and damage areas caused by hazardous natural disasters is very important to make strategies for preventing and mitigating flood damage (Popovska and Ivanoski, 2009). According to Hirsch and Ryberg (2012), effective flood mitigation strategies depend on accurate assessments of flood risk. Assessment of a flood requires knowledge from meteorology, surface water hydrology and hydrogeology disciplines (Şen, 2018). One of the crucial factor for flood prone region short term and long-term protections has been the use of flood mapping. Flood mapping is one of the most important measures for preventing flood loss potential (Yoshino and Yoshikawa, 1985), and is limited to flood prone hazard mapping (De Moel *et al.*, 2009). In addition, detailed flood risk mapping is necessary to reduce the hazards of flooding (Safaripour *et al.*, 2012). For this reason, the realization of this map requires carrying out hydrological analysis, including determining design flows and flood hydrographs, and using the tools, as well as the hydraulic models (HEC-RAS) based on geographic information system, GIS (Evans *et al.*, 2002).

In recent years, a number of researchers have shown an increased interest in floods risks in several parts of the world using different techniques, due to their influence on the human being and natural environment. For instance, Hafnaoui *et al.*, (2009) examined the impact of climate and morphological factors affecting the flood in Doucen-Biskra region.

Four years later, Hafnaoui *et al.*, studied the vulnerability mapping of flooded area in the same region. Bashir *et al.*, (2010) integrated hydrological models with GIS to estimate the flood zone of Nullah Lai in Rawalpindi.

Arnell and Gosling (2014) assessed the implications of climate change for a number of indicators of flood hazard, across the global domain, and the effect of climate model uncertainty by using scenarios constructed from a wide range of climate models. *Yamani et al.*, (2016) combined hydrological and hydraulic models to fix the areas vulnerable to floods in the arid region Oued M'zab-Ghardaïa region. Sein and Myint (2016) integrated flood frequency analysis with HEC-RAS and GIS to prepare flood hazard maps of different return periods in Ayeyarwady River at Mandalay city in Myanmar. Thakur *et al.*, (2017) used precipitation and land use to assess the extent of flood plain in Copper Slough Watershed in Champaign, Illinois. Hachemi *et al.*, (2019) studied the effects of morphometric characteristics on flash flood response in the arid region wadi Deffa-El Bayadh. Hafnaoui *et al.*, (2020) proposed a practical method based on rainfall values to determine flood-prone areas. In the present research, Bechar region has been selected as an investigator area in order to perform flood risk assessment using appropriate tools, such as HEC-RAS and digital elevation model (DEM) data collections in GIS Software, because it has witnessed abnormal flood event in October 2008 when about 84.6mm of rainfall in a couple of hours.

This event resulted in high impact damage to the human being and natural environment, and the inhabitants were in fear after each rainfall period. Thus, the main objectives of the research are to carry out detailed meteorological and land use information of the study area and to conduct hydraulic model to delineate a flood hazard map. Precipitation frequency analysis and results presented herein have the potential to assist planners, decision makers and relevant agencies to develop effective flood management strategies in the region.

Material and methods

Study area

Bechar region is located in the Northwest part of the Algerian Sahara (Fig. 1). This region is considered as a largest province in Southwest of Algeria covering an area of 161.400km². It occupies about 6.77% from national territory, which extends over three major morphologic units, represented by a faults mountain (*Djebels*), deposits plateau (*Hammada*) and depressions. Its natural boundaries are the High Atlas to the north, the Meharez shoal to the east, the Guir Hammada to the west, and finally the Ougarta range to the south. In addition, is surrounded by mountains range named Antar, Grouz and Bechar lying at elevations of 1953, 1853 and 1206 m above sea level (asl), respectively.

Bechar region is influenced by hyper-arid to arid climate with low and scarce rainfall. Average annual rainfall during climatological period 1988-2008 is about 71.48mm (Bouhellala and Cherif, 2014). In addition, the daily average temperatures ranges between 10°C in winter (December); and 46°C in summer (Juley), with a potential evaporation rate of 2623mm/year. Increasing temperatures tend to be increase evaporation, which leads to more precipitation (IPCC, 2007). As average global temperatures have risen, average global precipitation has also increased (Teegavarapu, 2012).

The hydrographic system is constituted by three ephemeral rivers, namely, Guir, Zousfana and Bechar. These rivers are characterized by the irregularity of flow and a strong fluctuation hydrological (Arab *et al.*, 2004), and supplied in an intermittent way by local rainfall. Bechar Ephemeral River takes birth in Djebel Grouz intermediate with El Biodh Ephemeral River, and has a length of 140km with a catchment area of 3575km² lying at an elevation of 1590 m above sea level (asl), after rapid flowing joins R'tem and Roknet El Betoum Ephemeral Rivers. Our assessment is applied over the sub-basin area, which located in the upstream of Bechar basin (Fig. 2). Table 1 summarize the principal characteristics of Bechar sub-basin.

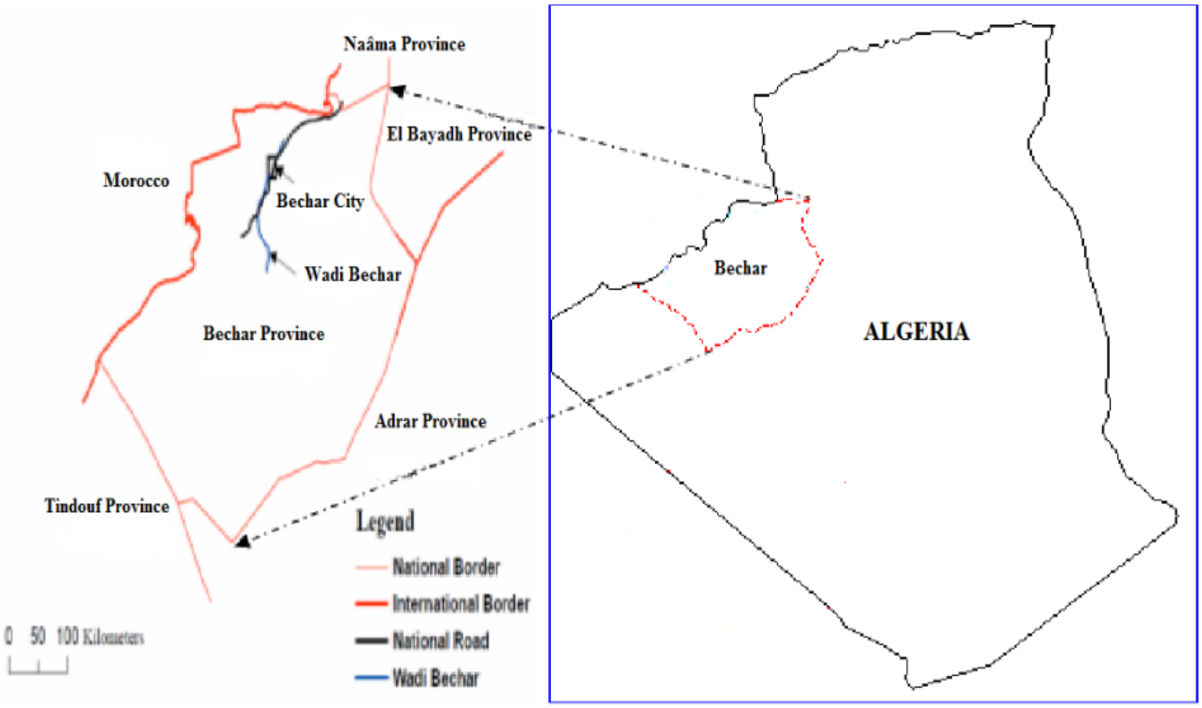

Fig. 1. Geographic location of Bechar region.

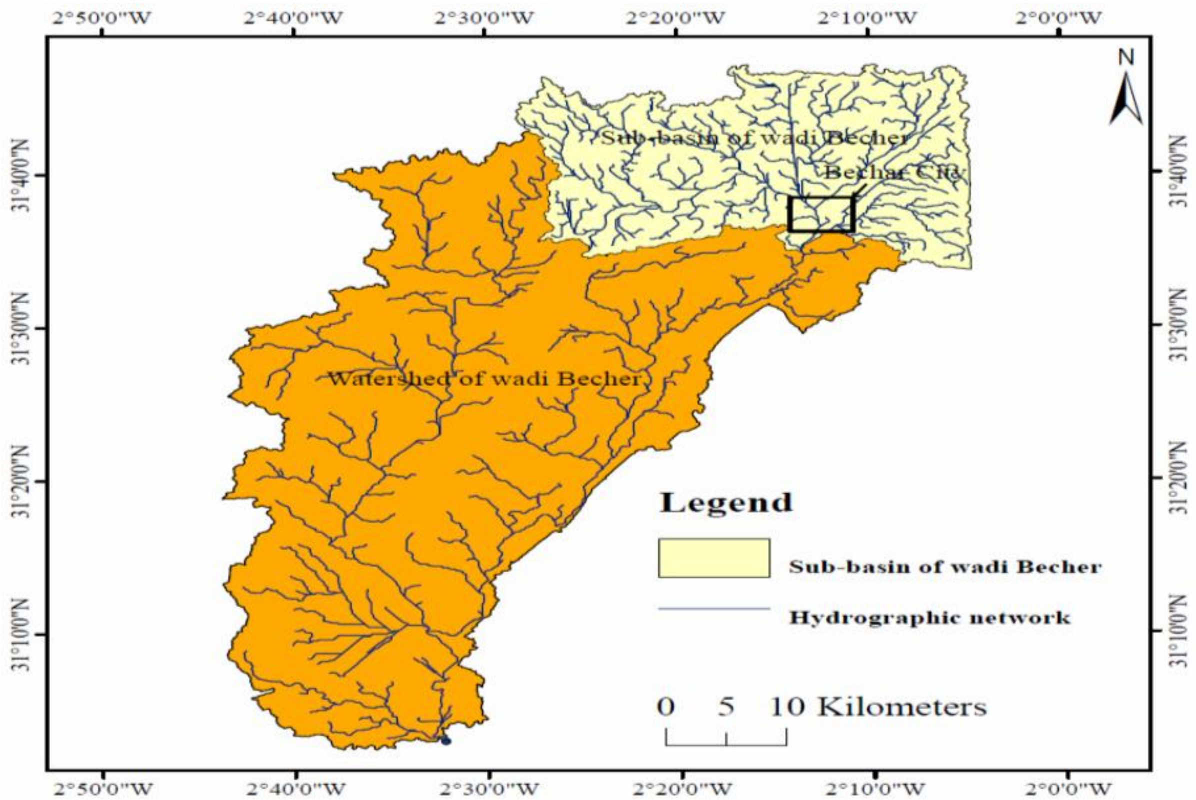

Fig. 2. Watershed and Hydrographic Network of Bechar Ephemeral River.

One of the greatest challenges that the world currently faces is the rapid growth of population in urban areas, particularly in the developing countries (Dewan, 2013). WESP (2014) classify Algeria as a developing country. Bechar city is pertains to the arid area, where the population growth rate has increased most dramatically in the last 60 years (Fig. 3). According to the direction of Planning and Urban Development (DPAU, its French acronym), the number of inhabitants was 56 600 in 1977. By 1987, it had risen to 107 300 inhabitants (Fig. 4a), and reached 165,627 inhabitants in 2008 (Fig. 4b). This tremendous growth is reflected also by the increasing land use; in particular reduce the cross section of Ephemeral River and made some areas exposure to floods.

Table 1. Principal characteristics of Bechar sub-basin.

Characteristic	Parameter	Unit	Symbol	Value
	Area	km^2	A	675.4
	Perimeter	km	P	96.1
Sub-basin morphology	Compactness index	-	K_c	1.043
	Length of the equivalent rectangle	km	L	69.71
	Width of the equivalent rectangle	km	l	11.31
	Maximum altitude	m	H_{max}	1960
Relief	Minimum altitude	m	H_{min}	547
	Mean altitude	m	H_{ave}	810
	Length of the main thalweg	km	L_t	27
	Coefficient of elongation	-	C_e	1.08
Hydrographic system	Drainage density	km/km^2	D_d	0.43
	Coefficient of torrentiality	-	C_t	0.03
	Time of concentration	h	T_c	11
	Runoff velocity	km/h	V_r	2.45

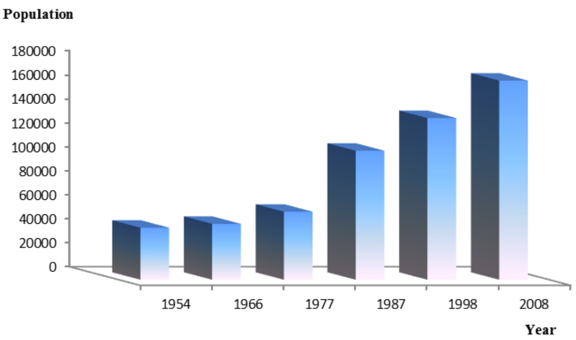

Fig. 3. The population growth rate of Bechar city over the period of 1954-2008.

Fig. 4. Urban expansion in Bechar city. (a) in 1987 and (b) in 2008.

The increase in urban expansion has become one of the most serious environmental issues, and is often linked with exacerbating the damage caused by natural hazards (Al Saud, 2015). The changes in land use and urbanization increase the non-previous area resulting increasing the runoff from the watershed by reducing the infiltration (Parker, 2000; Sohn *et al.*, 2015; Thakali *et al.*, 2016). Consequently, the flood events are accompanied by the change in land use and intensification of storms due to climate change (Thakur *et al.*, 2017). Assessments of flood affected areas resulting from extreme precipitation and changing land use can be helpful in better understanding the flood events (Ahmad and Simonovic, 2006; Mosquera-Machado and Ahmad, 2007; Dawadi and Ahmad, 2012). In addition, the flood extent is one important factor that contribute significantly to direct flood losses (Green *et al.*, 1994). The physical and anthropogenic factors affecting floods are key vital to study regions which have been subjected to frequent natural hazards in order to identify the mechanism of occurrence, as well as to assess the magnitude of impact (Al Saud, 2015). In spite of our region is characterizes by a significant rainfall deficiency (Average rainfall does not goes far beyond 90mm per year); it is common for storm precipitations to cause considerable damage in human life and material. This amount was provided by Hydraulic direction of Bechar province (DHWB, its French acronym) in 2002. Throughout history, Bechar region has experienced many devastating floods in the past. Floods that occurred in the 1959s and 2008s are still the reference floods. The major floods that occurred in 1965, 1979, 1993, 1994, and 2012 also sternly affected urban areas. The last major floods occurred in December 1994, October 2008 and September 2012, where there were large amounts of precipitation in a relatively short period. In 1959, the extent event was regional, which experienced the heavy rainfall recorded during the period from 19 to 21 March by meteorological services. Bechar was again flood in 2007 and 2008; however, the magnitude was not as destructive as the 1959 flood. Intense rainfall during October 2008 (e.g., 84.6mm in 18 h) made the flood situation particularly worse (Fig. 5). According to statistics provided by the directorate of Civil Protection (DPC, its French acronym), the damage caused by floods in the Bechar region is estimated to have 08 victims, loss of animals (17.677 head) and Broken of two main bridges. More than Hundreds of hectares damaged of agricultural land. Fig. 6 shows the damage caused by the October 2008 floods of the Bechar region.

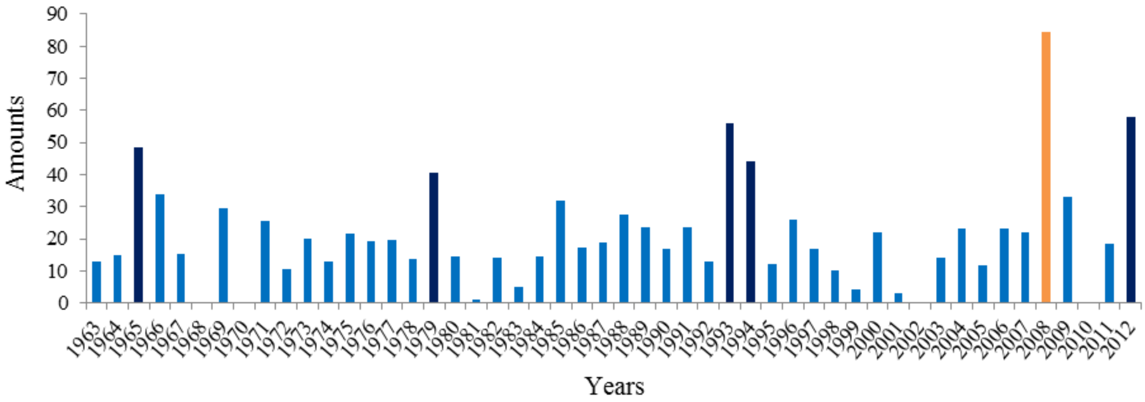

Fig. 5. Daily maximum precipitation values (from 1963 to 2012) at Bechar city.

Fig. 6. Examples of damage caused by October's flood 2008. (a) Main bridge broken, (b) Livestock died, (c) Cultivated land damaged, (d) Primary school submerged, (e) Houses affected and (f) main bridge submerged.

Climate and precipitation

Precipitation is one of the important climatic variables due to its changes in the intensity and the amount affecting appearing of the hydrological hazards such as flood and drought (Zhang *et al.*, 2015). The precipitation in arid areas is commonly characterized by extremely high spatial and temporal variability. In this study, maximum daily precipitation was collected from National Meteorological Office (ONM, its French acronym) over 49 year from 1963 to 2012 (Table 2), and was used for the distribution fitting and flood recurrence calculation.

Table 2. The maximum daily precipitation in Bechar for the period of 1963-2012.

Year	$P_{max,d}$	Year	$P_{max,d}$	Year	$P_{max,d}$	Year	$P_{max,d}$	Year	$P_{max,d}$
1963	12.8	1973	20.2	1983	5	1993	56	2003	14
1964	14.9	1974	12.8	1984	14.6	1994	44	2004	23
1965	48.4	1975	21.6	1985	31.9	1995	12	2005	11.7
1966	33.9	1976	19.1	1986	17.3	1996	26	2006	23
1967	15.4	1977	19.6	1987	18.9	1997	17	2007	21.9
1968	0	1978	13.7	1988	27.6	1998	10	2008	84.6
1969	29.6	1979	40.7	1989	23.6	1999	4	2009	32.9
1970	0	1980	14.3	1990	17	2000	22	2010	0
1971	25.7	1981	1	1991	23.7	2001	3	2011	18.3
1972	10.6	1982	13.9	1992	13	2002	0	2012	57.8

Therefore, long-term precipitation data are essential for research on or assessment of flood risk, for natural hazards and water resource management. These data provide important information for the design of hydrologic structures (Teegavarapu, 2012). The design of hydrologic structures for water control is usually concerned with extreme events (e.g., rainfall, floods, or droughts) and thus based on risk analysis (Volpi and Fiori, 2014). These hydrologic structures, include water retaining structures (e.g., Concrete and embankment dams), water conveying structures (e.g., canals, tunnels, aqueducts, flumes, siphons and pipelines) and special purpose hydrologic structures (Chen, 2015). Hydrologic structures are normally designed to safely handle most extreme precipitation and flood events that are possible in the design life of the structure (Teegavarapu, 2012). Several researchers, including Changnon and Kunkel (1995); Karl and Knight (1998); Kunkel *et al.*, (1999); Groisman *et al.*, (2001); Schaller *et al.*, (2014); Siswanto *et al.*, (2015) and Van Oldenborgh *et al.*, (2017) have studied the effects of global warming on extreme precipitation and flood events. Siswanto *et al.*, (2017) suggest that any extreme precipitation event, different local weather situations may lie at their origin despite a dominant large-scale atmospheric configuration. Evaluation of extreme precipitation events in relation to intensity, duration and influences of climate variability and change is critical to address the issues of floods and flooding mechanisms under climate change scenarios (Teegavarapu, 2012). These scenarios allow an assessment of the relationship between rate of climate forcing and impact response, and a preliminary evaluation of the magnitude of impact at different levels of change in temperature (Arnell and Gosling, 2014).

Frequency analysis

Several statistical distributions are commonly used in hydrological applications for assessing the extreme precipitation values of given data sets. Some of these methods use three parameters (location, scale and shape) such as Log Pearson 3 (LP3) and Generalized Extreme Value (GEV) distributions (Chin, 2006; Teegavarapu, 2012; Farooq, 2018), and others use two parameters (location and scale) such as Gumbel Maximum, Normal, log Normal and Exponential distributions (Maidment, 1993; Millard and Neerchal, 2001; Chin, 2006; Millington *et al.*, 2011; Teegavarapu, 2012; Farooq, 2018). Detail of these methods can be obtained readily from the relevant literature (McCuen, 2003; Maidment, 1993; Hosking and Wallis, 1997). The GEV distribution is based on extreme value Type I (Gumbel), II (Frechet), and III (reverse-Weibull) distributions for maxima (Chin, 2006); and reverse-Gumbel, reverse-Frechet and Weibull distributions for minima (Cooray, 2010). In 1954, von Mises was the first who introduce the GEV, one year later Jenkinson incorporates all types of extreme value distribution (EVD) into a single distribution. More recently, Rulfova *et al.*, (2016) used GEV for precipitation frequency analysis. Frequency analysis of precipitation is widely used to estimate the precipitation return periods and their probability based on the total amount and distribution of precipitation over the study area. Precipitation is the only source of runoff and flood in the one or other form but the transformation of the runoff from precipitation is governed by the parameters such as land use, soil type, evaporation, and storage (Thakur *et al.*, 2017).

In the current study, the sub-basin flood is predetermined according to the local morphology and climatological effects. The predetermination of floods aims to identify the most important flood frequency to ensure maximum safety for hydrologic structures. Flood frequency approaches vary from statistical methods (i.e., directly applied on the observed annual maximum flood series) to adopting rainfall-runoff simulation models that transform design rainfalls to flood discharges (Saghafian *et al.*, 2014). The Gumbel's or extreme value Type I distribution is used to the flood frequency analysis and flood recurrence estimation, the distribution function represented by:

$$F(x) = e^{-e^{-y}}$$

With

$$y = \frac{(x-\mu)}{\alpha}$$

Where y is Gumbel reduced variate, x is maximum daily precipitation, μ and α are, respectively, the scale and location parameter. The location parameter describes the shift of a distribution in a given direction on the horizontal axis (Farooq, 2018). While scale parameter describes the spread and shape parameter (Millington *et al.*, 2011). The basic parameters, mean $\overline{x}$, standard deviation σ_x and variability coefficient C_v of the x series are estimated as:

$$\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

$$\sigma_x = \left(\sum_{i=1}^{n} \frac{(x_i - \bar{x})}{n}\right)^{1/2}$$

$$C_V = \frac{\sigma_x}{\bar{x}}$$

where n is the number of values in the datasets.
Gumbel's equation is given by:

$$\overline{P_{max,d}} = \frac{1}{\alpha} y_{P\%} + x_o$$

Peak discharge calculations are necessary for flood control studies in water engineering domain (Şen, 2018). The relationship between precipitation and peak discharge plays a fundamental key in any hydrological applications (Viessman and Lewis, 2002; Wang and Melesse, 2005), such as engineering design (Debo and Reese, 2003), flood forecasting (Nash and Sutcliffe, 1970; Hapuarachchi *et al.*, 2011), and assessing effects of watershed best management practices (Arnold *et al.*, 1998, 2001; Wang and Melesse, 2006; Wang *et al.*, 2008; Wang *et al.*, 2010; Nalbantis *et al.*, 2011).

There are various methods have been developed and introduced to transform the precipitation into peak discharge. In hydrology, the term peak discharge, often called peak flow or maximum instantaneous flow, stands for the highest concentration of runoff from the basin area (Roy and Mistri, 2013). Gaume (2006) refers to the peak discharge as a key issue of post flood studies and further hydrological analysis and makes an extensive reference to a number of indirect estimation methods, discussing the estimates accuracy. The methods used to predict the peak discharge are classified into two groups. First, is based on precipitation like Sokolovsky (1968); secondly, is based on return periods like Fuller (1914); Kallel (1979); Crupedix (CTGREF, 1980); Ghorbel (1984); National Soil Conservation Service (NRCS, 1986); Frigui (1995); Rational (Mulvaney, 1851; Turazza, 1880; Kuichling, 1889; Chow, 1964). The return period is possible, the time between two hydrologic events of interest, and the unconditional time to the next event of interest (Vogel and Castellarin, 2017). The unconditional return period is much more widely adopted and useful than the conditional return period (Lloyd, 1970; Vogel and Castellarin, 2017). In our studied area, peak discharge is estimated by Sokolovsky method. This method was chosen because it is widely used in arid catchments and most adapt to the Algerian context (Boulghobra, 2006; Hasbaia and Adoui, 2015; Daifalah *et al.*, 2017), and because of the simplicity in calculations processes. The Sokolovsky formula is given by:

$$Q_{P\%} = \frac{0{,}28.P_{t\%}.\alpha_{P\%}.A.f}{T_c}$$

where $Q_{p\%}$ is the peak flow in m^3/s, $P_{t\%}$ is amount of precipitation for a duration equal to t_c, $\alpha_{P\%}$ is the runoff coefficient, A is a sub-basin area, f is the shape coefficient of hydrogramme varying from 0,95 to 1,2 and T_c is time of concentration. The characterization of basin or sub basin based on two keys called the time of concentration and the runoff coefficient.

Time of concentration represents the minimum time required after runoff begins for the entire basin to contribute flow to the outlet (Donald and Richard, 2006). In our studied area, this time was estimated according to Giandotti's empirical formula $T_c = (4\sqrt{A} + 1.5L_t)/0.8\sqrt{H_{ave} - H_{min}}$. The runoff coefficient is defined as the ratio of runoff to rainfall (Pilgrim and Cordery, 1993), ranges between 0 and 1, where a value of 0 indicates that none of the rain falling on the basin generates runoff, and a value of 1 indicates that all of the rain falling on the basin generates runoff (Donald and Richard, 2005). This coefficient can be also related to the abstractive (e.g., infiltration, depression storage and evapotranspiration) and diffusive properties of the basin (Donald and Richard, 2006). The diffusive properties is a measure of the attenuation of the flood peak attributable to basin runoff characteristics (Ponce, 1989).

Hydraulic model

The flood peaks for different return periods were obtained using the extreme value Type I and used as an input to HEC-RAS model. HEC-RAS is based on the U. S. Army Corps of Engineers' HEC-RAS water surface profile model used for modeling both steady and unsteady flow (Robert *et al.*, 2012; Azhar, 2017), one dimensional river flow using the Saint Venant equation (Brunner, 2010), gradually varied flow in both natural and man-made river channels (Sami *et al.*, 2016; Azhar, 2017). It is numerical software for flow of river hydraulics calculations (Darshan *et al.*, 2014). HEC-RAS also allows delineating the extent flood zone under different flood intensities. Another tool was used is GIS through the software ARC GIS of ESRI institute (Environmental Systems Research Institute). ASTER DEM was used as input data to generate sub-basin in HEC-GeoRAS. HEC-GeoRAS is another program, developed by the USAGE, for an ARC GIS environment that can be used to transfer data from ARC GIS to HEC-RAS for modeling simulations (Sami *et al.*, 2016). These simulations require each cross- sectional line to carry a Manning value in the geometric file (Sudha, 2012). A land use map, in the form Manning coefficient, forms to know the nature and type of soil (Sami *et al.*, 2016).

Results and discussion

Precipitation analysis

The precipitation analysis is focused on the development of intensity-duration-frequency (IDF) curves. IDF curves are plotted for the different return periods of 2, 5, 10, 20, 50, 100 and 1000 years (Fig. 7). The rainfall intensity is selected from IDF curve generated from point rainfall data collected in the local area, and is estimated by the basin time of concentration as duration in hours through the desired storm frequency curve in the same manner as shown in fig. 7. These curves are generated by fitting daily maximum rainfall intensities for specified durations to a Gumbel probability distribution, usually by plotting the data on extreme value probability paper (McKay, 1970). Alternatively, IDF curves can be developed by assuming that the historical extremes can be best characterized by an extreme value Type I (Gumbel) distribution and using a frequency factor-based analysis (Teegavarapu, 2012). The Gumbel's distribution is used to analyze the extreme events and flows of different return periods of 2, 5, 10, 20, 50, 100 and 1000 years using observed precipitation data.

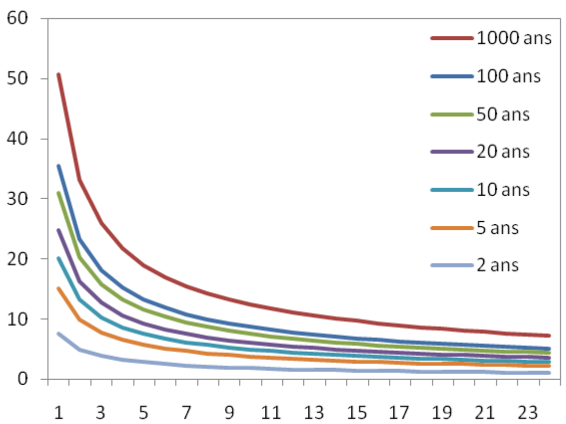

Fig. 7. Intensity-Duration-Frequency (IDF) curves for the different return periods.

Kamal *et al.*, 2016 concluded that Gumbel gives good result for low sample size. This law comprises two parameters, the mode $\overline{x_0}$ and the Gradex $\frac{1}{\alpha}$ (exponential gradient). The parameters for distributions are generally estimated using the moment method that gives the following estimators: $\overline{x_0} = 18.02$, $\frac{1}{\alpha} = 22.73$. This method is also referred to as the method of matching moments (Teegavarapu, 2012), and the equation of the adjustment line is of the form: $\overline{P_{max,d}} = 22.73y_{P\%} + 18.02$, with coefficient of correlation was found to be 0.95. The maximum daily rainfall values obtained for the different return periods are shown in table 3.

Table 3. Maximum daily rainfall for different return periods by Gumbel's distribution

Frequency (%)	0.1	1	2	5	10	20	50
Return period (year)	1000	100	50	20	10	5	2
Reduced variate ($y_{p\%}$)	6.91	4.60	3.90	2.97	2.25	1.50	0.37
$P_{max.d,p\%}$ (mm)	175.08	122.58	106.67	85.53	69.16	52.12	26.43

The amount of precipitation fell over a period given has been estimated by the Body formula $P_{t\%} = P_{max.d,f\%}(t/24)^b$, where $P_{t\%}$ is the precipitation of short duration (Table 4), $P_{max.d,f\%}$ is the maximum daily rainfall of the different return periods and b is climate exponent in Algeria varying from 0.36 to 0.42. The maximum daily rainfall of the different return periods was transformed to the flood peak discharge using Sokolovsky method that was previously described.

Table 4. Short duration precipitation for different return periods.

Time	Frequency (%)						
	0.1	1	2	5	10	20	50
1	50.69	35.49	30.89	24.76	20.03	15.09	7.65
2	66.43	46.51	40.47	32.45	26.24	19.78	10.03
3	77.81	54.48	47.41	38.01	30.74	23.16	11.75
4	87.05	60.95	53.04	42.52	34.39	25.91	13.14
5	94.96	66.49	57.86	46.39	37.51	28.27	14.34
6	101.96	71.39	62.12	49.81	40.28	30.35	15.39
7	108.28	75.81	65.97	52.90	42.77	32.23	16.35
8	114.07	79.86	69.50	55.72	45.06	33.96	17.22
9	119.43	83.62	72.76	58.34	47.18	35.55	18.03
10	124.44	87.12	75.82	60.79	49.16	37.04	18.79
11	**129.15**	**90.42**	**78.69**	**63.09**	**51.02**	**38.45**	**19.50**
12	133.61	93.54	81.40	65.27	52.78	39.77	20.17
13	137.85	96.51	83.98	67.34	54.45	41.04	20.81
14	141.89	99.34	86.45	69.31	56.05	42.24	21.42
15	145.76	102.05	88.80	71.21	57.58	43.39	22.00
16	149.47	104.65	91.07	73.02	59.04	44.50	22.56
17	153.05	107.15	93.25	74.77	60.46	45.56	23.10
18	156.50	109.57	95.35	76.45	61.82	46.59	23.62
19	159.83	111.91	97.38	78.08	63.14	47.58	24.13
20	163.06	114.17	99.35	79.66	64.41	48.54	24.62
21	166.20	116.36	101.26	81.19	65.65	49.48	25.09
22	169.24	118.49	103.11	82.68	66.85	50.38	25.55
23	172.20	120.56	104.91	84.12	68.02	51.26	25.99
24	175.08	122.58	106.67	85.53	69.16	52.12	26.43

Estimated flood peak flows based on Sokolovsky method for 2, 5, 10, 20, 50, 100 and 1000-year return periods are shown in Table 5.

Table 5. Peak flows for different return periods according to Sokolovsky method.

Return period (year)	1000	100	50	20	10	5	2
Peak flows (m^3/s)	1898.40	1255.30	1027.55	772.81	583.30	408.19	191.09

Floodplain map

Several flood events were recorded during 49 year from 1963 to 2012. The most important of it was from 08 to 09 October 2008 with amount of 84.6mm. This value correspond the peak flow is 878.99 m^3/s, the frequency curve is given in Fig. 8, showing that flood 2008 event was between 20 and 50 years return period. Return periods are placed on x-axis while peak flows are placed on y-axis. In the same meaning, this event was between floodway and floodplain. The floodway term is used for 5% annual probability, which corresponds to 20-year level of probable flood water and floodplain is employed for 1% annual probability corresponding to 100-year flood water level (Şen, 2018). In addition to that, US National Flood Insurance Program (NFIP) defines the floodplain in terms of 100-year flood, which is defined as the annual maximum river flood discharge that is exceeded with an annual exceedance probability of 1% (Vogel and Castellarin, 2017). The US Federal Emergency Management Agency (FEMA) defines the floodway as the active zone (Brych *et al.*, 2002).

The calcul finding that flood 2008 event was of 33 years return period. A 33-year flood water level between floodway and floodplain describes an event to a 3% (1/33=0.0303) probability of a certain size flood occurrence, and a 97% ((1-1/33) =0.9697) non-occurrence in any future year. If flood infrastructure were designed to protect against such an event, the structure would be 97% reliable, in any given year. This concept does not mean that such a flood will occur only once at a certain time during the next thirty-three years. Streams will equal or exceed the mean annual flood once every 2.33 years (Leopold *et al.*, 1964). The time duration between two flood occurrences is assumed independent from each other (Şen, 2018). Gumbel (1941); Thomas (1948); and Yen (1970) introduced the concept of reliability. This concept is widely used in irrigation and water supply planning (Hirsch, 1979; Vogel, 1987; Harberg, 1997; Tung, 1999; Loucks and van Beek, 2005) in hydrology as well as for numerous other natural hazards including wind loads, sea level, earthquakes, temperatures, flood and drought (Vogel and Castellarin, 2017) and many other fields (Kottegota and Rosso, 1997; Modarres *et al.*, 2009).

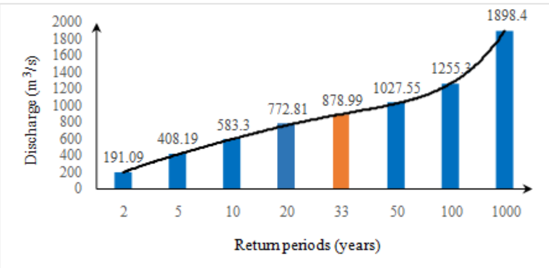

Fig. 8. Discharge frequency curve for the different return periods.

Fig. 9 illustrate the simulation area and cross-sections for 100-year. From this simulation, it is possible to determine the water surface and to validate the flood extent at a control cross section with the simulation of the flood wave. Floodplain maps were produced using Digital Elevation Model (DEM) and bassin network data; the extraction of geometric roughness coefficient data was performed in ArcGIS and then extracted by HEC-GeoRAS tools. Using the water surface data and DEM created for the basin, the flooded area under different return period floods was delineated.

Although floodplain maps were prepared for various return periods, namely 2, 5, 10, 20, 50, 100 and 1000-years, but only the 100-year floodplain map is presented. Thus, the boundary of the 100-year flood is commonly used in floodplain mitigation programs to identify areas, where the risk of flooding is significant as a consequence of inundation (Şen, 2018). In other words, the changes in flood frequency are indexed by change in the magnitude and the return period of the current 100-year flood (Arnell and Gosling, 2014). The focus on the 100-year event enables a direct comparison with other studies (Lehner *et al.*, 2006; Hirabayashi *et al.*, 2008; Dankers and Feyen, 2009). For example, Hirabayashi and Kanae (2009) and Hirabayashi *et al.*, (2013) counted each year the number of people living in 1x1° grid cells and flood-prone areas respectively where the simulated flood peak exceeded the current 100-year flood.

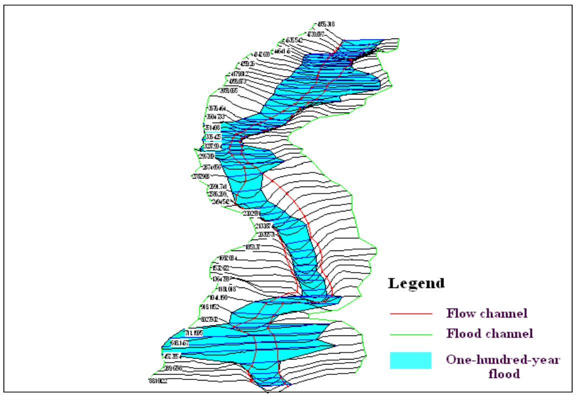

Fig. 9. Numerical simulation for One-hundred-year flood.

Fig. 10 show the areas that are likely to be inundated under 100 year return period flood. Analysis and simulation show that the 100-year flood hazard area touching a surface of 2.679km². The flooded area percentage for each flood time can be calculated using the Dewan formula (Dewan, 2013), (a/a + b) 100 = 23%, where *a* is flooded area and *b* is non-flooded area. This result indicated that the traffic roads and buildings surrounding the ephemeral river are highly vulnerable to flooding by the 100-year event.

Flood hazard 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). More recently, Werren (2015) defined the flood hazard map as useful tool to make a decision for hazard-aware urban development in the studied area.

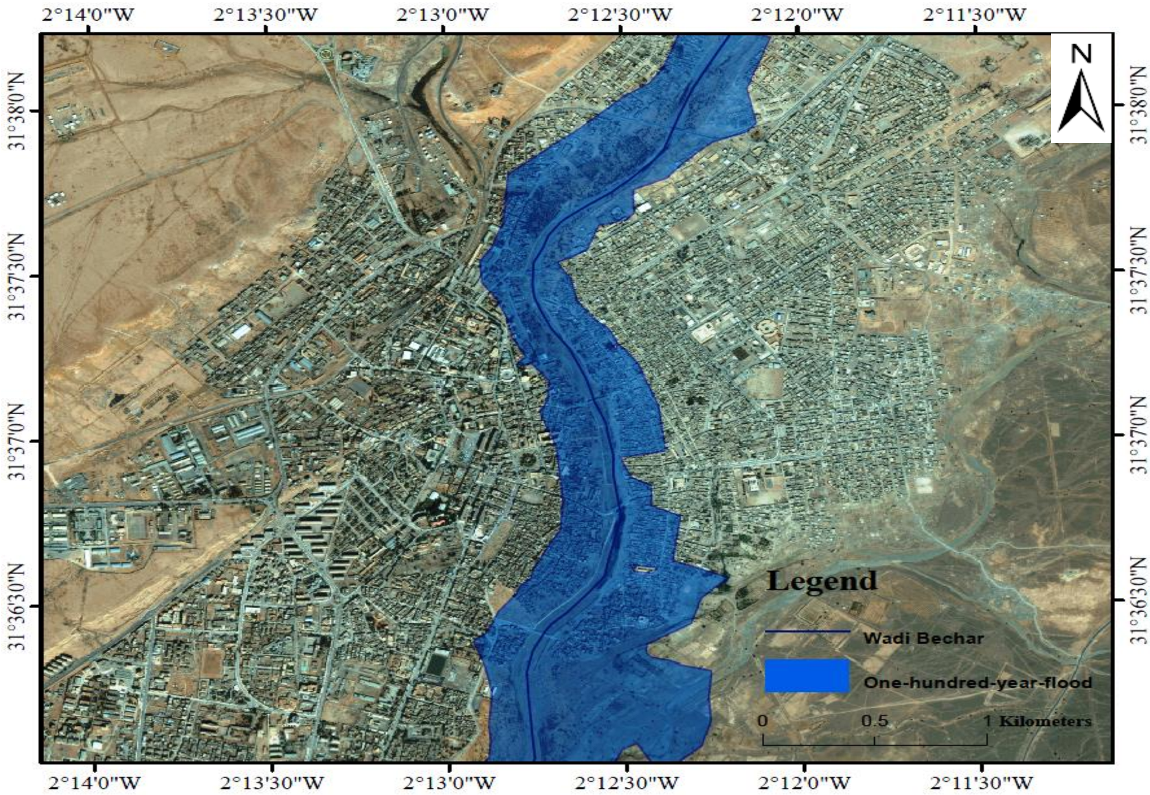

Fig. 10. Flood hazard map for One-hundred-year return period in Bechar city.

Conclusion

Flood risk assessment in this research has been conducted by three analysis. The first, precipitation analysis based on 49 years maximum daily precipitation data to develop the curves of intensity-duration-frequency (IDF) for the different return periods of 2, 5, 10, 20, 50, 100 and 1000 years. The hydrological analysis was carried out by Gumbel's distribution and flood recurrence calculation. Sokolovsky method applied to transform the maximum daily rainfall of the different return periods to the flood peak discharge, because the calculations processes is mainly related to computation of the time of concentration and runoff coefficient.

Through flood History, several events were recorded during 49 year from 1963 to 2012. The flood event that occurred in the 2008s was significant and most damage from those that occurred in the past, with precipitation amount of 84.6mm. This value correspond the peak flow is 878.99m^3/s with return period is 33 years.

Hydraulic Analysis based on input in and on output from the HEC-RAS hydraulic model. The HEC-RAS hydraulic model allowed to simulate the flood hazard mapping at Bechar ephemeral river. When the ephemeral river is raising water moves laterally away from the river, inundating the flood plain and filling available storage areas. A sharp increase in areal flood extent can be attributed to the growing occupancy of flood-prone areas, the development of urban infrastructures and dilapidated drainage infrastructures without considering the hydrological responses of land-use change.

The flood hazard map compiled in this paper can be used as baseline information for planners and emergency managers to improve the economic condition of the people. It can also be used for flood risk analysis and flood hazard management to ameliorate flood loss in the days ahead.

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