Flood risk assessment and territorial planning in the playas canton

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***Abstract*— The General Villamil Playas canton suffers every year from floods in some neighborhoods and proportions, in some places, especially in informal settlements and high-risk sites. Over the years, it increases with each winter season instead of diminishing the threat, especially in years corresponding to the El Niño phenomenon. The PDOT 2019 – 2023 of the Playas canton identifies the risks in the territory without evaluating the specific places and the levels of risk. This research applies the method developed by the National Secretariat for Risk and Emergency Management (SNGRE) in the Playas canton. The methodology was used to assess the risk of flooding due to extreme rainfall and the arrival of a tsunami. As a result, this canton has a medium risk level for floods caused by extreme rainfall and a high-risk level in the presence of a tsunami.**

Keywords: Risk; threat; floods; extreme precipitation

I. Introduction

THE Coastal areas around the world favor the concentration of the population due to the multiple natural resources found there. Historically, civilizations have developed alongside bodies of water, such as large river mouths or sea banks [1] [2], creating pressure on fragile ecosystems, which can evolve into real environmental and social problems [3].

Urbanization is a complex process that determines the occupation of the territory and generally does not care about the ecosystems where it is installed, which creates centers of growth and development with consequences for the ecosystem [4].

The population of the canton Playas is a community of artisanal fishermen; its history has evolved along with its population. Due to its proximity to a large population center such as Guayaquil and the commercial axis that it represents, it has become the favorite tourist destination of the province and the country, thanks to the benefits of its climate. In 2007 the Playas canton became the only sun and beach tourist destination in the province of Guayas, along with the construction in 2010 of the 4-lane highway that connects Guayaquil with Playas and the construction of the new deep-water port in 2016 in the town of Posorja, located less than 20 km away from the Playas canton, generated great momentum and accelerated growth. In this way, Villamil Playas went from being just a settlement of artisanal fishermen to being a beach tourism destination preferred by the population of Guayaquil and its axis of influence.

The objective of this work is to evaluate the risk associated with floods caused by extraordinary climatic events in the canton Playas, as a contribution to the management of the municipal government in decision-making regarding the application of territorial planning. The Playas canton is part of the Province of Guayas and is located 93 km from the city of Guayaquil, at an average height of 3 ms.n.m, with a total area of 27 014.27 ha, and an urban occupation area of 8 108.57 ha and rural of 18 905.7 ha. It should also be considered that it has a protected area of 2 478.12 hectares, of which 93.17 ha are terrestrial and 2,384.95 ha are marine [5]. Playas is bordered to the north by the cantons of Guayaquil and Santa Elena, to the east by Guayaquil, and to the west by the Pacific Ocean (Fig.1).

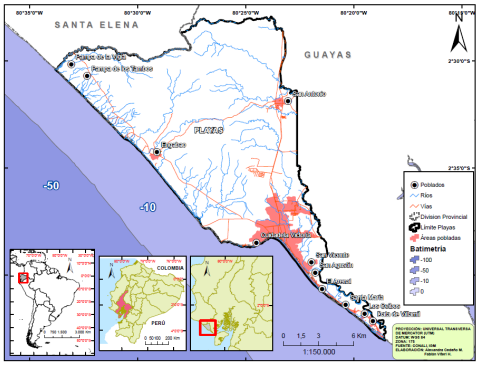

Fig. 1. Geographical location of the canton Playas (Beaches) Source: IGM 2018. Own elaboration

The Playas canton is known for having a pleasant climate all year round, with an average temperature of 24.4°C, a maximum of 29.7°C, and a minimum of 19°C. The normal accumulated rainfall is 400 mm a year; the rainiest months are February and March. The average relative humidity is 80% [6]. However, the range of variability of rainfall has been high, especially in the rainy season, due to the presence of the El Niño phenomenon that from time to time, between 7 and 10 years, occurs off the coast of Ecuador, bringing meteorological, biological, social and environmental consequences. On the climate issue, events such as El Niño are of special importance in the whole country's coastal territory and are no less important in the Playas canton. The topography of the relatively flat coast is an exceptional feature that elevates it as a strong tourist attraction. Still, it is also a disaster scenario when rainfall occurs out of range during El Niño events [7], also making it vulnerable to the arrival of an eventual tsunami because it is located in the Pacific ring of fire [8]. In addition to the high amount of precipitation, the climate in the coastal area is altered by the winds, and the sea temperature that raises the sea level facilitates the presence of waves of great magnitude that carry large bodies of water inland razing the structures and constructions that are in its path.

These flooding events can occur in a short period of time with such a magnitude that, in general, the Municipality does not expect it and no infrastructure has been planned to face them [9] [10]. Reports of heavy flooding during the rainy season have been in the news in local newspapers [11]. The consequences after the damage assessment can cost a lot in human lives, material goods, and infrastructure.

The accelerated growth of the population and productive activities of the Playas canton attracts increasingly important investments, which generates imminent and accelerated urban growth [12]. However, the adequate territorial planning of the Playas canton has not grown at the same speed, the city is expanding without planning or providing adequate coverage of basic services, nor is the protection of the fragile ecosystems that surround the city, such as the dry forest, hills, and riverbeds considered [13].

The demand for space for population growth puts pressure on ecosystems; many build on places of risk, such as the dry channels of seasonal rivers, which are filled with water eventually, creating floods that overflow, devastating any construction that has settled on top and endangering the lives and property of many people [14].

The territory of the canton has three different areas: the populated area or in the process of expansion included, which occupies 20%; the industrial production area, which occupies 10%. And the cantonal protection area, which occupies 70%, Table 1.

TABLE 1
APPROXIMATE OCCUPATION OF THE TERRITORY PLAYAS TO 2021

Territory	%
Village	20
Production	10
Protection	70
Total	100

Source: PDOT 2019 – 2023 of the playas canton and Ecuador in INEC 2019 figures. Own elaboration

During each winter season, the Playas canton suffers from floods that risk the life and property of the inhabitants of the city, who are mainly engaged in beach tourism and artisanal fishing. The National Secretariat for Risk and Emergency Management (SNGRE) has to respond to the population's calls for help and performs a response task to emergencies arising. Although the

Municipality of the canton is the entity that has by law the competence on the issue of risks caused by floods [15], it is recognized that there is the problem of high vulnerability to floods in some fully identified sectors and even the causes of this vulnerability in the canton are known. However, there is a gap in an adequate and up-to-date technical study of the threat posed by flooding at this site, both due to the heavy rainfall that occurs during the rainy season and the presence of a tsunami that reaches the coasts of the canton, which to date has not happened. In that case, the spa would suffer terribly since the greatest productive activity is based on the coastal edge.

II. Materials and Methods

For the assessment of the risk, its identification, and assessment in the event of floods due to severe rainfall in the Playas canton, the toolbox of the National Secretariat of Risk and Emergency Management SNGRE was applied, as has been done in other regions of the world [16].

To explore and evaluate the risk of threats of natural origin of the territory of the playas canton that cause flooding and loss of human lives, infrastructure and material goods, it was determined what is the threat to which this study refers, and through the tools of the SNGRE it was determined that the threat is the flood caused by heavy rainfall.

A tsunami risk assessment was then carried out applying the results of the studies carried out in the playas canton by the SNGRE, using flood maps, and the research carried out by Arreaga [2]. Finally, interviews were conducted with some directors of the thematic tables of the Cantonal COE Emergency Operations Committee of Playas in order to obtain their criteria on the risk faced by the inhabitants of the canton. The interviews aimed to obtain more information to help assess risk in low-lying areas subject to flooding. The interview was sent online. The modality was with open questions; the directors of the technical tables of the cantonal COE who present themselves to the emergencies were chosen. Their responses reflect the reality experienced by the affected people, what happens in the territory during the floods, the causes of the disaster and what could have been avoided or minimized.

A. Threat determination. -

The threats analyzed in this research paper are floods caused by heavy rains and tsunami arrival. The floods due to extreme rains that occur from time to time during the occurrence of El Niño events are well documented in the scientific literature [17], and are also reported by local news.

For this work, a technique was used to assess the threats in the territories; following this indication, the following analysis has been carried out:

B. Threat calculation. -

For each identified threat (flooding due to rainfall and tsunamis), the intensity, frequency, and affectation of the territory will be analyzed using the methodology of the SNGRE. From this data, the threat is rated in a matrix with the following scale:

Equation (1) Threat (A) = frequency (F) + affected territory (T) + Intensity (I)

The resulting values that arise after the corresponding calculations according to the territory to be analyzed range between 1 and 9 and are scaled as shown in Table 2.

TABLE 2
Threat rating

Interval	*Threat Rating*
1-3	Casualty
4-6	Stocking
7-9	Loud

Source: SNGRE 2019 Toolbox. Own elaboration.

The Risk Management Unit and the Cadastre Department of the Decentralized Autonomous Government GAD of the Playas canton have identified 18 areas vulnerable to flood risks due to extreme rainfall [12]: Barrio Unidos Venceremos, Barrio Riveras del rio, Barrio Mónica de Verduga, Barrio Voluntad de Dios, Barrio Garay, Barrio Narcisa de Jesús, Barrio Manabita, Barrio Chacralinda, Barrio Tiwintza, Barrio La planta, Barrio Santa Isabel, Barrio Aguas verdes, Barrio Altamira, Barrio Torbay, Barrio Hospitalario, Barrio Venecia, Barrio San Jacinto and Barrio Playas Dos, which represent 30% of the total urban area. This qualifies the threat as a High occurrence for extreme precipitation flooding according to Table 5 of the event.

TABLE 3
Territory affected due to dangerous events

Territory	*Qualification*
More than 30% in 5 years	Loud

Between 15 - 30% in 5 years	Stocking
Less than 15% in 5 years	Casualty

Source: PDOT Playas 2019. Own elaboration.

During the last flood events, the SNGRE carried out a survey and diagnosis of the situation and reported that 146 homes were affected as reported by the Municipality in its 2017 diagnosis [12], but it is estimated that at least 15% of the homes settled in the low-risk areas that do not have adequate sanitary infrastructure would be at risk according to the beach flood map in Figure 2.

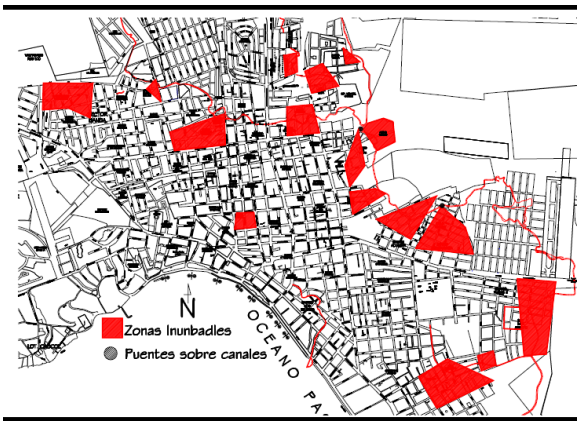

Fig. 2. Beaches Flood Map
Source: PDOT Beaches 2021

Applying the data reported by the Municipality of Playas after the assessments of each flood event to the threat assessment equation is the following approach: The frequency (F) of occurrence of hazardous events refers to how many events have been identified by the SNGR in a period in the territory and is evaluated according to Table 4.

TABLE 4
DANGEROUS EVENTS QUANTIFIED IN THE CANTON PLAYAS

Frequency	*Qualification*
More than 1 time in a period of 1 to 3 years	Loud
At least 1 time in a period between 3 and 5 years	Stocking
At least 1 time in a period longer than 5 years	Casualty

Source: PDOT Playas 2019. Own elaboration

The second variable is evaluated according to the affected territory (T) during the occurrence of past dangerous events. Table IV. The third variable to evaluate is the intensity of hazardous events (I) in the canton. This is done by identifying the percentage of homes affected in past events, according to Table 5.

TABLE 5
INTENSITY OF THE EVENT

Intensity	*Qualification*
More than 10% of homes destroyed or more than 30% of the population affected in 5 years	3
Between 5 - 10% of homes destroyed; or between 15 - 30% of the affected population in 5 years	2
Less than 5% of homes destroyed or less than 15% of the population affected in 5 years	1

Source: PDOT Beaches Data 2019. Own elaboration

Applying equation (1) of the flood threat due to heavy rainfall, we have the following:
Equation (1) Threat (A) = frequency (F) + affected territory (T) + Intensity (I)

$$A = 2 + 2 + 3$$
$$A = 7$$

According to Table 2, a value of 7 corresponds to a High Threat of flooding due to heavy rains in the canton.

C. Tsunami vulnerability assessment

The evaluation for this work took as a reference the flood map generated by the SNGRE through the platform of the United Nations Office for Disaster Risk Reduction UNDRR (Figure 3), where it can be estimated that a population of approximately 20% of the total population of the Playas canton (49,000) would be exposed in the line of the impact of an eventual arrival of the tsunami, which gives an approximate of 9,800 people who would be at risk [18].

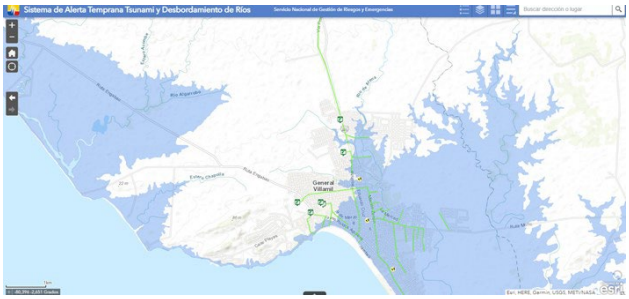

Fig. 3. Estimated image of the flood zones due to the arrival of a tsunami in the playas canton. Source: Risk Management Ec.

The Municipality of Playas together with the SNGRE carried out a cartographic survey in 2015 of the areas of Playas that could be affected by an eventual tsunami in the canton, which indicated how far the flood could go and which sectors would be under this threat, which is presented in Figure 4 where it can be seen that the flood zone closest to the coast is the one with a slope of up to 12%, it is located less than 600 meters from the coast and, depending on the degree of the tsunami and the height of the wave. The canton's threat of tsunami is high.

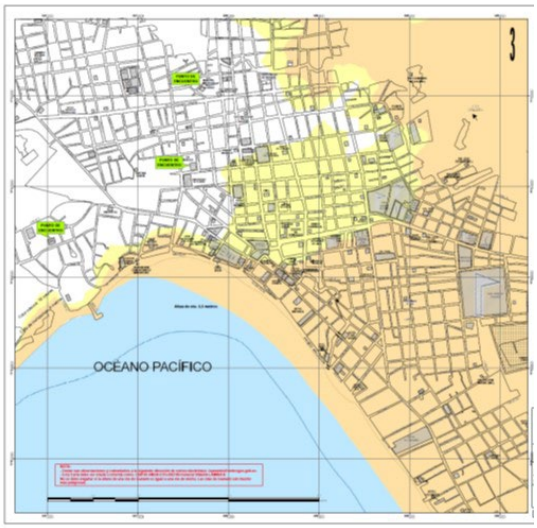

Fig. 4. Tsunami flood charter in the Playas canton. Source: SNGRE. EC

Applying the same equation (1), but now to qualify the threat in the presence of a tsunami on the coasts of the canton Playas, and Tables III, IV, and V, the following result is obtained:

(1) $A = F + T + I$

$A = 1 + 1 + 2$

$A = 4$

D. Organization of the interview. -

In the interviews, questions 1 – 4 refers to the perception of authority about the cause of the vulnerability experienced by people in flooded neighborhoods, what characteristics those people have and what affectation they can identify. Questions 5 and 7 refer to the response of people at risk to the events themselves. Questions 6, 8, 9, and 10 refer to the professional criteria of the director of the technical table on what would be the best strategy to face these events and minimize the risk of flooding in the canton Playas.

III. Results

As a result of the application of the SNGRE methodology in this research work, it can be indicated that the threat of flooding due to extreme rainfall and tsunamis in the Playas canton would be identified as follows (Table 6):

TABLE 6
CANTONAL THREAT ANALYSIS MATRIX

Threat	Frequency	Territory concerned	Intensity	Threat rating
Floods	2	2	3	7
Tsunamis	1	1	2	4

	Threats	Event	Qualification			
			Loud	Stocking	Casualty	Not applicable
Natural	Geological	Tsunamis				
	Hydro meteorological	Floods				

Own elaboration

The results obtained in this work refer only to the so-called "high vulnerability" sectors that are less than 5 ms.n.m, identified in the PDOT as sectors at risk.

Analysis of interviews

The analysis of the responses to the interview gave the following result

Questions 1 – 4

The responses reflect that the people who arrive in these sectors at risk are mostly foreigners, have little knowledge, and also due to lack of planning and order in the delivery of construction authorizations in previous municipal administrations.

Questions 5 and 7

People at risk do not leave the home, even when it is flooded; they prefer to stay before losing what they consider a valuable possession. They are aware of the risk, but they don't care much.

Questions 6, 8, 9 and 10

In the opinion of the interviewees, the best strategy would be better planning, better control, and a lot of socialization of citizens on issues of risk and environment.

IV. Discussion

The results of the risk assessment against climate threats in the Playas canton focused on two main events:

a) Flooding by Tsunamis which, as presented in the analysis, is of medium risk due to temporality.

b) Flooding by intense rainfall that is expected to be frequent due to the way irregular settlements have been growing. Although the rains are not heavy every year, when they exceed the annual average, emergencies occur in the lower neighborhoods due to the blocking of natural vent channels.

In both cases, the most vulnerable areas will be the coastline, from the breakwater of the sector called Humboldt to the mouth of the Data estuary and from the high tide line to the level of 5 m.a.s.l. In addition, the low areas of the center of the canton in the urban area. These sectors have already been identified in the PDOT 2019 – 2023 and corrective measures are not yet taken to evict illegal and dangerous settlements.

In the political-administrative sphere, it is necessary to apply the law that empowers the municipal authority with regard to housing construction permits in areas declared as at risk. Regardless of whether they have many years of possession, they are still in danger, and all these illegal constructions must be relocated [19].

On the technical issue, the proposal is to plan the provision of basic services according to the growth and demand that urban expansion will require [20] [21].

In the country, not a single case of application of this proposal has been found before any GAD. In other parts of the world, it has been found that there is experience from risk and disaster management to urban planning, especially in countries with more frequent natural disasters, such as Chile [22] and Japan [23]. According to data published by the International Strategy for Disaster Reduction (ISDR), more than 200 million people worldwide, especially in Asian countries, are affected by different natural events, including droughts, floods, tsunamis, and other threats [24]. This is compounded by poverty, high population density, environmental degradation, forest loss, desertification, unplanned expansion of the urban and agricultural frontier, as well as global warming [25] [26].

The Playas canton is a territory that can be managed with the application of risk management tools. The constructions that must be relocated are few, and some roads that must be improved are a few kilometers. With some good management, firm decisions, and better controls, it is possible to apply the proposal of this research work in the GAD of Playas. A certain fact is that the relocation of illegal settlements that are in risk areas is not a very popular issue in the municipalities, there is a lot of resistance to relocation, and people who invade municipal or private land in search of a place to build their home are not willing to retire even knowing that the place is high risk. In their ignorance, they ask that adaptations be made to them, or they make them themselves, fill the dry and saltpeter channels, or extract the thickets that are part of the ecosystem with the idea that it is useless vegetation and that is dead.

The population affected by the floods of the canton is all those who live in vulnerable places, as reflected in the responses to the interviews conducted with departmental heads of the Municipality of Playas who are in charge of the planning and execution of works in the canton, including the Department of Planning and Institutional Advice, Environment Management and the Director of Risk Management. In addition, the officials of institutions that participate in the cantonal COE also agree with the responses of the Municipality, including representatives of the Ministry of Health, the Fire Department, and the public drinking water company of Playas HIDROPLAYAS.

Of the interviews carried out, in total 6, it was obtained as a result that 100% agree that irregular settlements in risk areas are due to invasions that have occurred in other administrations, that floods are due to the fact that it is built without permits in high-risk areas, and that as a consequence there are effects on the environment and people's health. The options to follow are eviction, law enforcement of invaders, and provision of basic services in these risk areas. It is important to mention that the municipal and health authorities recognize this problem and know that it must be solved, but that there must be an accompaniment and socialization of the issue to avoid confrontations with the population.

V. Conclusion

The risk associated with natural disasters caused by floods in the Playas canton was evaluated, and the SNGRE methodology yielded conclusive results that allow quantifying the vulnerability of the canton to this type of threat, in addition to putting into context the need to consider risk management in the Development and Territorial Planning Plan and PDOT, by incorporating these results into the planning, it will be possible to improve decision-making on public works, minimizing flood risks

The study of the threat of a tsunami in the canton of Playas [2], corroborates the sense of vulnerability that the territory has to this type of threat; although its frequency of occurrence is minimal, it was shown that the threat is medium type according to the data that this study yielded.

The development of this work contributes not only to the improvement of municipal management by applying it to the PDOT, but also meets Goal 11 the SDGs (Make cities and human settlements inclusive, safe, resilient and sustainable) and Goal 13 (Adopt urgent measures to combat climate change and its effects).

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