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Methodology for Tracing a Coastal Flood Risk Card in the Coastal Area of Hammam Lif

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Introduction : Hammam lif is a Tunisian coastal area threatened by the flooding for years, it underwent exceptional meteorological events which are manifested in 4 major storms 1931, 1981,2003 and 2012.
From the study of the anthropogenic and natural damage resulting from each storm, one can deduce the parameters generating the flood in Hammam Lif and generally in each coastal zone threatened by the risk of flooding.
The parameters are: rainfall, wave run-up, urbanization and infrastructure. How to highlight the generating parameters of the coastal flood with the aim of mapping a map with detailed flood risk areas that will serve as a flood risk prevention plan for the Hammam Lif area ? and what census methods and tools to use ?

Keywords : Risk of coastal flooding, hazard, stake, risk map, risk zones, coastal topography, storm impact, coastal zone hammam Lif.

1. Location of the study site

The beach of Hammam Lif is located between the siren restaurant and the municipal stadium. The beach, which has a length of 1540m and a width of 45m, is bordered by a very busy cornice in the evening in summer. This beach is also bordered by a series of residences and buildings especially the Casino. The use of the beach in this area is almost nil because of the presence of protective structures which are the 8 breakers water which made bathing very dangerous. (See Figure 1).

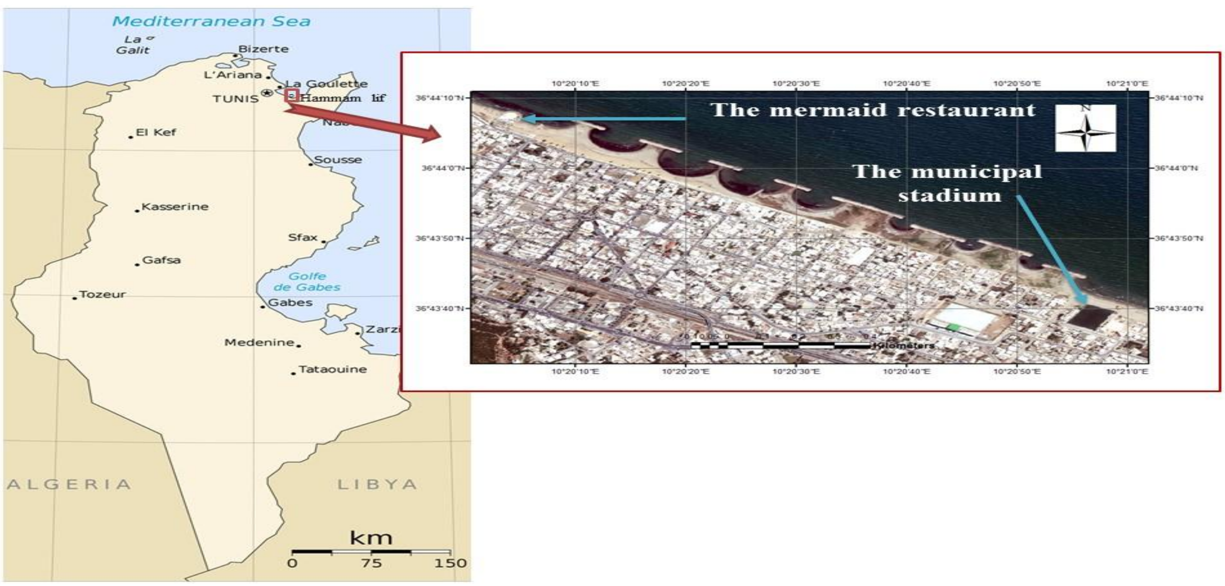

Figure 1. Location of the beach of Hammam LIF

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The beach of Hammam Lif is a beautiful beach, very little frequented at the beginning of the summer and has a sandy beach (see photo 1 and photo .2).

Photo 1. Hammam beach Lif very uncommon in early summer (2012)

Photo 2. Sandy beach of Hammam Lif (2012)

2. Historical major storms and their impacts on the study area

The meteorological events can indeed be of an exceptional brutality which is translated by storms in Tunis and which touched the southern maritime facade and in particular the fringe of Hammam Lif.

The exceptional rainfall events experienced by the coastal zone of the southern gulf of Tunis are the following:

*** The September 2003 rainfall events caused heavy flooding in the Tunis area.**

*** Other episodes of heavy rainfall resulted in heavy flooding:**1931, 1940, 1969, 1973, 1981, 1986, 1989-1990, 1996. At that time, it was possible to note the extreme vulnerability beaches and constructions built nearby. The first reaction was to seek to defend themselves against the sea. It was then that the kick-off was launched to the heavy defense in the southern gulf of Tunis.

The impact of storms on Hammam Lif is studied according to a survey carried out in the Hammam Lif area on 15 September 2014 by visiting elderly citizens: eyewitnesses (60 and 90 years old), other ONAS, the municipality of Hammam Lif and according to the information required from the National Institute of Meteorology and some Internet sites.

*** Storm 1931**

The storm of 1931 is characterized by a rainfall of 212 mm in 6 consecutive days measured at the station of Tunis Mannouba (period of return centennial). This flood affected Oued Meliane, this wadi pours its contained in the sea of Hammam Lif. (BRGM, 2011), (see Table 1 and Figure 2).

Table 1. Storm 1931 and its impact on Hammam Lif

	Impacts on the study area
Storm 1931	- Damage due to the silting up of some roads. -Death of animals -A water table height of 7cm to 30 cm recorded in the walls of houses (See Figure 2) -a marine submersion is recorded.

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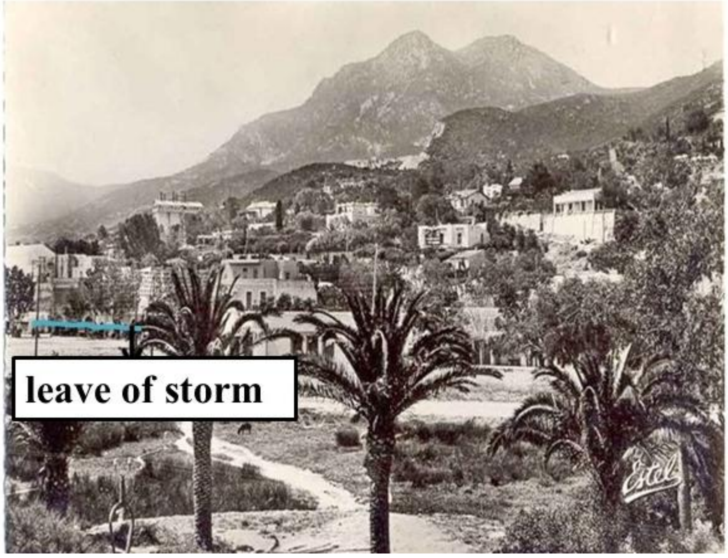

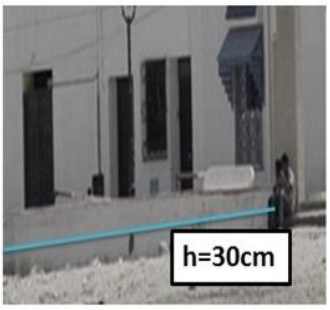

Figure 2. Schematic diagram of the 1931 Storm Leash in Hammam Lif and the water height marked on a wall of a house

*** Storm 1981**

Table 2 and Figure 3 show the impact of the 1981 storm on Hammam Lif

Tableau. 2. *Tempête 1981 et son impact sur Hammam Lif*

	Impacts on the study area
Storm 1981	-A water entrance into the houses. -A road damage and death of animals and people. -A storm leash of 100 cm with recording of 50 to 75 cm as the height of water in the walls of the houses. (See Figure 3). -The waves attacked the beach amenities and favored a large sand transit. -Recording of the coastline after the storm.

Figure 3. Diagram of the 1981 Storm Leash at Hammam Lif and the water depth marked on a wall of a house

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***Storm 2003**

Table 3 shows the impact of the 2003 storm on Hammam Lif

Table 3. Storm 2003 and its impact on Hammam Lif

	Impacts on the study area
Storm 2003	-A water entrance into the houses. - Infrastructure destruction -An asphyxia of the Agglomeration for several days. -A road damage and death of animals and people. -The isolation of certain sensitive areas for several weeks - overflow of sewage networks. -A storm leash more than 100cm with recording from 50 to 100 cm as the height of water in the walls of the houses.

During this flood, all the sanitation networks and their associated retention basins were overwhelmed, causing the pavements to flood through extremely violent torrential flows. For this flood, significant water heights exceeding 50cm to 1.00m have been observed in different areas of the Lif hammam area. (See Figure 4).

Figure 4. Schematic of the 2003 storm leash at Hammam Lif and the water depth marked on a house wall

*** Storm 2012**

Table 4 shows the impact of the 2012 storm on Hammam Lif

Table 4. Storm 2012 and its impact on Hammam Lif

	Impacts on the study area
Tempête 2012	-A water entrance into the houses. - Infrastructure destruction -An asphyxia of the Agglomeration for several days. -A road damage and death of animals and 1 person. -The isolation of certain sensitive areas for two days - overflow of sewage networks. -A storm leash more than 100cm with recording from 50 to 100 cm as the height of water in the walls of the houses.

The National Institute of Meteorology launched on its site that during the days 14 November and Thursday 15 November 2012, stormy and intense rain in significant quantities 132 mm / 24h, the wind is from sector east is strong

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from 50 to 70Km / h near the coast of Hammam Lif and exceeds 80km / h under thunderstorms, the sea is very restless. For this flood, significant water heights exceeding 50 cm to 1.00 m have been observed in various areas of the Lif hammam area (see Figure 5).

Figure 5. Schematic of the 2012 storm leash in Hammam Lif and the water depth markedon a house wall

2.1. Period of storm return to Hammam Lif

The return period is calculated from the data collected for the type of event desired, classified by intensity: Interval between two events the same intensity of

I= n+(1) /m Eq(2.1)

With:

n : the number of years covered by the data;

m : the number of events with the intensity considered, during these years (Meylan.P (2004)).

The lower the occurrence of the intensity of the phenomenon, the more difficult it is to use this equation. A statistical distribution is therefore most often used. Over a period of n years, the probability that a number k of an event has a return period of t is given by a binomial distribution. For a long period, n tending to infinity, the equation converges towards a distribution of fish:

$$1/T = \frac{m}{n+1} \qquad \text{Eq(2.2)}$$

If the probability of an event is p, the probability that it does not occur is q = (1-p).

The binomial distribution can then be used to find the occurrence r of an event during the n-year period:

$$\binom{n}{r} \times p^r \times (1-p)^{n-r} \qquad \text{Eq(2.3)}$$

* The various historical storms of Hammam Lif which constitute reference events for this study given the availability of the data are as follows:

* Storm 1931, Storm 1981, Storm 2003, and Storm 2012.

The following table 5 is a summary table of all the storms, their rainfall, wind speed and their corresponding water table heights.

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Table 5. Historical storms in the Lif hammam area, their corresponding rainfall patterns and associated water levels.

Year, Month and Storm Days	Rainfall (mm / h)	Wind speed (Km / h)	Height of water blade in the walls of houses
Novembre 2012	132mm/h	70	De 50 à 1,00m
17 Septembre 2003 24 Septembre 2003	186mm/24h 136mm/h	60	De 50cm à 1,00m
20 et 21 Janvier 1981	-	140	De 50cm à 100cm
1931	212 mm/6jours	80	De 7 à 30cm

Over a period of 81 years, the period of return of a storm with extreme characteristics (Wind intensity of rain) and generating the marine submersion in the zone of Hammam Lif is of 20 years.
I=n+1/m= (81+1) /4= 20 Years.

3. Materials and Methods

The mapping of flooded areas is important in order to assess the damage and to help the managers, the insurance to prevent the risk of flooding in the area of Hammam lif. (Wijtunge, 2006).
The possible Methods for mapping flooded areas in Hammam Lif are :

Method 1 : Use of satellite imagery to map flooded areas over large areas (Wang, 2004, Kiage et al., 2005).

Method 2: Photograph the flooded areas by aerial overflight at the time of submersion, which in a macro-tidal environment generally takes place during a lowland (Benavente, 2006).

Method 3: Collect clues in the field. Many authors choose to conduct eyewitness interviews to delineate flooded areas (Keating and Al, 2004).

Method 4: Use of physical markers or markers as indicators of flood limits such as seagrasses, visible heights on building walls are excellent markers (Wijentunge, 2006), the study of the state of vegetation (deterioration of vegetation due to salt water may also help to delineate areas that have been under water for a few hours (Tsuji et al., 2006). The figure 6 shows a synthetic diagram of the diffèrent layers GIS for the mapping of flooded areas by the sea (after Cariolet, 2010).

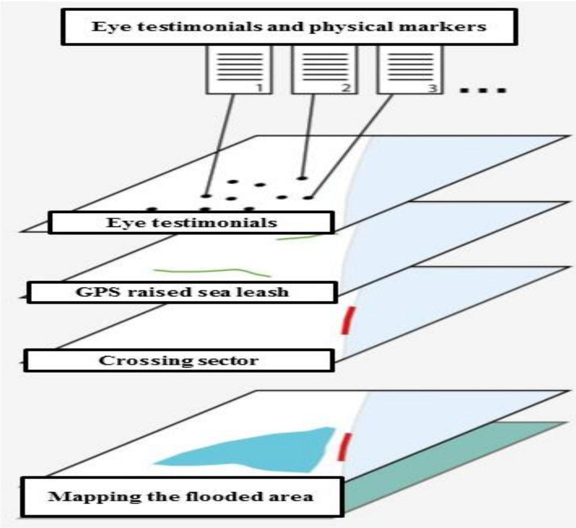

Figure 6. Synthetic diagram of the different layers integrated into the GIS for the mapping of flooded areas by the sea (Modified from Cariolet, 2011).

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Method 5: Study of the sedimentary deposits: study of the particle size sorting, many authors have demonstrated the link between the granulometry and the delimitation of the flooded zone.

Method 6: The position of the low pressure center at the time of the open sea because it plays a key role in the location of submerged sites (Cariolet, 2011).

***Field data collection on 16 November 2012**

A field trip on 16 November 2012 for a census of the physical marks of the flooding

- ✓ On the ground, the method of investigation was based on a series of informal interviews with local residents and a census of the physical marks showing the limits (vertical and horizontal) of the flood. For each informal interview, the following information was noted.
- ✓ The exact address noted on a map (at El Kehna, Azziza Othmana, Moufida Bourguiba and Libya) serves to spatialize the interview,
- ✓ Schedule and duration of the flood
- ✓ The height of water reached in the walls of the houses (house of Marrakechi, house of Trabelsi, mosque, Corniche, the church, the old Casino ...) measured by a meter.
- ✓ The direction of the current and the origin of the water (to trace the sectors of crossing and / or overflow).
- ✓ The boundaries of the flooded area (near the place of maintenance). The spatialization of the identified limits of the flooded areas was carried out by GPS survey or by annotation of the address of the house closest to the limit.

*** Mapping of areas at risk of flooding in Hammam Lif:**

The methodology for mapping flood risk areas is generally around three points (Benavente et al., 2006, Fletcher et al., 1995, Bellomo et al., 1999, Suanez et al., 2007, Kumar et al. al., 2008). Initially, submersion hazard is estimated by quantifying the extreme water levels at the coast for a given return period, usually 100 years.

This estimate takes into account the different parameters acting on the rise of the level of water at the coast, in particular the surcharge and sometimes the effects due to the marine agitation such as the wave run up. In a second step, the mapping of the hazard is obtained by plotting the extreme water level on the topography of the study area. (See Figure 7).

Finally, risk mapping is performed by comparing the potentially submersible zone with the location of human issues (Solomon and Forbes, 1999, Meur-Férec et al., 2008, De Pippo et al., 2008, Vinchon et al.) In France, Marine Submersion Risk Prevention Plans (PPR-MS) aredeveloped using this method.

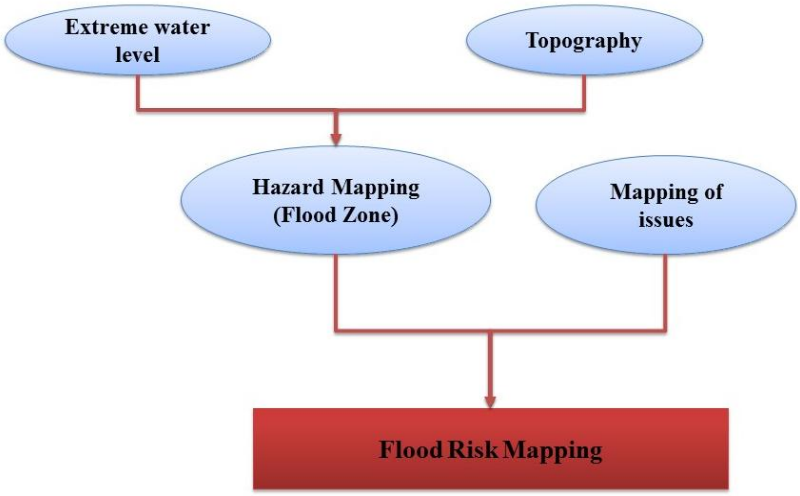

Figure.7. Conventional method of mapping areas subject to the risk of marine submersion.

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The potentially submersible zone obtained is then compared with the location of the human stakes. This approach creates regulatory zoning maps. The captions vary according to the operators but generally:

- High risk areas (red areas).
- Medium risk areas (orange areas).
- Areas with low risk (Blue Zones).
- Areas with very low risk (Green Zones).

* The red zones are inconstructible and the extension of the existing frame is not allowed. Only non-perennial installations can be tolerated under prefectoral authorization.
* For orange areas, the construction of new dwellings and the extension of the existing building are permitted subject to special requirements. For example, the living area must be above a shelter level, usually a few tens of centimeters above the previously defined centennial coastline.
* For blue zones, the risk is low, construction of new dwellings and extension of the existing building are allowed subject to special requirements.
* For green areas, the risk is very low but there is, the construction of new dwellings and the extension of the existing building are allowed subject to still special requirements.

4. Results and discussions

The co-ordinates of the measurement points of water table heights immediately after storm 2012 are illustrated in the following Table 6:

Table 6. Measurement points for water table heights after storm 2012

N°	Measuring point	GPS coordinates X: Longitude, Y: Latitude (°)	Corresponding water blade height (cm)
1	A	10,334- 36,733	100
2	B	10,336-36,734	100
3	C	10,334-36,731	100
4	D	10,338-36,732	100
5	E	10,34-36,732	100
6	F	10,338-36,729	100
7	G	10,336-36,732	80
8	H	10,339-36,728	80
9	I	10,341-36,730	80
10	J	10,343-36,730	80
11	K	10,341-36,729	80
12	L	10,342-36,727	80
13	M	10,344-36,728	50
14	N	10,344-36,729	50
15	O	10,346-36,729	50
16	P	10,347-36,728	50
17	Q	10,348-36,728	50
18	R	10,343-36,727	5
19	S	10,344-36,726	5
20	T	10,345-36,726	5

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4.1 Intégration of data in a Geographic Information System

All the informations gathered in the field was then integrated into a geographic information system (GIS), using the ARCGIS 9.2 software. Flooded areas deduced from physical marks were digitized. The vectorization of these sectors made it possible to calculate surfaces. The seafloor delineating the flooded area - measured by GPS - was integrated into the GIS via Surfer 11. They are represented by a linear figure and are used to define more precisely the flooded areas in certain places. Each water level measured on the ground is represented by a punctual figure (many information such as the water height of the point are integrated in the attribute table). Finally, the crossing and overflow sectors are represented by a linea figurative.

***Storm 2012**

Figure 8 shows the water table heights that vary between 5cm and 100cm with a delimitation of the zone flooded in blue during the storm 2012 in Hammam Lif.

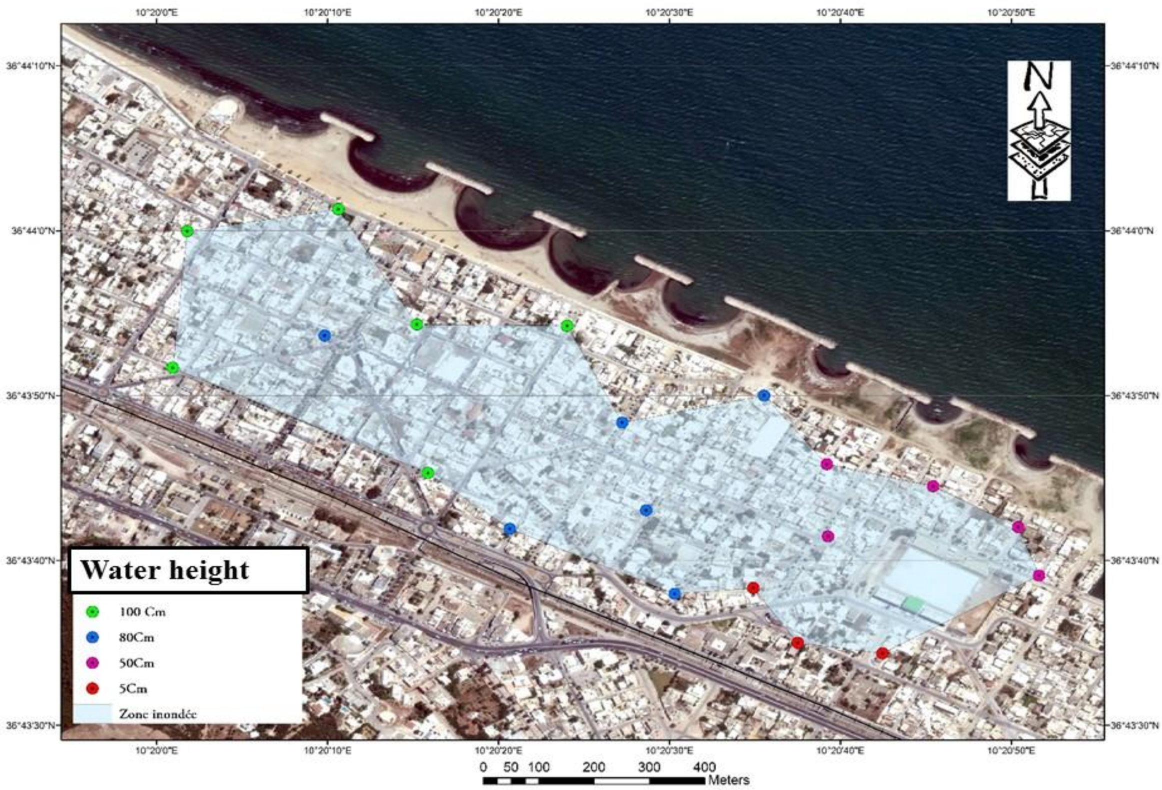

Figure 8. Representation of flooded areas in Hammam Lif for storm 2012

The heights of water slides of 100 cm are represented by green dots, the heights of water slides of 100 cm are represented by blue dots. The heights of 50cm water slides are represented by pink dots and the heights of 5cm water slides are represented by red dots.

4.2Tracing Flood Risk Map to Hammam Lif

The mapping of the zones of risk requires a topographic map and a detailed urban plan of the urban area near the coast of Hammam Lif.

The tracing of risk areas was based on:

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1-The maxima of the heights of water slides reached during a storm for each zone.
2-The rate of urbanization in each zone, the more the urbanization is intense the more the flood is favored
3-Terrain topography: Flooding is intense in low areas whereas it is medium in areas with medium topography and low in high areas.
4-The condition of sanitation networks in the total area.

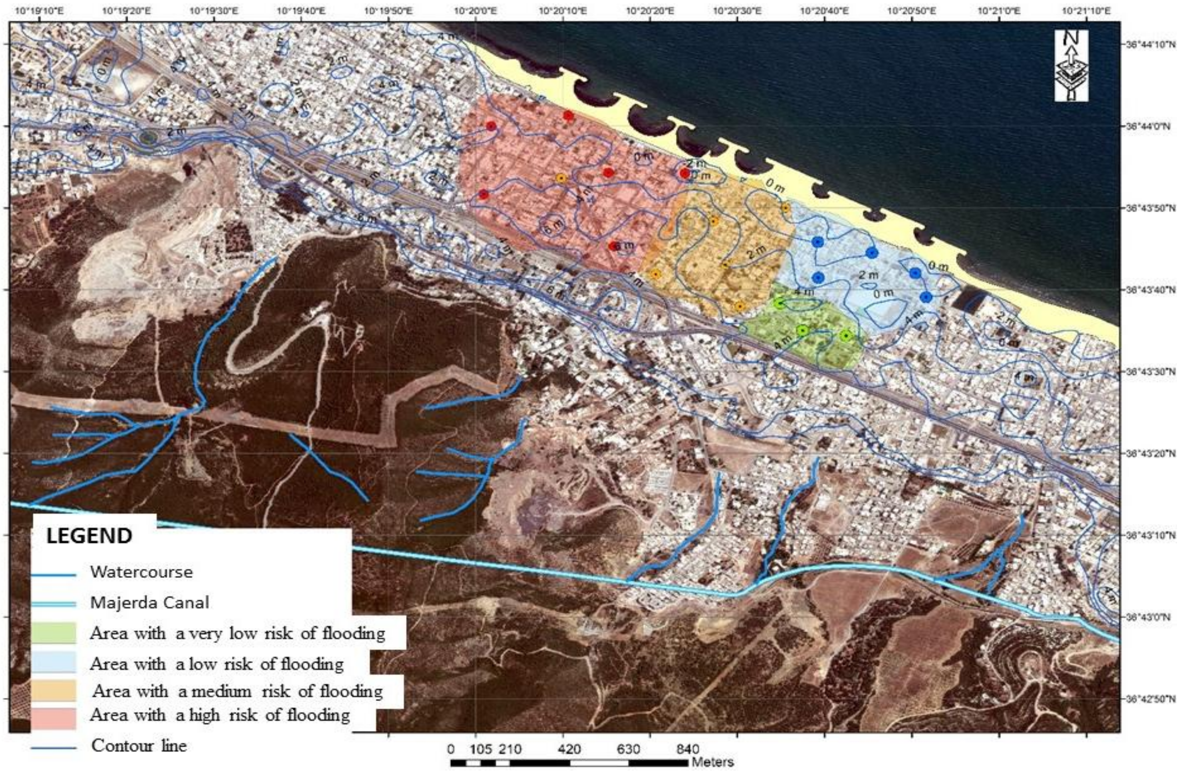

Figure 9 : Hammam Lif flood risk map

4.3. Interprétation and discussion

Flood risk zoning in the coastal area of Hammam Lif gave the following findings:

Red zone:
This is a zone with a high risk of flooding characterized by:
* Maximum water levels of 100 cm.
* An intense urbanization, therefore a strong coefficient of waterproofing from which an important runoff.
* Irregular topography at low with contours (-2m, 0m, 2m, 4m and 6m).
* Unit sewerage networks blocked and full, the fact that it is used to perforate them to evacuate waters to the sea.

This highly hazardous area (red zone) is inconstructible and the extension of the existing building is not allowed. Only non-perennial installations can be tolerated under prefectoral authorization.

The orange zone:
This is a zone with a medium risk of flooding entities by:
* Maximum water levels of 80 cm.
* Average urbanization therefore a strong coefficient of waterproofing from which an important runoff.
* Irregular topography with low level contours (0m and 2m).
* Unit sewerage networks blocked and full, the fact that it is used to perforate them to evacuate waters to the sea.

This zone, moderately exposed to risk (orange zone). the construction of new dwellings and the extension of the existing building are allowed subject to special requirements. For example, the living area must be above a shelter level, usually a few tens of centimeters above the previously defined centennial coastline.

The blue zone: It is a zone with a low risk of flood characterized by:
* Maximum water levels of 50 cm.
* Average urbanization therefore a strong coefficient of waterproofing from which a large runoff.
* Medium low irregular topography with contours (-2m, 0m and 4m).
* Unit sewerage networks blocked and full, the fact that it is used to perforate them to evacuate waters to the sea.
This area, which has a low risk of flooding (blue zone), presents a low risk, but there is a risk that the construction of new dwellings and the extension of the existing building are permitted subject to special requirements.

The green zone :
It is a zone with very low risk of flood characterized by:
* Maximum water levels of 5 cm.
* Average urbanization therefore a strong coefficient of waterproofing from which an important runoff
* High topography with contours (4m).
* Unit sewer system blocked.
This area is poorly exposed to the risk of flooding (green zone). The risk is very low but there are existing, new housing construction and extension of the existing building are allowed subject to still special requirements.

6. Conclusion

In a direction from north to south, the present study has shown that Hammam Lif presents a zone with a high risk of flooding over an area of 607.83m, presents a zone with a medium risk of flooding over an area of 362, 72m and a low risk flood zone over an area of 477.47m.

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