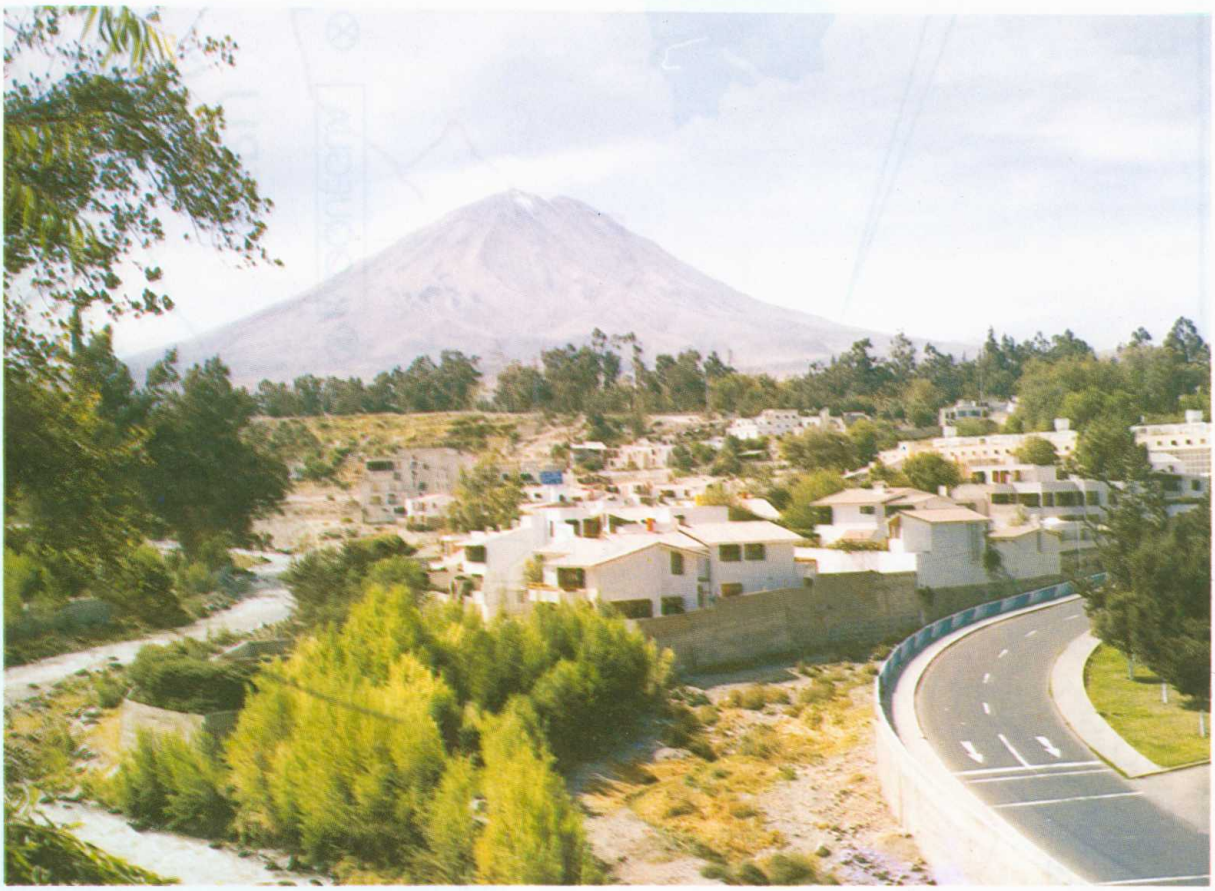
MITIGATION OF SEISMIC, VOLCANIC AND FLOOD RISKS IN THE CITY OF AREQUIPA



PARTIAL VIEW OF THE CITY OF AREQUIPA. IN THE BACKGROUND, EL MISTI; TO THE LEFT, A BEND IN THE CHILI RIVER. IN THE CENTRAL FOREGROUND, A DRY TRIBUTARY, THE SAN LÁZARO GULLY, WHICH RISES AT THE PEAK OF THE VOLCANO.

According to the 1993 census the city of Arequipa has 631,318 inhabitants. It is Peru's second most populous city, although it is far behind Lima, the capital, with its more than 7 million inhabitants.

During its nearly 500 years of history, Arequipa has been destroyed by major earthquakes on several occasions. In the early fifteenth century, the El Misti volcano erupted, causing hundreds of deaths. In recent decades, the city has been subjected to serious floods caused by the overflowing of normally dry watercourses which fill up when it rains heavily in their upper basins, about once every 10 years.

One of the critical problems affecting the largest third world cities is explosive population growth, which increases the need for building land, entailing the occupation of extremely dangerous marginal areas and disorderly urban growth patterns.

It was in order to overcome these difficulties that the microzonation study of the city was carried out.

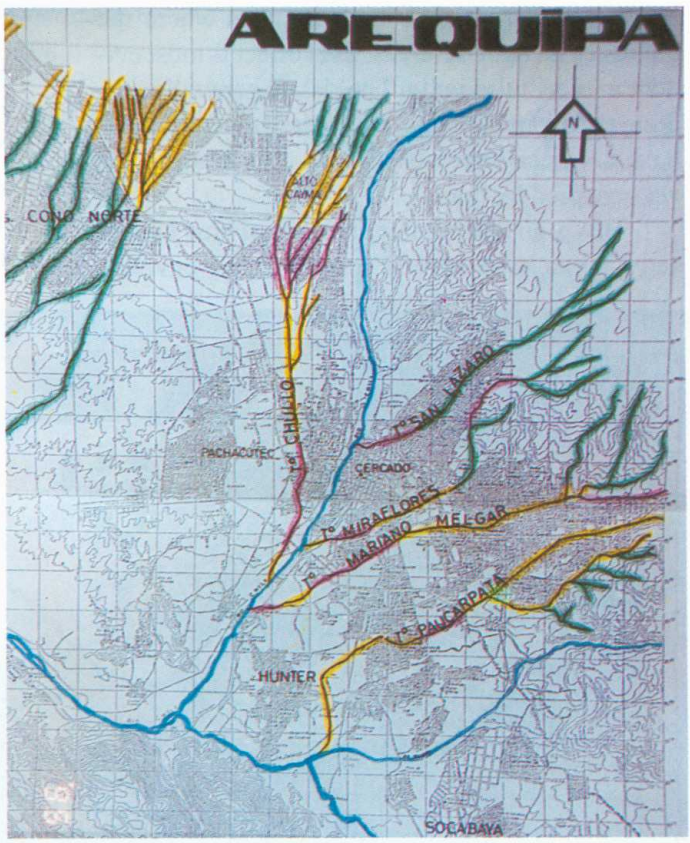
Microzonation consists of the multidisciplinary study of the zone concerned, in this case, the city of Arequipa and its expansion area, taking into account the natural hazards to which it is exposed. Preliminary studies indicated that the following had to be taken into account: earthquakes, floods and the threat from the El Misti volcano. The zone studied, 362.36 sq. km., contained within the quadrangle of coordinates 16°19' to 16°29' S, and 71°28' to 71°38' W, was divided into different

risk sectors.

The safest sectors, and those where the ground has the greatest capacity for support are then marked out for urban expansion, while the sectors at greatest hazard are designated for parks, cultivation or other appropriate uses. Demographic encroachment on sectors which prove to be dangerous is restricted or prohibited, and further population growth in sectors already occupied is avoided. In this way the above-mentioned objectives are achieved and savings are made in construction budgets in most cases, since land with good support capacity reduces the cost of laying foundations and there is little or no increase in the seismic coefficient due to the soil factor; savings are also made in the structure of buildings while lifelines network - water, drainage, means of transport and communication - all have to be more reliable once the impact of natural hazards is substantially reduced.

Sucess depends on a good land-use plan, with proper interpretation of the microzonation study findings.

Flood hazard of Arequipa



Flood hazard zones in Arequipa are represented by the gullies, normally dry tributaries of the Chili river. Note that the sections at greatest risk are those which cross built-up areas.

Earthquake hazard

For purposes of practical applications, seismic hazard is represented by the map of expected intensities in the various sectors into which each area under study is divided. Field inspections carried out in the wake of destructive quakes clearly show that the characteristics of soil, geology and topography have a major influence on the severity of damage and its geographical distribution. This phenomenon is called the microzone effect, since places in close proximity to each other frequently display substantial variations in the degree of damage.

The multidisciplinary studies carried out in Arequipa were summed up in maps with geomorphological, geological and geotechnical features, the latter including the soil bearing capacity; using the measurement of microtremors, calculation of flow and level of underground water, and the percentage of distribution of damage caused by the 1979 earthquake.

The findings of the studies and the maps were collated to obtain the seismic microzonation plan, which shows expected intensities ranging from VI MM to IX MM.

The first sector corresponds to very competent rocks and the last to low-lying marshy zones with low support capacity, where even sand liquefaction and land subsidence may occur. Fortunately, the grade IX MM sector is not very large compared to the overall area under study.

Degree of hazard

- Low
- Medium
- High

The Chili river, the city's main drainage channel, divides the area into two sectors, of which the left bank is the more developed. The built-up area and its expansion zones are crossed by tributaries of the river, known locally as gullies (torrenteras). These watercourses become active only very sporadically, when torrential rains saturate their upper basins and the water begins to flow downstream. About every 10 years the volume of water flowing through the gullies rises, causing increasingly severe floods. This is due to the fact that the natural drainage capacity is reduced by the negative impact of human activity: building within the gully beds and disposal of scrap material, refuse and sewage.

In the poorest areas, which are crossed by the gullies, there is a serious problem of environmental pollution. Both sides of these normally dry watercourses, up to about 300 metres, are filled with garbage and wastewater, provoking the spread of such