URBAN PLANNING FOR DISASTER PREVENTION IN THE LOW COASTAL AREA OF METROPOLITAN LIMA

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SUMMARY

During the seventies a microzonation method was developed in Peru considering all possible natural disasters menacing the area of interest. Near the end of that decade the method was simplified for its application in urban plan ning.

In the next 20 years approximately 5 million people are going to settle in Lima, many of them on the vacant areas of its 100 kms of shore line where according to historical data the tsunami menace is main of concern. Previous investigations have also shown that in the Lima buil-up area, located at the coastline tsunamis as in 1746, may cause numerous victims.

The tsunami behavier, in the zone of engineering interest; in shallow water and on land is very complicated. Using macro and micro scale batimetric and topographical information it is possible to foresee for practical purpose, the severity of the tsunami attack at a given location. This data is very important to make safe urban planning projects, protect the built-up area and to locate important engineering projects on the coast.

INTRODUCTION

The present population of Metropolitan Lima (ML) of 4.5 million will double by the year 2000. Hundreds of thousands of new inhabitants are going to settle along the country's most important 100 kms coastline which extends from Ancón to Pucusana, with the busiest Peruvian harbor of Callao being the focal point. Fig. 1. In October 1746, Callao was erazed by tsunami waves generated by a 8.4 magnitude earthquake, killing 4,800 of its 5,000 inhabitants, most of them over a long, narrow and low peninsula.

A seismic vulnerability study carried out from 1975 to 1978 had shown that the two most critical problems of ML are the weakness of the adobe constructions of the city's old sections and the tsunami menace at the nearby port of Callao (1).

On the other hand a microzonation study method was developed, in Peru in the last decade (2). It is a muldidisciplinary approch to investigate the menace of all possible natural disasters in the area of interest, including tsu namis, for their use, mainly in urban planning (3).

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So, in January 1981, a study on the tsunami effects on the low coastal area of ML was started under the auspice of UNDRO (United Nations Disaster Relief Office) with two objectives:

- Try to save the lives of the people living in the low coastal areas in the event of a destructive tsunami.
- Make future human settlements less vulnerable or safer against natural disasters by proper planning.

THE COAST OF ML.

The studied area is just the transition zone between the high coast and narrow continental shelf of southern Peru and the north with low coast and wide continental shelf. Most of Lima is settled on the Rimac valley, on average some 100 m, overlooking the Pacific ocean. Near the shore. The cliff is about 80 m high at its highest point in Chorrillos and descends gradually toward the port of Callao and suburb of La Punta where this accident disappears. There is a narrow peninsula 200 to 500 m wide, about 2.4 km long and 2.5 to 3 m over the sea level. Ample area of Callao is below 6m from the sea level. Tens of thousands of people live and/or work there. In La Punta the Peru Naval Academy is located. Callao is the most important naval base and port, also there is an industrial zone Lima, a gas refinary and other key instalations of the country, like the international airport. On the rest of the coast the - towns are mostly summer resorts but gradualy are becoming permanent residential areas.

URBAN PLANNING

The natural sites conditions, the resistance of buildings and other structures to earthquakes and tsunamis and the land use of the built-up area of ML were studied, together with the socio-economic aspects of the people living in the tsunami inundable and adyacent areas.

The behavior of tsunamis in shallow water and on land is very complicated and highly non linear, so to determine the tsunami waves heights and the inundation limits, simple and practical methods were used, accompanied by engineering judgement and over 400 years of historical data. The first were found using the batimetric information provided by DHINA of the Peru Navy and the Yamaguchi method (4) It was found near 7 m for Pucusana and about 4 m. for Ancon. The inundation zones were delimited assuming an inclined plane - with 1 to 2% of slope (depending on the rugosity of the soil) declining in the tsunami advancement direction. The intersection of this plane with the ground gave the limit of inundation. Each locality situated from Ancon to Pucusana was studied in this way.

The Callao old section (See fig 4), located a few tens of meters from the shore, 3 to 4 m over the sea level, with thousands of 2 to 3 stories adobe and quincha dwellings, deteriorated by time and humidity, is the most critical problem existing in the investigated area. Using air photographs provided by the Peru Air Force (scale 1:2500), the construction material and others characteristics of the constructions were plotted block by block with the cooperation of students of architecture of UNI, covering all Callao and La Punta.

It is thought that a + 8 M tsunamigenic earthquake near Callao is going to cause the destruction of those buildings and the rescue of the victims will be very difficult before the arrival of the tsunamis waves.

La Punta, a long, narrow and low laying peninsula is an other problem to consider with priority. As in 1746, the tsunami waves may pass, from one sho re to the other washing away any non fixed object below 1 to 2 stories high. There live over 5000 people in this area however the soil conditions and the construction quality are much better than in the Callao's port old section. There are some buildings strong enought to resist an earthquake & a tsunami - and they may be used as emergency shelters.

In some of the towns where the study was carried out the greatest inconvenience is caused by the invasion of constructions dwellings on use beaches leaving no room for the vacacionists and exposing their lives and properties to the tsunamis hazard.

In the Callao old section the two most critical problems found in ML are given together, so it is necesary to start as a first priority and urban rene wal program and the increase of green area where it is practically non existent now. At La Punta a detailed study is needed to gradually improve, at mi nimum cost the existing safety condition, maintaining the present population low density.

In addition to having a beautiful ocean view, the area houses a XVIII cen tury pentagonal fortress named "San Felipe" and others monumental constructions. With an adecuate urbanistic treatment the area may be tranformed in a touristic atraction increasing the land value, benefiting the community and the owners.

For safely settling the ML future inhabitants in the vacant areas along its shore, a previous seismic microzonation investigation (2), (3) is necessa ry in which the soil liquefaction and seismic waves amplification are the main topics to consider together with the delineation of tsunami inundation zone which have been already made.

Considering the high cost of the coastal land, taking a calculated risk, planning the possible future losses, strict restriction for the land use have been confined to a narrow strip of 200 m from Lima to the south and 150 m - from Lima to the north. The authors think is the minimun reserved area required for summer recreation for the near 10 millions people of ML for the year 2000. Recommendations for the land use of the ML shore is given in Table 1.

EVACUATION PLAN

Finding the minimum arrival time of the first tsunami wave caused by a near earthquake to the shore line of ML was the critical problem to solve to prepare the built-up area evacuati on plan. The 1974 earthquake (M_s = 7.5) had its epicenter off shore, just in front of Lima. Using this event parameters, refraction curves were despicted (See fig. 2). It took 25 minutes for a wave to travel from the border of the assumed lifted area to La Punta. On the other hand the difference between the local origen time of that earthquake and the arrival time of the first wave recorded at the mareograph at La Punta was

21 m. The 1746 tsunami reached Callao 30 m after the earthquake. Twenty minutes is the time being considered for the plan, which is enought for every studied place, except for La Punta and the Lima beach, down the cliff where in summer over half a million of persons may gather during the weekends and holidays. For each locality the refuge area and the evacuation route have been selected. In Callao in due of the volume of people and cars to evacuate the pedestrian and vehicular routes are separate. Fig. 4.

PROTECTION OF ENGINEERING STRUCTURES

To minimize the tsunamis waves effects over engineering structures it is necessary to reduce as much as possible walls and column areas facing the tsunami attack direction. However this direction is not obvious at places like La Punta & Callao where there is a peninsula and an island. Extending the refraction curves to near the shore, telescoping the scale, it is possible to find the tsunami attack direction with enought aproximation for practical application as shown in fig. 4.

From the refraction curves of tsunamis originated from the north (that of 1966) and south (Hypothetic) from Lima, it was found that the waves, 17 - 18 minutes before their arrival to the shoreline, become practically parallel to that line. From that position to the coast, the refraction curves of all of them including that with origen in front of Lima, have the same patern. At the San Lorenzo island the waves open their path and then attack the peninsula simultaneously from the north and from the south, diagonally.

This study also made clear why there is no historical records of important tsunamis from 1540 to 1983, in about 1000 km of the peruvian northern coast, extending from Lima to the province of Lambayeque, in spite that the seismicity is the same as in any section of the circumpacific belt in South America. There, the continental shelf is wide and the shallow water extend for tens of kms from the coast. Most of the tsunami energy is consumed by the sea bottom friction, but this problem is not well understook yet and need to be investigated. On the contrary in southern Peru, in Chile, in Hawai and in Sanriku, Japan, deep water and the tsunamigenic earthquake epicenters are close to the shoreline, the tsunami waves are high, the travel time is short and those places have been attacked repeatedly by destructive tsunamis. This information is very useful for selecting the site of important engineering project on the coast.

CONCLUDING REMARKS

Instead of using sophisticated mathematical model to represent a highly non lineal phenomenon in the zone of engineering greatest interest as it is behavier of tsunamis waves in shallow water near the shore and on land; by the use of simple and practical existing methods, comparing the results with historical data, and using engineering judgement it is possible to reach to useful conclusion respect to waves height and the limit of inundation, with enough aproximation for their application in planning new human settlements near the shore, to prepare evacuation plans for the people living in low coastal area and to select the best location for important engineering projects. By doing so it is possible to drastically reduce future losses of lives and properties and the restriction on the land use near the shore is reduced to a minimum.

It is worthwhile to mention that in about 1000 kms of the northern Peru coast, destructive tsunamis have not been reported in the last 400 years. The most outstanding characteristic of that portion of the circumpacific belt, is that continental shelf is very wide and 100 kms offshore the sea is only 200 m depth.

For any important engineering project on the coast an special and detailed investigation of the natural site condition is recommended.

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TABLE I

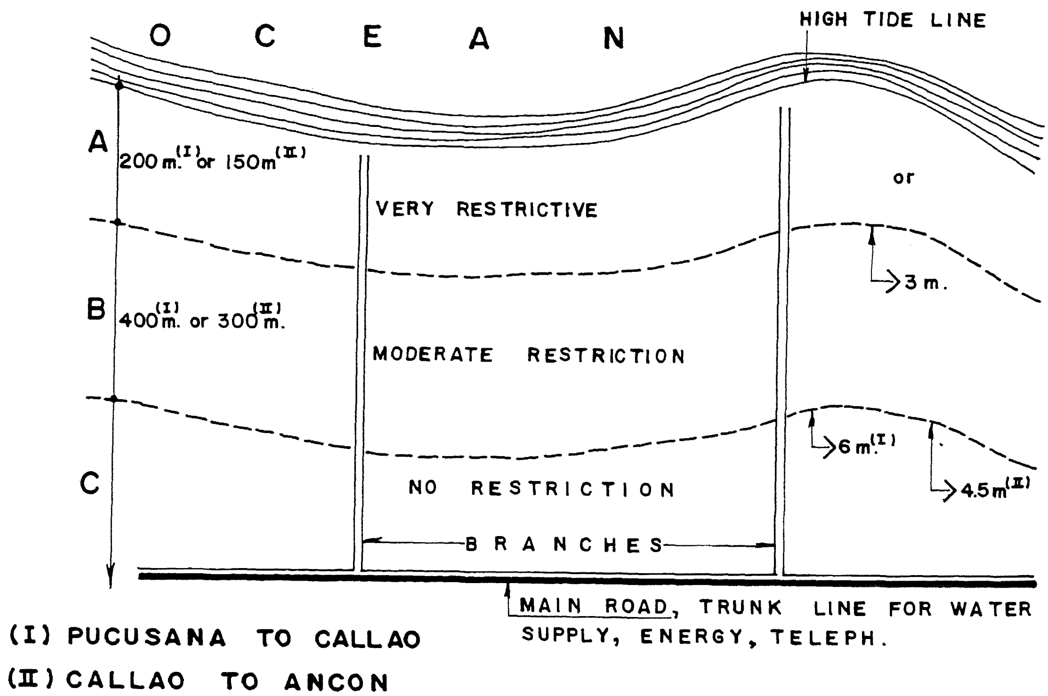
GENERAL PLAN FOR LAND USE

ZONE A : FOR SEA RELATED ACTIVITIES, RECREATIONAL, AGRICULTURAL, ECOLOGICAL PROTECTION USE. FOR OTHER USES SPECIAL SITE INVESTIGATION AND PERMISSION ARE NEEDED.

ZONE B : FOR CONSTRUCTIONS WHERE THE POSSIBLE LOSSES OF LIVES AND PROPERTIES ARE LOW (i.e. FARMS, LOW DENSITY RESIDENTIAL AREA, ETC.) NOT PERMITTED: HOSPITALS, ASYLUMS, SCHOOLS, BUILDINGS IMPORTANT IN CASES OF DISASTERS, PUBLIC BUILDINGS.

NOTES

1. ALL STRUCTURES LOCATED IN A & B ZONES REQUIRE TSUNAMI DESIGN CONSIDERATION (i.e. MINIMUM WALL AND COLUMN AREA EXPOSED TO WATER - PRESSURE, SHEAR WALLS ORIENTED PERPENDICULAR FOR THE TSUNAMI ATTACK DIRECTION, FOUNDATION SCOURING PROTECTION ETC.).
2. MAIN ROADS AND TRUNK LINES FOR WATER SUPPLY, ENERGY AND TELEPHONE SHOULD NOT PASS THROUGH ZONES A & B (See Fig. below).
3. EVACUATION ROUTES FROM ZONES A & B TO PREVIOUSLY SELECTED, SHELTER AREAS IN C HAVE TO BE DESIGNED.



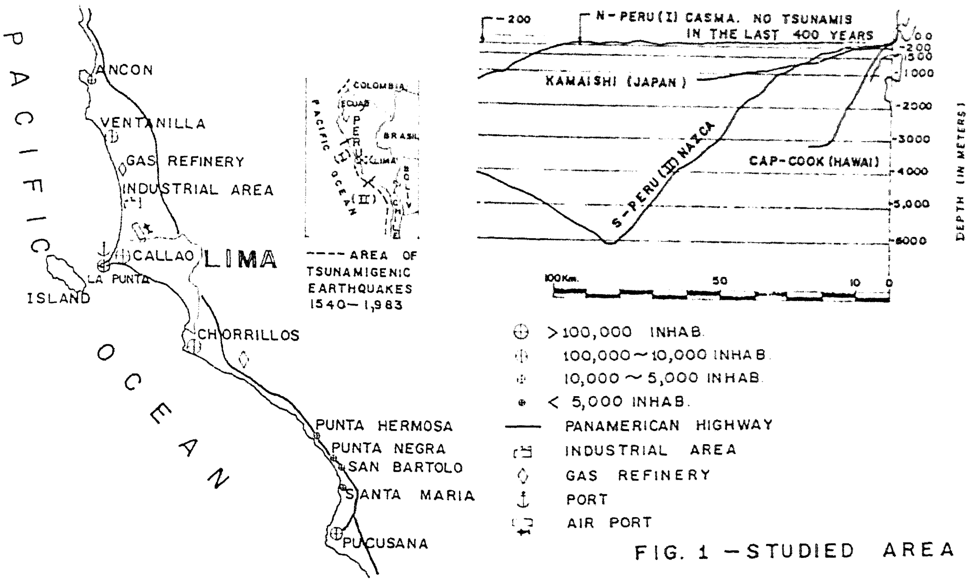


FIG. 1 —STUDIED AREA

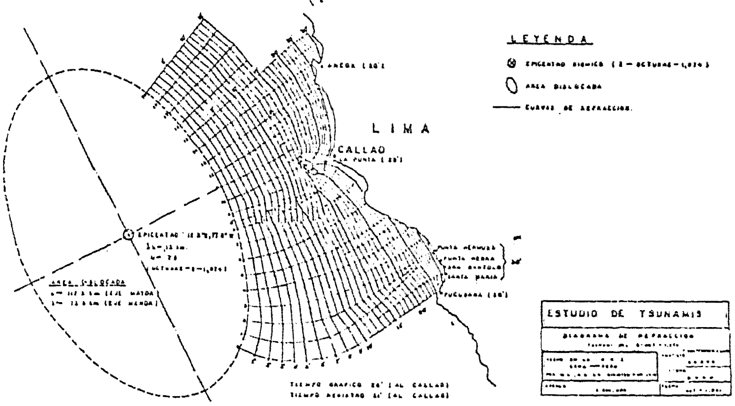


FIG. 2 : REFRACTION DRAWING OF THE OCTOBER 3, 1974 TSUNAMI

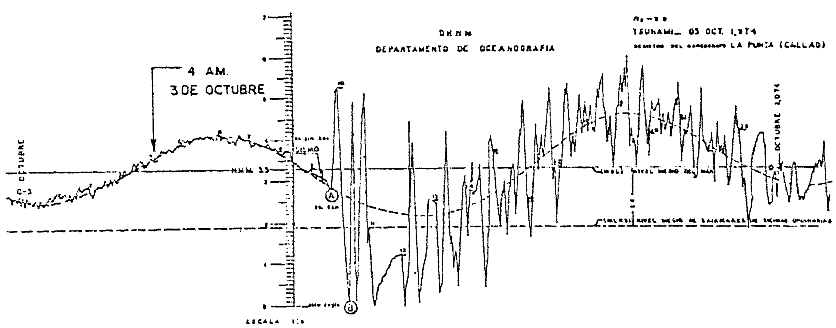


FIG.3 : TIDE RECORD AL LA PUNTA SHOWING THE OCT. 3, 1974 TSUNAMI

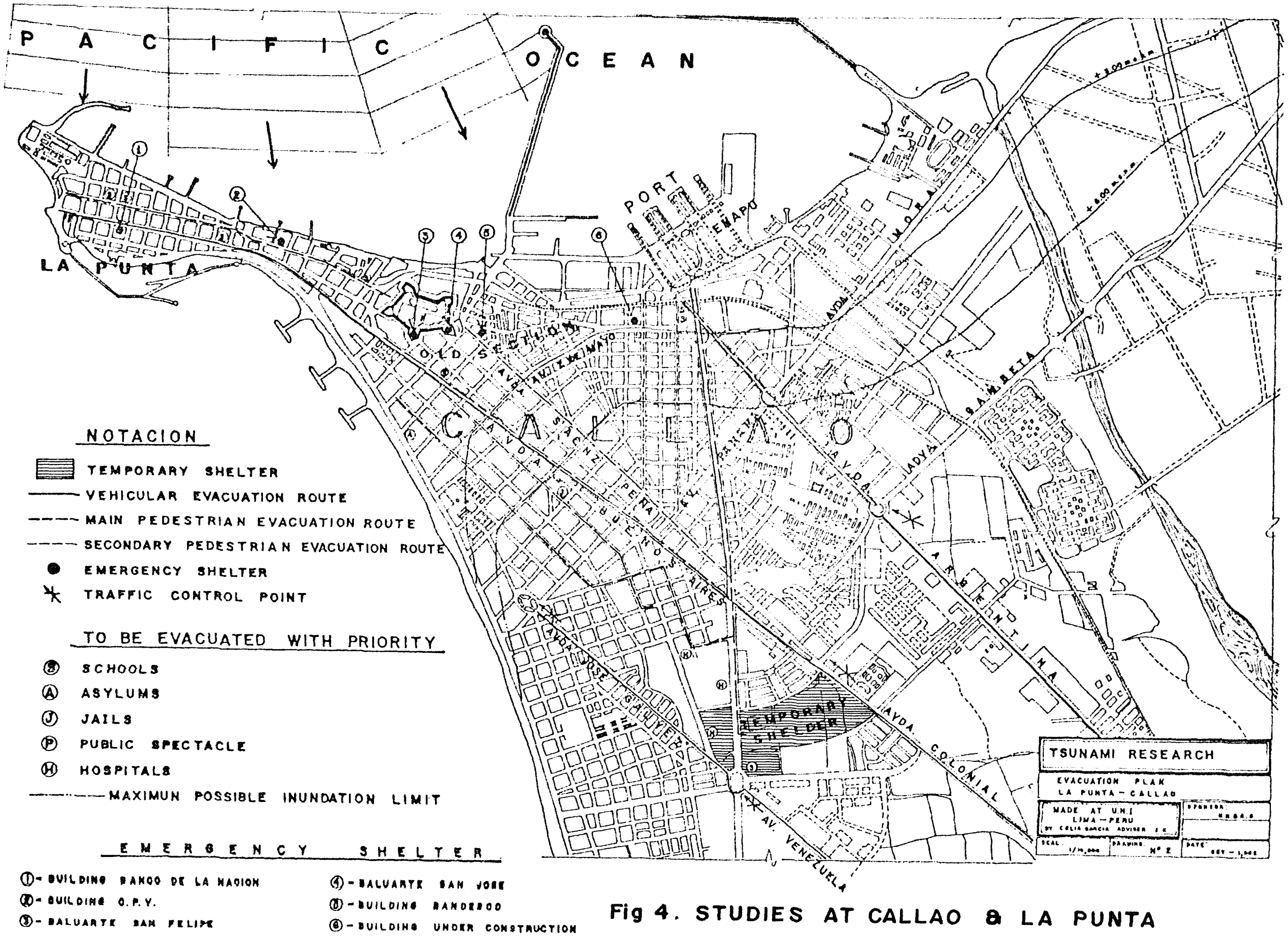


Fig 4. STUDIES AT CALLAO & LA PUNTA