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# Methods for Studying Maximum Flows. Application to the Wadi Sebdou Watershed (Tafna - NW Algeria)

H. Abdelmoumene[1*], A.Bouanani[2], K. Baba -Hamed[3]

*[1, 2, 3] Department of Hydraulics, Faculty of Technology, University of Tlemcen, Tlemcen BP 230, 13000 Chetouane Tlemcen, Algeria.*

***Corresponding author:** abdelmoumenehanane1996@gmail.com*

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**Abstract.** The estimation and predetermination of extreme flood quantiles is a necessary step in the studies of strategic projects for the prevention and management of flood phenomena in at-risk watersheds.
The Oued Sebdou watershed is a tributary of the Tafna, with an area of 439.3 km$^2$, characterized by a semi-arid climate. It has an elongated form, with a lithology that favors flow (Bouanani, 2004).
The objective of this study is to analyze the morphological characteristics, the rainfall regime and the determination of the frequency of floods, using the different empirical formulas that have been developed in the Algerian context for use in specific areas.
The errors generated by the application of these formulas can lead to serious technical, financial and environmental problems such as a wrong dimensioning of storage or protection works, an erroneous cartography of the floodable zones whose consequences would be disastrous.
In this work, the analysis of the error of using these formulas in the Sebdou sub-basin was established. Also, the Gradex method was tested in this study. The results indicated that the GIANDOTTI method is the most reliable with a relative error of 19.7% (T=1000years), and the formulas of SOKOLOVSKY and TURRAZA are satisfactory and give flows close to those obtained from observations in the Sebdou hydrometric station.

***Keywords.*** Oued Sebdou, Tafna, Maximum flows, Empirical formulas, Gradex.

## INTRODUCTION

Protecting the population from natural disasters is one of the major concerns in a country's development strategy. Also, floods are one of the most common phenomena that cause the most human and material damage in the world.

Over the last three decades, Algeria has experienced quite spectacular floods in different regions in the North and South of the country. These floods are the result of violent flood events specific to the characteristics of the climate and particularly the very irregular and stormy rainfall that the country experiences, combined with a lack of scientific knowledge or poor consideration of this phenomenon (development of watercourses, definition of flood zones, inappropriate occupation of spaces ) (Abdelmoumene, 2021).

The prediction of extreme and rare hydrological events is an exercise that requires a good knowledge of the maximum flows of a river and their variability because it is on this that the safety and durability of the construction of drainage works will depend (Bouakaz, 2018).

The main objective of this work is to explore empirical formulas for the determination of maximum flows such as those of Mallet-Gauthier (Coutagne, 1951), Turraza (EMI, 1999), Sokolovosky and Giandotti (Bennis, 2007) (Table 1), as well as the Gradex method (Guillot et al., 1967), to estimate the probabilities of extreme floods which will be used, after the choice of the most realistic results, for the construction of the flood hydrograph (Laborde, 2013), of the Sebdou Oued.

Table 1. Summary of the main formulas used in this study (Abdelmoumene, 2021).

| Empirical formulas for estimating peak flows based on the return period. | Empirical formulas for estimating peak flows involving precipitation | Empirical formulas for estimating peak flows used in Algeria. | |
|---|---|---|---|
| **Mallet-gauthier Formula** | **Turraza Formula** | **Sokolovsky formula** | **Giandotti formula** |
| Q max. P%=2K log (1+A.Pmoy).$\frac{S}{\sqrt{L}}\sqrt{1+4.LogT-LogS}$ | Qmaxp%= $\frac{C.It.S}{3.6}$ | Qmaxp%= $\frac{0,28(Pct\%-H0).\alpha p\%.F.s}{Tm}$ | Qmax%=$\frac{C.S.(Hmoy-Hmin)^{\frac{1}{2}}}{4.(S)^{\frac{1}{2}}+1.5.L}.Ptc\%$ |
| Qmaxp%: Maximum flow for a given frequency (m3/s).<br>Pmoy: Mean annual rainfall (m).<br>S: Watershed area (km$^2$).<br>L: Length of the main slope (km).<br>K: Constant depending on the characteristics of the basin varying from 1 to 3 K (1-3).<br>A: Regional coefficient taken equal to 20.<br>T : Return period (year). | S: area of the catchment area (Km2).<br><br>It: maximum average intensity of precipitation for duration equal to the time of concentration in (mm/h).<br><br>C: Runoff coefficient according to the given probability. | H0: Initial losses in mm ($H0$ = 8mm).<br><br>Pct: Short duration frequency rainfall corresponding to the concentration time (mm).<br><br>S: Area of the basin (Km$^2$).<br>0.28: Coefficient of change of unit.<br><br>αp%: Runoff coefficient of the probable flood for a given period.<br>αp%= $\frac{\sqrt{Pct\%}-\sqrt{H0}}{\sqrt{Pct\%}+\sqrt{H0}}$<br><br>Tm=Tc, Tm: Time of concentration of the watershed in hours.<br>F: Flood shape coefficient, it is expressed as:<br>F=12/(4+3γ)<br><br>The value of γ as a function of watershed: for large basins =4≤ γ ≤7 | Qmax (%): maximum flood flow in m3/s of the same frequency as the short duration rainfall.<br><br>C: Topographical coefficient varies between 66 and 166, we take C = 16 for the catchment areas in the north west of Algeria.<br><br>S: Watershed area (km$^2$).<br>L: length of the main talweg (km).<br><br>Hmoy, Hmin: average and minimum altitudes in (m).<br><br>Ptc: short duration rainfall (mm). |

## STUDY AREA

The city of Sebdou located 36 km south of the wilaya of Tlemcen (northwestern Algeria) is the relay between the steppe areas and the atlas chain tellienne.With an area of 439.3 km$^2$ (Fig. 1).

The Sebdou watershed extends from 1°19' West longitude and 34°38' North latitude, and is limited to the North by the Titmokhen plateau and to the South by Djebel Lato, Si Abdellah, Maiter, Zninia, Toumiet and Koudiat el Harcha, to the East by Djebel Mazoudjène, Djebel El Ahmer and Djebel el Arbi, and to the West by the Azaïls plateau.

The North and the North- East of the watershed correspond to a Jurassic horst, notably carbonate. To the South and East, there is a graben filled with plio-quaternary sediments representing the Sebdou Graben (Baba-Hamed et al., 1991).

Table 2 presents all the physical parameters of Sebdou basin.

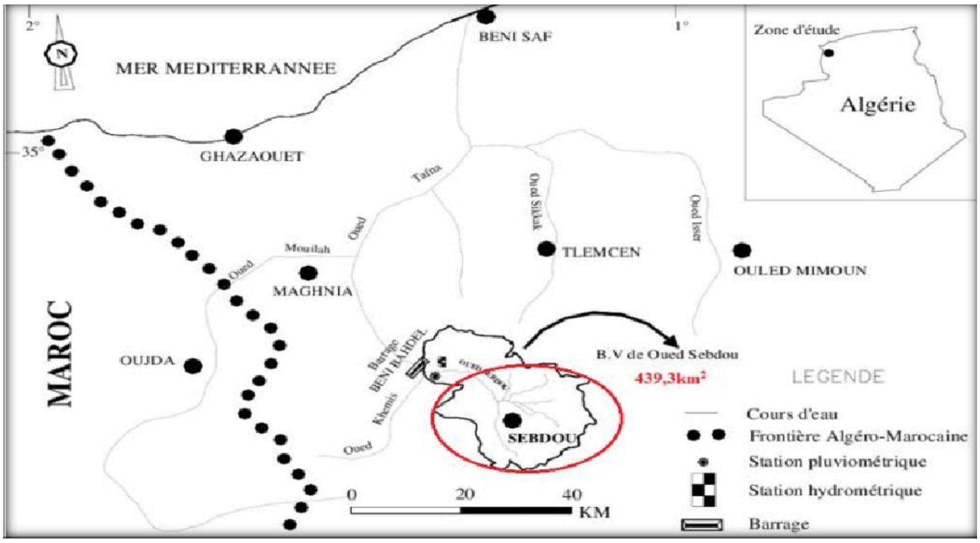


Fig.1. Situation of Oued Sebdou watershed (Ghenim and Megnounif, 2013 modified by Abdelmoumene, 2021).

Table 2. Main physical parameters of the Oued Sebdou sub-basin.

| Parameters | | Watershed of Oued Sebdou |
|---|---|---|
| Area (km2) | | 439.3 |
| Perimeter | | 153.88 |
| Length of main thalweg | | 24.85 |
| Compactness index | | 02.06 |
| Rectangle equivalent | length | 70.91 |
| | width | 6.2 |
| Elevations | maximum | 1616 |
| | Average | 1128 |
| | Minimum | 852 |
| Rock Slope Index | | 0.9 |
| Global slope index (m/m), (m/km) | | 0.01, 0,00621 |
| Average slope index (m/m), (m/km) | | 0.011, 10.8 |
| Average slope of main thalweg(%) | | 2 |
| Specific gradient (m) | | 130.16 |
| Drainage density(Km /km$^2$) | | 1.3 |
| Confluence ratio | | 7.88 |

| | |
|---|---|
| Length ratio | 0.39 |
| Hydrographic density($km^{-2}$) | 2.42 |
| Hydrographic density for order 1($km^{-2}$) | 1.34 |
| Torrentiality coefficient | 1.74 |
| Elongation coefficient | 159.1 |
| Time of concentration (h) | 6 |
| Runoff speed (km/h) | 4.14 |

## METHODOLOGY

### Hydro-pluviometric data

The data (precipitation and flows) used in this work come from the responsible body ANRH (the National Agency of Hydraulic Resources) (Fig.2), observed at the Sebdou rainfall station over the period from 1979/1980 to 2019/2020.

The inter-annual rainfall pattern is very discontinuous from one year to another, over a 41-year study period (1979/80-2019/2020), 17 years have recorded rainfall amounts above the average of about 354.4mm. It is observed that 1995-1996 is the wettest year with 694mm and 2019-2020 the driest year with a minimum of 197.5mm. Over the whole period considered, two years of good rainfall (> 650mm) stand out (1995/96 and 2009/10).The average annual temperatures are irregular and tend to increase from one year to the next. Indeed, an annual increase of 0.013 °C and an interannual average temperature of 17.9 °C are recorded and the curve of the variation of annual flows at the station of Sebdou, shows that the interannual average flow is 0.29 $m^3$ / s, the maximum is recorded in 2008 - 2009 with 1.32 $m^3$ / s by cons, the minimum is observed in 2010-2011, it is only 0.03 $m^3$ / s (Abdelmoumene, 2021).


Fig.2. Presentation of the measuring stations of Sebdou watershed (Map of hydro-climatological network and water quality monitoring ANRH).

### Working tool

We applied empirical formulas and the Gradex method using the HYFRAN version 1.1 software for the estimation of the maximum flow and its evolution as well as the construction of the flood hydrograph by (Laborde, 2013) software The LABORDE program under Excel is designed for the estimation of flood quantiles for the ungauged catchments of Northern Algeria and the generation of the flood hydrograph for the requested quantile.

The formulas used were modeled from a sample of decadal flows of 120 hydrometric stations of Northern Algeria controlling catchments of surface varying from 10 to 5000 $km^2$.

The model requires input parameters which are: the surface of the watershed, the slope of the Oued, the daily decennial rainfall and the rainfall gradex.

For the extrapolation to the rare frequencies it uses a runoff model of the SCS type and is based on the hypothesis that the extreme daily rainfall follows a Gumbel law (Fig. 3).

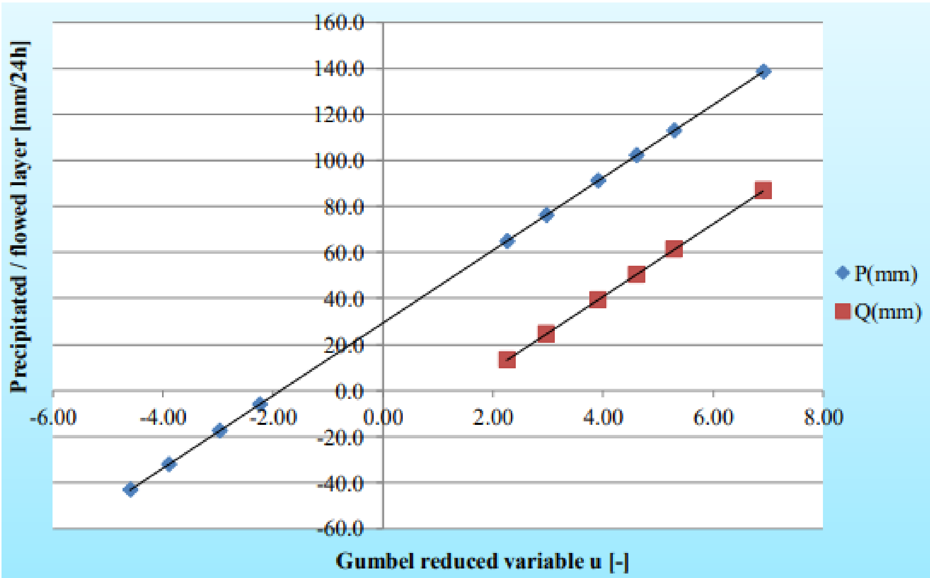


Fig.3. Rainfall adjustment graph and flow extrapolation line (Abdelmoumene, 2021).

The estimated flood quantiles can be corrected by a coefficient. The generated flood hydrograph is based on a three-parameter model (rise time, peak flow and shape parameter).

The user's attention is drawn to the fact that this tool provides a first approach of flood flows on an ungauged watershed that the hydrologist must confirm by a complementary analysis (GIRE project flood, 2013) (Abdelmoumene, 2021). In the end. We compare the results obtained by these formulas with the values observed in the rainfall station, in order to highlight the most suitable formula or method for our watershed.

## RESULTS AND DISCUSSION

From the results obtained we can conclude that the Sokolovsky and Giandotti methods are the most optimal for the determination of the maximum flows for the Oued Sebdou watershed. Also, among the main methods used for flood estimation (Fig.4,5, 6).

We opted for the "Laborde-ANRH" program, to draw the hydrographs of the floods which will allow us to see the evolution in time and to better define the optimal flow in order to use it in the dimensioning (Fig. 4). This method gives us a millennial flow of 389 ($m^3$/s).

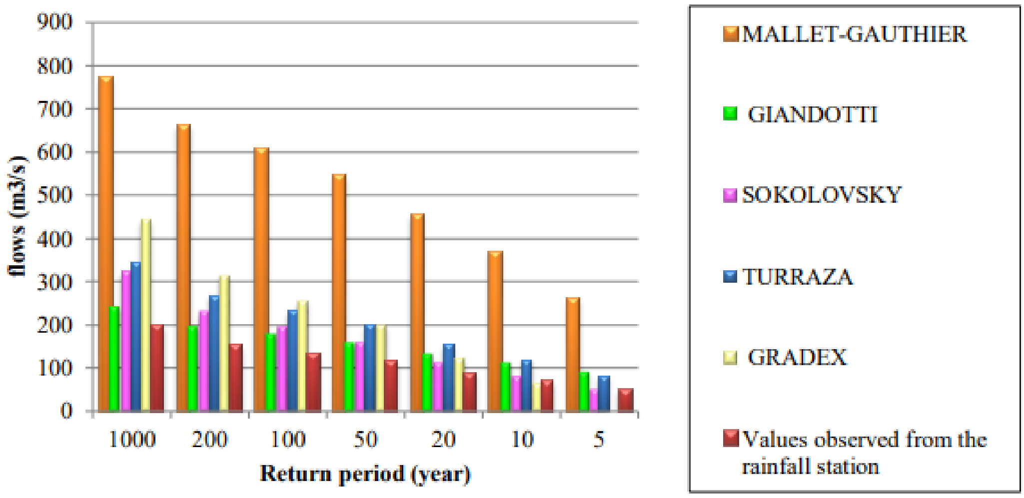


Fig. 4. Summary of the results of the Oued Sebdou flood flows (Abdelmoumene, 2021).

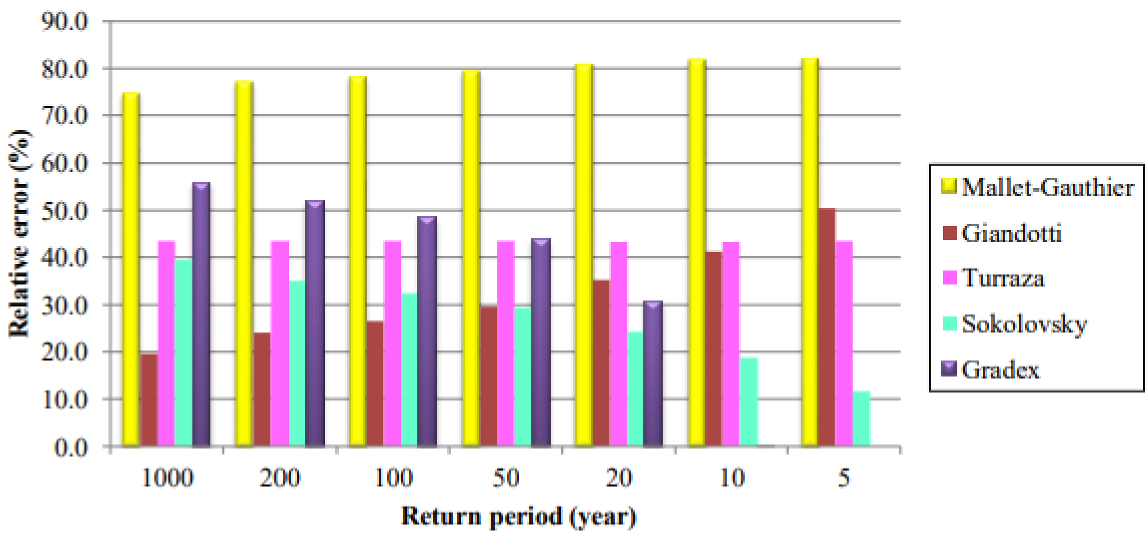


Fig. 5. Graphical representation of the relative error of the flow estimation of Oued Sebdou (1980/1981-201/2012) (Abdelmoumene, 2021).

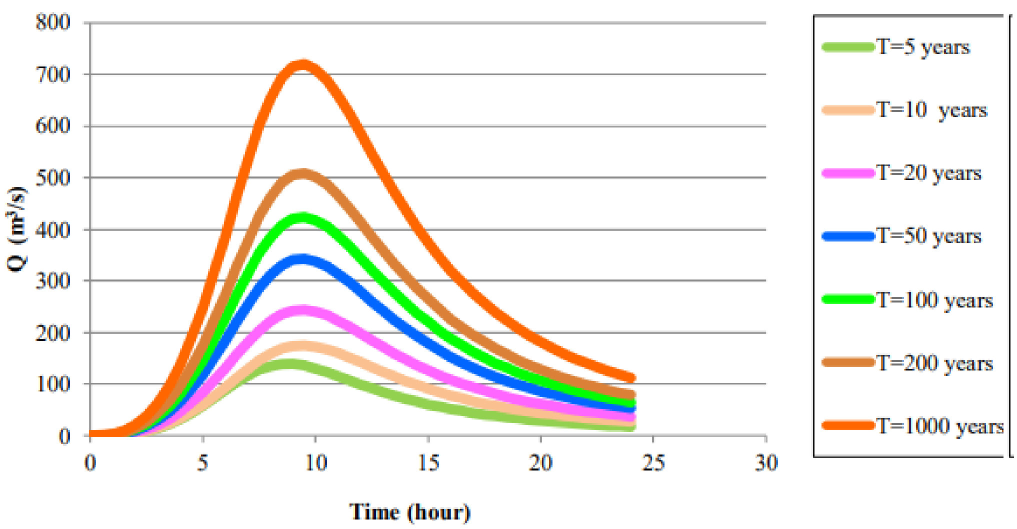


Fig. 6. Frequency hydrograph of the different return periods of the Sebdou Oued (Abdelmoumene H. 2021).

## CONCLUSION

The accurate estimation of extreme hydrological events is fundamental due to the significant risks associated with a poor knowledge of these variables and for this reason the evaluation of exceptional events constitutes an indispensable task for the dimensioning, safety and good production of hydraulic works as well as the elaboration of flood risk prevention plans (PPRI) (Abdelmoumene, 2021).

In fact, the management of this risk is becoming more and more a necessity that must bring together all the actors and all the available means possible to face the risks. We expect that this study will be the subject of other works where these formulas will be tested on all the West and North of Algeria so that we can bring out the adequate formula in the Algerian context in order to better manage our rivers against the exceptional phenomena.

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