THE EXCEPTIONAL INUNDATIONS OF DECEMBER 1984 IN THE SAF-SAF BASIN AND SKIKDA CITY (NORTH-EASTERN ALGERIA): ORIGINS; SPREAD AND IMPACTS

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ABSTRACT:
This article focuses on the study of the exceptional and generalized floods of December, 1984 which affected the city of Skikda, by approaching the study of physical and geographical ability of the basin that supplying as an impluvium inciting the surface runoff, and the hydropluviometric circumstances which caused the genesis and the spread of the floods, by putting into consideration their spatial extension and immediate impacts on the urban and industrial area of Skikda. The city of Skikda, which is one of the high floodability zones, requires an appropriate plan of management and prevention against the risk of inundation.

Key-words: *Algeria, Saf-Saf, Skikda, rainfall, flow, December 1984, flood, damages.*

1. INTRODUCTION

The Hydrometeorological archive of Saf-Saf basin (North Eastern Algeria) and consequently the city of Skikda (the downstream) is particularly marked by a peak hydrology, mainly translated into floods of sudden, violent and widespread features. For example, the floods of 1957 and December 1984 which were the most dramatic hydrological events that affected all cities and impluviums of north eastern Algeria. The singularity of the year 1984/1985 appeared in its exceptional rainfall at the annual, monthly and even daily levels. In a period of 10 days (20 to 31 December, 1984), the basin of Saf-Saf received a total rainfall of 401,3 mm giving rise to a daily flow of 404 m^3/s. Such substantial runoff was difficult to be drained to the downstream of the basin. This caused a submersion of great magnitude which affecting not only the city of Skikda, but also the entire of the region. The damages were enormous; Casualties (11 deaths), destruction of infrastructures, socioeconomic installations, ruined buildings, loss of agricultural lands and isolation of the city of Skikda for more than 10 days.

This paper highlights the physio-geographic and pluviometric conditions of the flood genesis, their extension areas and their devastating effects.

2. GEOGRAPHICAL SITUATION

Belonging to the basins called „Constantinian Coasts" in the north eastern Algeria (**Fig. 1**), the basin Saf-Saf extends over 1150km2 of surface area. The main water course is of 55 km of length and is called Oued Saf-Saf, from which the name of the basin is derived.

The wilaya of Skikda, whose administrative center is located in extreme north, is situated in the north eastern Algeria and covers an area of 4138 km^2. It has about 898,680 inhabitants (NSO 2008). The wilaya has borders with cities of Annaba, Guelma, Constantine, Mila and Jijel, while at the north, it faces the Mediterranean Sea. Also, it

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includes important technical infrastructure (Highways, railways and ports...) and has potential for tourism which allow it to play an important role in economic activities in Algeria. The city of Skikda is located in the far downstream of the Saf-Saf basin adjacent to its estuary and coincides with its floodplain (**Fig. 2**).

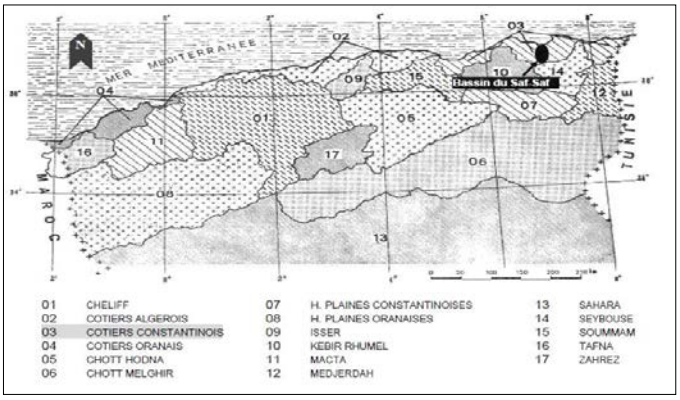

Fig.1 Geographical situation of Saf-Saf basin in Algeria.

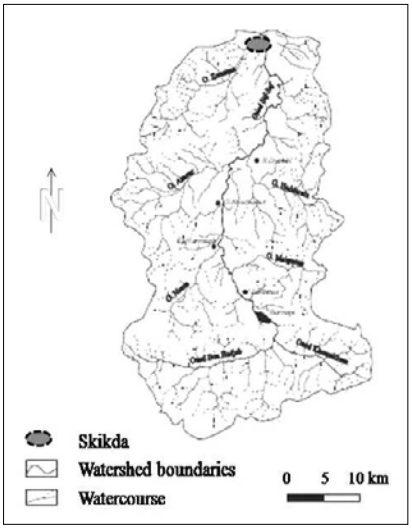

Fig. 2 Situation of Skikda city with regard to the Saf-Saf basin.

3. PHYSIO-GEOGRAPHICAL ASPECT OF THE SAF-SAF BASIN: GREATS ABILITYS TO RUNOFF

As a result of their interactions, the physical, lithologic and biogeographical characteristics of a basin may be a relevant factor of the hydrological phenomena (i.e. a main factor determining the temporal and spatial importance of the hydrological phenomena). The study of the monography of Saf-Saf basin and the calculation of its various morphometric parameters (**Table 1**), in addition to its upstream have enabled us to distinguish two entities of contrasted natures (**Fig. 3**).

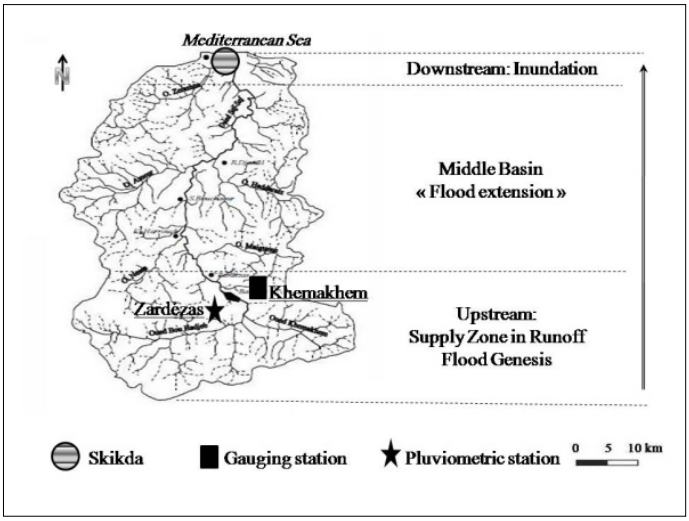

Fig. 3 Saf-Saf basin: areas of supplying flow and hydraulic receiving.

Table 1. ***Morphometric parameters of the Saf-Saf basin and its upper basin.***

Parameters	Upper basin of Saf-Saf	Saf-Saf basin	Unit
(A): Area	322	1154	km²
(P): Perimeter	81	150	km
Altitudes> 400m	97,15	34	%
(C): Gravelius compactness coefficient	1,26	1,24	
(L): Length of the Equivalent rectangle	29,6	46,65	km
(l): Width of the Equivalent rectangle	10,87	24,75	km
(Vd): Specific Vertical Drop	400,17	528,71	m
(Hmax): Maximum Altitude	1220	1220	m
(Hmean): Mean altitude	628	316,53	m
(H50%): Median Altitude	580	286,6	m
(Hmin): Minimum altitude	206	26	m
(Dd): Drainage Density	3,39	0,92	Km/km²
(Tc): Torrentiality coefficient	22,1	0,22	
(Ct): Concentration time 'Giandotti'	6,56	14,57	h
Low to very low permeability	51,82	25,5	%
Perennial vegetative cover	31	25	%

3.1. Zone of suplying runoff (upstream of Saf-Saf)

The upstream of Saf-Saf basin is well surrounded because of rugged relief of considerable altitude (over 400 m), which could be classified among the severe reliefs (Vd = 400,15 m). The dominance of lithologic formations of low to very low permeability (51,82%), with low cover of perennial vegetation that occupied only 31% of its area, promote the surface runoff. Furthermore, the importance of lands with high slopes usually exceeding 12% (68,62%) leads to the formation of dense water system (Dd=3,39 km/km ²) and especially, to large capacity of the runoff mobilization (Ct = 6,56 h).

3.2. Zone of receiving flow (plain and city of Skikda)

This part is marked by the regression of slopes (less than 5%) and by its very low permeability (Quaternary formations), thus, representing highly favorable circumstances for the genesis and spread of immersion.

However, at the whole basin, precipitations result in runoff and flow from considerable heights. In lands of: hard relief (Vd = 528,71 m) and steep slopes, low permeability and permanent vegetative cover, through a dense water system (Dd = 0,92 km/km²) which led to a rapid mobilization of surface water (Ct = 14,57 h) to finally reach the downstream basin (floodplain and Skikda city), where the river is still unable to evacuate the excess runoff in an urban space of low permeability and slope, thus, flooding of areas bordering the river of Saf-Saf.

4. HYDROPLUVIOMETRIC CIRCUMSTANCES OF THE DECEMBER 1984 FLOOD IN THE SAF-SAF BASIN

The Genesis of December 1984 flood is due to concentration of rainfall in time where the rain water is quickly transformed into flow. This concept of concentration is monthly, daily and even hourly visible.

4.1. Monthly Level

The upper basin of Saf-Saf contains the rainfall station of Zardézas and gauging station of Khemakhem that we adopted for the reason of reliability. The monthly rainfalls and flows are shown in the **Table 2**.

Table 2. ***Upper basin of Saf-Saf (1984/1985): Monthly changes in flow (Khemakhem)according to rainfall (Zardézas).***

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Year
Rainfall (mm)	42,3	137,3	17,5	452,5	99,5	46,5	159	38,5	46,3	0	0	0	1039,4
Runoff (mm)	0,39	1,48	0,39	154,3	82,1	25,76	106,6	8,0	4,5	0,5	0,36	0,2	32,09
Runoff coefficient (%)	0,91	1,08	2,24	34,1	82,6	55,4	67	20,8	9,7	0	0	0	3,09
Maximum daily rainfall (mm)	23	20	11	137	20	18	44	18,5	23	0	0	0	Max: 137
Maximum instantaneous flow (m^3/s)	0,23	9,5	0,07	558,6	90,7	12,5	266,5	6,3	10,4	0,1	0,05	0,04	Max: 558,6

December was the wettest (452,5 mm) and the more abundant in average flow (154,4 mm), with a coefficient of monthly flow of 34% (**Fig. 4**), it was marked by two maximum peaks: daily and instantaneous of 404 and 558,6 m^3/s respectively. This was generated essentially by a maximum daily rain of 137 mm (**Fig. 5**).

Also, January is characterized by the largest monthly runoff coefficient, where 82,6% of rainfall (99,5 mm) was transformed into flow (82,19 mm) due to soil saturation by preparatory rains of December.

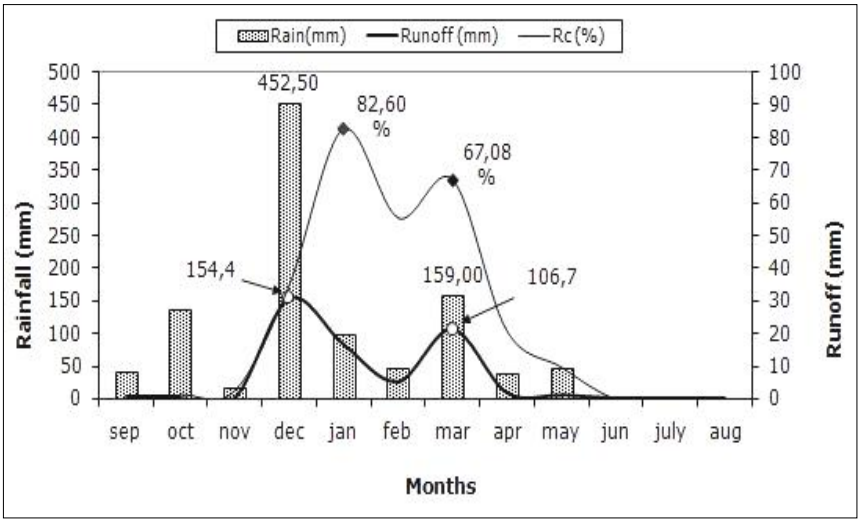

Fig. 4 Upper basin of Saf-Saf 1984/1985: Monthly variations of average flows (Khemakhem) according to rainfall (Zardézas).

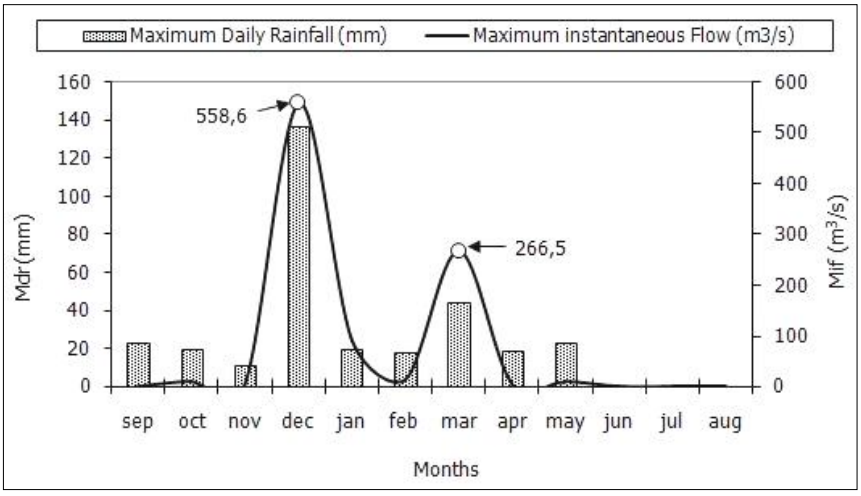

Fig. 5 Upper basin of Saf-Saf 1984/1985: Monthly variations of instantaneous peak flows (Khemakhem) based on maximum daily rainfall (Zardézas).

4.2. The event: daily rainfall-daily runoff and flood evolution

Because of the abundance and continuity of the rain showers, the flood of December 1984 was characterized by a clear correlation between maximum daily flow (404 m^3/s) and instantaneous (558,6 m^3/s) at December 30. During 10 days (from December 18 to 27), the daily rainfalls did not exceed 30 mm, but they were marked by the temporal continuity and consequently, the flow did not exceed 1,4 mm (5,1 m^3/s). However, these rains that were regarded as preparatory have increased the flow to reach 32,3 m^3/s in December 29, following a downpour of 53 mm corresponding to December 28 (**Fig. 6**)

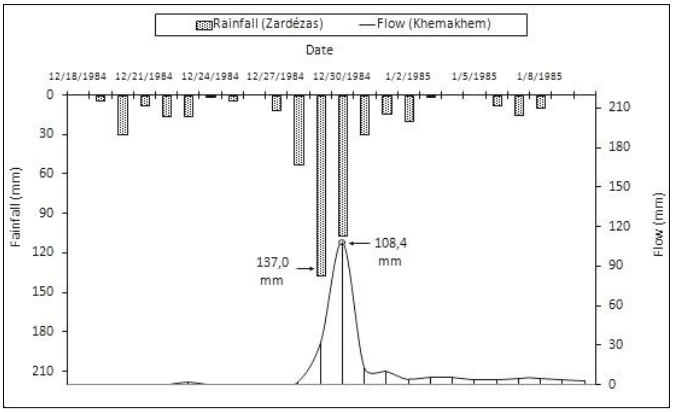

Fig. 6 Flood of December 30, 1984: Changes of daily flows (Khemakhem) and daily rainfalls (Zardézas).

4.3. Hour level: instant evolution of peak flows according to daily rainfalls and events chronology

Due to lack of rainfall intensity data (no rain gauge), we will consider the daily rainfalls and their effect on the growth of flows (**Fig. 7**).

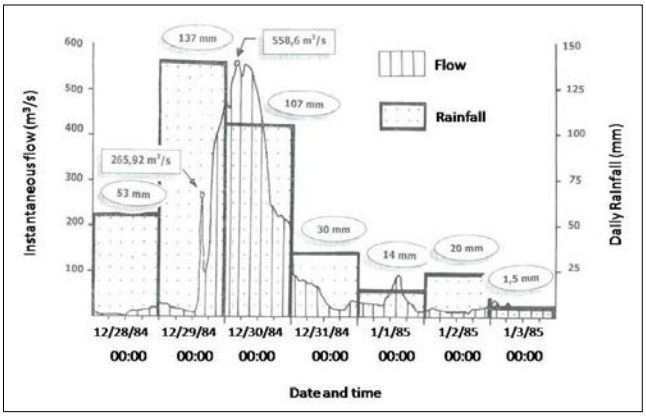

Fig.7 Flood of December 30, 1984: hourly variation of the instantaneous flow (Khemakhem) and daily rainfall (Zardézas).

- December 28, 1984: The flow increased progressively from 7,305 to 25 m^3/s during13 hours.
- December 29, 1984: The flow had taken two hours to pass from 10 m^3/s (15: 00) to 265.92 m^3/s (17: 00), before it attained 90 m^3/s after one hour.
- December 30, 1984: The day of flood, the flow increased from 90 m^3/s to 558,6 m^3/s after 12 hours, then to 250 m^3/s (17: 00) in nine hours, before decreasing again to 90 m^3/s after one hour.
- January 1, 1985: Following a rain of 14 mm, the flow passed from 25 m^3/s to 15 m^3/s (15: 00) in six hours before taking the same duration to decrease to 10 m^3/s.

- January 2 and January 3, 1985: The decrease of rainfall (20 and 1.5 mm) resulted in the stability of flow to the limits of 15 and 21,15 m^3/s.

The time of the hydrological response of the basin to rain sequences never exceeded the limit of 12 hours, and this was directly due to its characteristics that promote rapid mobilization of rain.

5. ESTIMATION OF THE PEAK FLOW OF THE FLOOD OF DECEMBER 1984 AT THE CITY OF SKIKDA (CHEZY AND MANNING'S HYDRAULIC METHOD)

Because of under-equipment of Saf-Saf basin for gauging stations in his downstream part, and in order to calculate the peak flow that suffered the city of Skikda, we have used an empirical method: the hydraulic method of Chezy and Manning's, which gives good results because it takes into account the physical characteristics of water courses, such as the roughness and the slope which are the determinant factors of the flow. After calculating the various parameters, we obtained the results shown in the **Table 3**.

Table 3. ***Parameters from calculating the flow of December 1984 flood in the city of Skikda (Chezy and Manning's method).***

Slope friction	Manning's roughness	Hydraulic radius	Chezy's roughness coefficient	Flow average speed	Flow area	Discharge
I (mm)	n	R (m)	C	S (m/s)	A (m^2)	Q (m^3/s)
0,08	0,03	1,77	36	13	650	8450

So, an exceptional flood flow of 8450 m^3/s was drained by Oued Saf-Saf, submerging large sections of Skikda and its industrial zone and causing damages of rare recurrence.

6. THE IMMEDIATE IMPACTS OF THE DECEMBER 1984 FLOOD

6.1. At the city of Skikda

Urban area of Skikda had suffered extensive damages because of its proximity to the basin outlet; the **Table 4** shows the daily evolution of the damages.

Table 4. ***Daily chronology of damages of December 1984 flood in Skikda city.***

Date	Damages
December 29, 1984	• Submersion of cities: '20 August 1955 ',' Salah Boulkeroua ',' brothers Saker ',' Timgad 'and' Bouabbaz '... • Inundation of the electrical energy station. • Stopping supply of drinking water and electricity • Demolition of communication channels.
December 30, 1984	• Landslides. • Demolition of the natural gas distribution system. • Break of roads and total isolation of the city.
December 31, 1984	• Submersion of the rehabilitation center 'Hamadi Krouma'. • Deterioration of roads, traffic disruption.
from January 1, 1985	• Gradual recovery of activities …

6.2. At the industrial zone: energy/petrochemical sector

Extending about 2000 hectares, the industrial zone of Skikda is located very close to the Saf-Saf river bed (**Fig. 8**). Therefore, it had suffered serious damages, particularly in the LNG unit. The extension of water exceeded 500 meters (**Fig. 9**):

- Deformation of loading lines.
- Destruction of LNG pumping plant: motors, instrumentations, control room, electrical substations.
- Shutdown of the natural gas distribution.

Fig. 8 Location of the industrial zone from Oued Saf-Saf (*Photo B.N, 2006*).

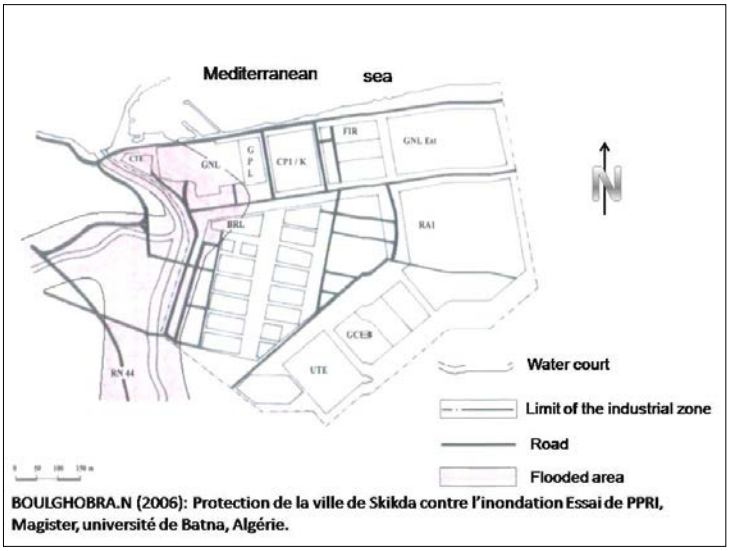

Fig. 9 Industrial zone of Skikda during the floods of December, 1984: the flooded areas.

7. CONCLUSION

Because of its location at the downstream of Saf-Saf basin, the city of Skikda receives flows from a vast and active impluvium, presenting big physio-geographical and hydro-meteorological capacities to the genesis, evolution and spread of the floods.

The year 1984/85 was emerged by hydropluviometric circumstances of exceptional recurrence at annual, monthly and daily levels. Consequently, it was distinguished by the exceptional floods of December 30th, which propagated on hundreds of square meters and provoked of seriousness damage at the floodplain of Skikda.

To overcome this critical situation, it is imperative to establish a prevention plan of flood risk, which focuses on harm reduction through: prediction, prevention and protection. This should include the appropriate managements to apply at the whole basin of Saf-Saf and simultaneously at the city of Skikda itself, and of course, these managements should have the qualities of effectiveness, integrity and complementarity.

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