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THE WATER RESOURCES OF LATIN AMERICA AND THE CARIBBEAN: WATER-RELATED NATURAL HAZARDS

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INTRODUCTION

This report on natural hazards forms a part of the efforts of the Secretariat to improve the information available on progress being made in Latin America and the Caribbean in water resources management. In 1977, ECLAC prepared a regional report entitled "The Water Resources of Latin America" and more recently, in 1985, a completely new edition was issued entitled "The Water Resources of Latin America and the Caribbean and their Utilization". This second report broadened the coverage of the report to include all the aspects of water management included in the Mar del Plata Action Plan adopted at the United Nations Water Conference.

In amplifying the coverage of the report, the limited resources available meant that some items were covered only superficially. Following the last meeting of the Committee on Water of ECLAC it was decided, therefore, that in preparing a new edition particular attention would be paid to those areas where information was weakest. This report is a reflection of that decision and is an attempt to present a useful review of the regional situation in respect of water-related natural hazards.

The report is presented in two parts. Part A includes a discussion of the characteristics of the water-related natural hazards that affect Latin America and the Caribbean, recent experience of such hazards and the measures adopted by the countries of the region to reduce the impact and damage caused to their economies. Part B consists of a list of recent water-related natural disasters giving the origin, the location, the casualties, numbers of homeless, and the damage caused.

Part A

THE REGIONAL SITUATION

Many areas of Latin America and the Caribbean are prone to natural hazards arising from extreme events related to water. Undeniably, the population of the region has been affected by natural disasters during all its history (e.g. in Mexico droughts are traced back as long ago as 1052 1/), but in recent years both the damage caused and the risk have increased.

Natural hazards, understood as extreme natural events producing adverse impacts on man and the environment and causing physical, ecological, economic and social damage, can be of geophysical or meteorological origin. Four natural hazards --droughts, floods, tropical cyclones and earthquakes-- are responsible for more than 90% of all loss of life and damage to man and the environment.2/ Most water-related natural hazards are of meteorological origin, but there are exceptions: for example, floods caused by a dam failure as a result of an earthquake. Natural hazards of meteorological origin account for over half of the total loss of life and damage caused by all natural disasters.3/ In Latin America and the Caribbean such hazards accounted for more than 30% of all deaths from natural disasters in the region during the only period for which such statistics are available.4/

THE DISTRIBUTION OF NATURAL HAZARDS

Apart from droughts, which affect both Central America and the Caribbean and South America, within the region there are considerable geographical differences in the relative seriousness of the types of hazards which prevail:

(a) The countries of South America are most frequently affected by floods and flood-induced land/mudslides. In these countries in recent years on average for every 99 persons killed, injured or missing as a result of floods and land/mudslides there was only one killed, injured or missing as a consequence of a storm or hurricane.5/

(b) In Central America and the Caribbean the most severe natural disasters are tropical cyclones, which cause about 50% of all disaster deaths.6/ In these countries in recent years, on average for every 9 persons killed, injured or missing as a result of storms, hurricanes and tropical

cyclones there was only one killed, injured or missing as a consequence of a flood or of a land/mudslide.7/

There is considerable variation among countries in the reported prevalence of natural disasters. Some countries appear to suffer from only one main hazard, e.g. floods in Argentina, Ecuador, Paraguay and Venezuela, while others —for example, Cuba, Mexico, Bolivia, Colombia and Peru— report a greater variety of hazards. This difference may be, more apparent than real given the haphazard reporting of hazards, but it could reflect the magnitude of the flood hazard in the countries mentioned. A complete list of recent reported hazard events can be found in Annex 1.

The overall impact of natural hazards on the regional economy is unfortunately not known. ECLAC estimates that in the five countries of the Central American Common Market (Costa Rica, El Salvador, Guatemala, Honduras and Nicaragua), the economic costs of disaster damage averaged 2.3% of the gross domestic product in the period 1960-1974. Since 1977, for Latin America and the Caribbean as a whole, with estimates only available for a quarter of the reported water-related natural disasters, damage has been reported to equal more than US$ 10 billion.8/

CHARACTERISTICS OF NATURAL HAZARDS

Droughts, floods, tropical cyclones and other water-related natural hazards have different effects on man and the environment (their major characteristics are shown in Table 1). Some of these effects are the same in both cases: e.g., the consequences of tropical cyclones and floods can sometimes be identical since flooding is one of the main damage causing factors of tropical cyclones.

The damage attributable to natural hazards depends on their intensity (speed of wind, intensity of rainfall, etc.) but, at the same time it bears a close relationship to the nature of the economic and social development of the affected area. The impact of any natural hazard on smaller countries tends to be relatively more damaging, since devastation from a single event may extend over the entire territory.

1. Droughts

(a) The nature of drought

Drought is typically defined as a period during which stream flows are inadequate to supply established uses under a given water management system.9/ Drought is the most insidious of natural hazards in that it tends to develop slowly and can last for long periods (e.g. the most recent drought in the northeast regions of Brazil lasted for 6 years, from 1979 to 1984).10/

There are four main causes of drought,11/ all of which are operative in Latin America and the Caribbean:

Table 1

MATRIX OF EFFECTS OF NATURAL DISASTERS

Characteristics and affected objects of natural disasters	Probability		
	Tropical cyclone	Flood	Drought
I. CHARACTERISTICS:			
1. Affected area (larger)	VH	L	VH
2. Duration (longer)	L	L	VH
II. AFFECTED OBJECTS: (damage higher)			
1. Industry	VH	VH	L
2. Agriculture	VH	VH	VH
3. Infrastructure			
(a) transport	VH	VH	L
(b) water supply	VH	VH	H
(c) waste disposal	H	H	H
4. Population			
(a) hunger	H	H	VH
(b) contamination by biological and chemical agents	H	VH	L
(c) destruction of social infrastructure	VH	VH	L
III. DAMAGE CAUSING FACTORS:			
1. Tropical cyclone	- surge of water and wind - torrential rain - see "Flood"		
2. Flood	- flood - surge of water		
3. Drought	- aridity - high temperature		

Source: This matrix was compiled particularly on the basis of material taken from "Salud ambiental con posterioridad a los desastres naturales", Publicación Científica No. 430, Pan American Health Organization, 1982.

Note: VH - probability is very high, H - probability is high, L - probability is low.

(i) Widespread and persistent atmospheric subsidence, which results from the general circulation of the atmosphere. Such subsidence is created in subtropical latitudes, the major areas affected in Latin America being the northeast of Brazil, northern Chile, southern Peru and northern Mexico.

(ii) Localized subsidence induced by mountain barriers or other physiographic features. The area affected in Latin America is very restricted as the phenomenon tends to occur in the middle latitudes. It is the cause of the aridity of much of southern Argentina.

(iii) Absence of rain making disturbances, causing dry weather even in the areas of moist air. It gives rise to the long dry summer of Central Chile and is the cause of droughts that frequently affect the highlands of Peru.

(iv) Absence of humid air streams. Some minor areas of Latin America -- northeastern Argentina and neighbouring parts of Bolivia and Paraguay, for example— are quite remote from sources of humidity.

There are four main types of drought, with the following occurrence in the region:12/

(i) Permanent drought, leading to desert surface conditions, in which there is no season of appreciable rainfall. The major regions of Latin America that suffer from permanent drought are: lower California; the north and northeast of Mexico; the Guajira region of Colombia; a broad coastal strip on the Pacific Ocean extending from latitude 4° south in northern Peru to approximately latitude 28° south in Chile, which includes the driest area in the world --the Atacama desert; vast areas of southern South America, including part of the Bolivian plateau; an extensive tract of the Chaco (Bolivia, Paraguay and Argentina), and the north-east, central-west and extreme south areas of Argentina (Patagonia) (table 2).

(ii) Secular drought, in sub-humid regions in which drought occurs in one sequence of years alternating with sets of years of adequate rainfall. This type of drought is prevalent in the north-east of Brazil. In this region some 1.8 - 2.1 million km^2 is affected by droughts in a 5 to 7 year sequence (in this century alone 1900, 1903, 1915, 1919, 1931-1932, 1942, 1951-1953, 1958, 1962, 1966, 1968-1970, 1972, 1976 and 1979-1984 were years of drought).

(iii) Seasonal drought, mainly in semi-arid or sub-humid climates with a short wet season. Some parts of the Peruvian coast are affected by seasonal (June to December) droughts, when half of the 52 rivers of the region dry up completely.13/

(iv) Contingent drought may strike temperate and tropical regions where water shortage occurs infrequently. From 1981 to 1983 contingent drought affected three Caribbean states (Cuba, Haiti and Jamaica) which in normal years have an adequate rainfall.14/

Table 2

AREA AFFECTED BY DESERTIFICATION IN SOUTH AMERICA

Degree of desertification hazards	Affected territory	
	Km^2	%
Moderate	1 602 383	9.0
High	1 261 235	7.1
Very high	414 195	2.3
Extreme desertification	200 492	1.1

Source: UN Conference on Desertification.

(b) The impact of drought on man and the environment

Drought produces severe impacts on both man and the environment. The main effects include the following:

(i) Human deaths and suffering through famine and shortage of drinking water. Droughts continue to take a heavy death toll in Latin America —for example, despite all the measures taken to mitigate their impact in the northeast of Brazil, droughts there continue to endanger some 25 million people. The recent 5-year drought in the sertao or "backlands" areas of this region, known as the "drought polygon", is estimated to have taken the lives of some 3 million people.15/ The populations of other countries are also affected by droughts, although not to the same extent as Brazil; for example, a recent drought in Cuba in 1984-1985 had a serious effect on Havana's water supply: supplies were sharply reduced and some residents received water only twice a week while others were entirely dependent upon delivery by truck.16/

Famine and shortage of drinking water are not the only causes of human deaths, since disease from the use of contaminated water, death of cattle, lack of water for waste disposal, malnutrition, etc., can also take a heavy toll. For example, the 1982-1983 drought in Bolivia and Peru led to an increased incidence of gastrointestinal and other diseases in the population of affected areas.17/

(ii) The failure of crop raising and the drying-up of pastures leads to death of cattle, declines in agricultural production and in related industrial production, and often the abandonment of land through migration.

For example, the 1977 drought in Mexico caused damage to the crops on 1 000 000 hectares of land (of which 500 000 hectares of crops were nearly

completely destroyed) and caused the death of some 45 000 head of cattle. The total losses to agriculture were estimated at US$ 310 million.18/ The 1982-1983 drought in Bolivia, for its part, completely or partially destroyed the crops of some 1.6 million peasants and caused the death of many cattle.19/

(iii) Increasingly, droughts affect not only agriculture but also the urban population, hydroelectric power generation and industries which use water in their production processes (oil refineries, iron and steel works, sugar refining, the chemical industry, manufacture of pulp and paper). The 1977 drought in Mexico, for example, caused a severe reduction in hydroelectricity production.20/ The detrimental effect of droughts may be aggravated through the lack of water for the dilution and transport of wastes.

(v) Drought degrades and removes the vegetation cover, induces soil erosion, kills wildlife, destroys some land and water-based ecosystems, etc. It was estimated that during the 1982-1983 drought in Bolivia 4.8 million hectares of pasture were destroyed by cattle and that some 40% of this area would not recover even under normal meteorological conditions.21/

2. Tropical cyclones

(a) The nature of tropical cyclones

Tropical cyclones (known as hurricanes in the Caribbean, cordonazos in Mexico or tainos in Haiti) are conventionally defined as circular storms with rotating wind speeds exceeding 32 metres per second (at the centre of a cyclone the wind may swirl at more than twice this speed).

A tropical cyclone 22/ forms over the open sea when the collision of hot, moist air and of cool air provokes an updraught and subsequent condensation of moisture into rain. This process releases heat which funnels the air upwards. Due to the earth's rotation the rising column of air begins to spiral and a cyclone comes into existence.

The average duration or life span of a tropical cyclone is from 6 to 9 days but may vary from a few hours to as much as four weeks. Cyclones move at a rate of more than 330 kilometres a day, often covering a distance of 2400 - 3300 kilometres in the course of their life. The average diameter of a tropical cyclone is approximately 160 kilometres but it may extend up to 480 kilometres in width. These figures help to understand why, when a tropical cyclone hits a Caribbean island or a small Central American country, devastation typically extends over the entire territory and can affect not one but several States at the same time.

On average, 8 tropical cyclones sweep yearly over the Caribbean and adjacent areas of the Atlantic Ocean, as well as over the Pacific Ocean, off Central America and Mexico. All the countries of the Caribbean and Central America experience cyclones on a regular basis, particularly during the summer and autumn. In recent years Cuba, Dominica, the Dominican Republic,

Guatemala, Haiti, Jamaica, Martinique, Mexico, Nicaragua and St. Lucia were affected by storms and tropical cyclones, some of them (e.g. Cuba, Mexico) several times.

Tropical cyclones are accompanied by torrential rains and high winds that can push walls of ocean water onto coastal areas. The volume of rainfall associated with individual storms varies, but amounts of as much as 500 millimetres or more are not uncommon; for example, in Honduras in 1982 600 millimetres fell in 3 days, in Nicaragua the rainfall from the same storm reached as much as 860 millimetres; and in Cuba, also in 1982, rainfall from the hurricane Alberto over nine days reached 800 milimetres.

(b) The impact of tropical cyclones on man and the environment

The heat energy released per day by an average cyclone can be compared to that released from about 400 hydrogen bombs of 20 megatons each,23/ and before it dies the energy released is likely to equal that from some 9 000 000 "Hiroshima - type" atomic bombs.24/ This explains why, if a tropical cyclone hits a heavily populated area, losses are likely to be enormous.

The damages caused by tropical cyclones are due to three factors: the high winds, the storm surge and torrential rain. The most destructive of the three is the rainstorm-surge combination in coastal areas, which gives rise to catastrophic flooding. The storm surge is a rapid rise in the sea level produced by the hurricane winds and falling barometric pressure.

Some of the biggest tropical cyclones that have struck Latin American countries in recent years include: Hurricane Fifi (1974) which caused 10 000 victims in Honduras;25/ hurricane David (1979) which devastated most of the island of Dominica and large parts of the Dominican Republic, killing over 1 400 people, injuring 6 000, leaving more than 260 000 homeless and causing damage estimated at US$ 830 million; and the hurricane that in 1980 ripped through St.Lucia, south-western Haiti and northern Jamaica, leaving 250 dead, 205 000 homeless, 525 000 deprived of their normal source of food and US$ 530 million of damage.26/ Mexico and Haiti seem to be the countries most frequently affected by cyclones. Between 1960 and 1981 Mexico suffered from at least 14 and Haiti 6 cyclones which resulted in 1 560 and 5 800 deaths, respectively.27/

Tropical cyclones not only cause human deaths and injuries and destroy property, but also strip cultivated land in coastal area of its vegetation cover, render it sterile by salinity and subject it to soil erosion. For example, when in June 1982 hurricane Alberto struck the western region of Cuba, seriously damaging housing and infrastructure (total losses were valued at US$ 85 million), an estimated 137 000 ha of cultivated fields were totally lost or seriously damaged.28/ The storm surge caused by cyclones can erode up to 10 - 17 metres of beach within an hour. Twelve hours of pounding by such waves is said to be equal to a century of normal wave action.29/

Apart from the immediate damage, the long-term consequences of tropical cyclones may also be serious. Large expanses of stagnant water and swamps can

be left after a cyclone, and these not only impede reconstruction but also offer ideal breeding grounds for vectors of debilitating diseases such as dengue fever and malaria. An outbreak of dengue fever as a result of the 1982 cyclone in Cuba was avoided only with the help of urgent applications of abate-malathion insecticide.30/

Nevertheless, although tropical cyclones produce severe adverse impacts, they may have beneficial effects too:

(i) Increased rainfall, because cyclones lift and evaporate sea water and deposit it as salt free rain;

(ii) Improved fishing, the upwelling of nutrient rich water along or near the storm track, as was recorded, for example, after hurricane Inez in the Gulf of Mexico when the phytoplankton mass at the surface was found to have doubled.31/

3. Floods

(a) The nature of floods

The most common type of flooding in Latin America is overflowing of inland waters, although sea floods caused by tropical cyclones, earthquakes and tsunami are also important. There are several causes of inland water flooding:

(i) The incidence of heavy rainfall is the most widespread cause of flooding in Latin America, as the majority of rivers in the region are entirely rainfed. For example, in June 1982 the intensity of seasonal rains in Paraguay caused such a rise in water levels along the length of the river Paraguay that surrounding areas were flooded over a distance of more than 1 100 Km, affecting over 100 000 people.32/ Also in 1982-1983 heavy rains in some areas of the Pacific Coast of South America reached the 500 year high of 4 000 milimetres, causing severe flooding of between 12% and 15% of the territory of Ecuador, as well as affecting the northern part of Perú and Bolivia. Losses in Ecuador were put at US$ 640.6 million.33/

(ii) The occurrence of a strong and protracted snow melt represents a problem only on some Latin American rivers, as it is only south of latitude 28°S that the upper basins of the rivers rising in the Andean cordillera receive a substantial quantity of water from glaciers and snowmelt.34/

(iii) Obstructions can cause a flood or exacerbate one which already exists. Common obstructions are the presence of weirs, bridge piers, floating debris or ice jams. In May 1960 a huge landslide caused by an earthquake blocked the Rio San Pedro below Lake Riñihue, Chile, raising its level so much that catastrophe was only prevented by artificial breaching of the "dam". Similar events took place in Peru in May 1970 and in Chile in June 1982;35/ in 1985 a glacier crossed the river Plomo (Argentina), damming up the river and creating a lake of considerable volume which posed a serious flood threat to populated areas.36/

(iv) Other factors, including tidal surges, wind set-ups in estuaries or downstream river surges caused by a dam failure, mud flow or other similar

events can cause flooding or aggravate already existing floods. Accidents arising from failure of hydraulical structures tend to be particularly grave. One such accident took place in April 1981, when during intense rainfall failure of six small upstream dams caused the Mae D'Agua Dam to fail, releasing approximately 12 million cubic metres of water and flooding Santa Cruz, Brazil. Many buildings were destroyed, and about 5 000 people were left homeless.37/

(v) Floods can also be produced by a combination of the above-mentioned factors: for example, in June 1986 heavy rains and strong snowmelt caused flooding in the central regions of Chile, with losses to roads and bridges alone estimated at US$ 3.7 million.38/

The character of flooding is generally but not exclusively determined by the size of the catchment area. On very large rivers flow is relatively slow to change in the downstream reaches. Flooding is therefore usually periodical and slow to develop, as in the flood plains of the middle course of the rivers Paraná and Paraguay in Argentina, Bolivia, Brazil and Paraguay, the lower reaches of the Magdalena in Colombia, the upper Orinoco plains of Venezuela, the valley of the river Guayas in Ecuador and the valley of the Beni in Bolivia. The extent of the flood plains of the river Paraná and its major tributary, the Paraguay, is so vast that flooding periods are very long. In the last 25 years, in no major flood in the river has the period between flood crest and flood peak been less than 15 days at Santa Fe, Argentina, and in most floods it has been closer to 30 days.

In contrast, short rivers such as those of the Pacific watershed are more commonly associated with "flash floods". Such floods are particularly dangerous because very little time elapses between the start of the flood and the peak discharge and quite often between the onset of the storm and the arrival of the flood wave. For example, in June 1982 a flood caused by strong rainstorms in the basin of the Mapocho river in Chile forced evacuation of some 8 000 people in Metropolitan Santiago;39/ in late March 1983 flash floods in Bolivia caused the death of more than 100 people;40/ and in 1982-1983, as on many other occasions, flash floods affected the north of Peru, particularly the Department of Piura.

(b) The impact of floods on man and the environment

Floods are very frequent in Latin America; since 1979 Argentina, Barbados, Bolivia, Brazil, Chile, Colombia, Cuba, the Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Paraguay, Peru and Venezuela have all suffered flooding. An idea of the degree of flood damage in Latin America can be gained from table 3.

In areas of high density of human activity, particularly urban zones, and also in zones of intensive agriculture where crops cannot withstand prolonged submergence, damage from floods can be catastrophic. In several Latin American countries a substantial part of the population (see table 4) and hence of agriculture and industry are located in areas exposed to catastrophic floods.

Table 3

FLOODS IN SELECTED COUNTRIES OF LATIN AMERICA
1960-1981

Country	Number of floods	Deaths	Deaths per flood
Argentina	9	200	22
Bolivia	13	160	12
Brazil	28	2 850	102
Colombia	10	600	60
Costa Rica	8	30	4
Ecuador	7	20	3
Mexico	41	370	34
Panama	6	100	17
Peru	9	350	39
Total	101	4 680	46

Source: League of Red Cross and Red Crescent Societies; U. S. Office of Foreign Disaster Assistance.

Table 4

LATIN AMERICA (SELECTED COUNTRIES): APPROXIMATE PERCENTAGE OF POPULATION LIVING IN AREAS EXPOSED TO CATASTROPHIC FLOODS

Country	Percentage
1. Argentina	8 - 10
2. Bolivia	7
3. Brazil	15
4. Costa Rica	3
5. Guatemala	15

Source: K. Szestay, "River Basin Development and Water Management", Water Quality Bulletin, Vol. 7, No. 4, October 1982.

The main effects of floods on economic and social development include the following:

(i) Human deaths and injuries caused either directly by flooding or indirectly, through flood-related landslides, destruction of buildings, etc. The number of deaths and injuries may vary considerably according to the quality of the warning system and the speed of flooding. In Latin American countries the number of killed, injured and missing as a result of a single flood in the last 6 years has ranged up to 2 000.41/

(ii) The destruction of buildings (heavy floods that took place in Bolivia in January 1986 left up to 30 000 people homeless),42/ of water supply and sewerage systems and of other social infrastructure, the swamping of large territories, etc. may not only cause hunger and suffering to the population of affected areas but also may lead to widespread waterborne or water-related diseases. For example, floods in Bolivia, Ecuador and Peru in 1982-1983 caused malaria epidemics in some regions,43/ and in 1984 some 300 children were reported to have died in northeast Brazil as a result of an epidemic of gastroenteritis which broke out in the region affected by extensive flooding.44/

(iii) As well as destroying industrial and agricultural structures and social infrastructure, floods may destroy already manufactured products, contaminate and disrupt agricultural production, etc. The economic cost of floods can be enormous; for example, in 1982-1983 floods in Bolivia, Ecuador and Peru caused losses estimated at some US$ 34 789 million: equivalent to 10% of those countries' GDP.45/

(iv) In their destructive impact on the environment, floods destroy vegetation cover and land-based ecosystems, kill wildlife, pollute rivers and lakes, induce soil erosion, spoil cultivated land through excessive sediment deposition, etc. It was reported that in 1982-1983 heavy flooding in arid zones of the northern coast of Peru caused severe erosion and sedimentation which affected several thousand hectares, with damage estimated at US$ 12 000 000. 46/ Particularly grave environmental consequences tend to be caused by flash river flooding, extreme sea floods or flooding in normally arid zones.

In many Latin American countries the destructive impact of floods is aggravated by peculiarities of relief and soil characteristics, and many are accompanied by land or mudslides which not only produce additional damage but also impede rescue operations and reconstruction. It has been estimated that in recent years at least 24% of all floods in Latin America were accompanied by land or mudslides.47/

However, in certain situations flooding may be envisaged as a beneficial process, particularly for some agricultural or pastoral uses. One example is afforded by the Apure flood plains around San Fernando, Venezuela, where major efforts have been made to retain floods so as to permit a longer growing season for natural pastures which support livestock production.

4. Other water-related natural hazards

Other less widespread water-related natural hazards are also important causes of damage in Latin America and the Caribbean:

(i) Avalanches, which frequently affect Andean regions of the Pacific coast of South America, where the combination of two factors --presence of populated areas in high mountain zones and high seismic and volcanic activity-- increase both the risk and damage from them. The average annual death toll is about 140 - 145.48/

(ii) Mudflows. These are provoked by flood causing factors --torrential rains or strong and protracted snowmelt-- that take place in mountains. Much more dangerous, because of their high speed and volume, are mudflows caused by eruptions of volcanoes with large crater lakes, such as the Soufriere in St. Vincent, West Indies.49/ Such a mudflow in November 1985 killed some 25 000 people in Colombia.50/

(iii) Landslides. These are produced either by flood causing factors, and therefore frequently are associated with floods --it has been estimated that 60% of floods in Peru are accompanied by landslides 51/ or by earthquakes. Landslides affect both South America and the Caribbean. The death toll is lower than that from avalanches, some 40-45 deaths annually.52/

(iv) Tsunamis are the tidal waves produced by the sudden displacement of a large column of water, usually caused either by an earthquake or by a volcanic eruption below or at sea level. Both causes are operative in the region. In the eastern Caribbean four submarine volcanoes have been reported active in historic times and there may well be numerous unidentified ones;53/ the Pacific coast of South America faces the ocean which, as a result of high volcanic and seismic activity, is the most frequent scene of tsunamis --on average 2-3 tsunamis are observed there annually.54/

MEASURES FOR THE MITIGATION OF NATURAL DISASTERS

Latin America and the Caribbean have been characterized in recent years by a series of severe natural disasters which have affected many countries of the region. The extent of the damage from them has in most cases been partially reduced by mitigation measures taken by the affected countries.

Measures for the mitigation of natural disasters can be divided into two broad groups:

1. Structural.
2. Non-structural.

1. Structural measures

The following structural concepts have been evolved as means of reducing the damage caused by natural hazards:55/

(a) Confinement (flood walls, levees, etc.);
(b) Detention (landslide retaining walls, flood control dams, etc.);
(c) Dissipation (wind breaks, sea walls, breakwaters, etc.);
(d) Diversion (avalanche diversion sheds, flood by-pass channels, etc.).

Structural measures have been adopted to a certain extent to control flood in many river basins in Latin America. The most widely diffused measure is the construction of dykes or containing walls to control the river course and prevent overbank flooding: for example, many of the Pacific coast rivers of Peru have been dyked; in Brazil levees, floodwalls, sluicing canals and other works are used to protect towns; the lower course of the Guayas in Ecuador was dyked in 1976, and the containing walls of the river Mapocho in Santiago, Chile, were extended into the upper suburbs of the city after the 1982 flood and reduced the area flooded in 1986.

The construction of flood control dams and reservoirs is not so common, but at least 2 large flood control reservoirs are in operation on the Sao Francisco river system in Brazil and yet still more flood control dams were proposed on tributaries,56/ while in 1985 the construction of a dam to protect some 100 000 hectares of farm land against periodic flooding was completed in the Cauca Valley, Colombia.57/

Sometimes several structural measures are used in different parts of a river basin; for example, frequent floods in the Grijalva river basin, Mexico have been controlled through the construction of a flood regulation dam in the upper part of the basin and of containing walls in the lower.58/

To reduce the impact of droughts, efforts have been concentrated on the construction of structures intended to improve the availability of water through its storage or through the tapping of groundwater. In recent years in Latin America reservoir storage capacity and land under irrigation have grown at an average annual rate of 5.8% (1972-1977) and 3.0% (1974/1976-1982) respectively.59/ Apart from traditional water storage techniques, other methods also have been applied, especially in the Northeast of Brazil: for example, pot-and-capsule irrigation systems; subterranean sand-trap dams; so called "salvation" dams, small reservoir systems designed for a sloping area leading to a cultivation area, manually filled porous earthen pots, among others.60/

Unconventional water sources have also been developed in the region. Argentina, Bolivia, Brazil, Chile, Mexico and Peru are investigating ways of utilizing rain water, and projects to capture fog humidity are under way in Chile, Peru and Ecuador.61/

Attention has also been paid to more efficient utilization of water. In municipal and industrial uses of water this concern is reflected in growing water reuse; in agriculture, in the use of techniques of microirrigation

--drip, sprinklers, etc., although such techniques are only applied to a small fraction of the irrigated area (for example, in Mexico such methods are used on approximately 0.1% of the irrigated area).62/ Undoubtedly, the most notable example in the field of water reuse is afforded by Mexico, where in the Federal District (which includes approximately 70% of the population of the Mexico City metropolitan area) treated water provides about 4% of current water use, mainly for irrigating public parks and filling recreational lakes. According to existing plans, in the year 2000 wastewater reuse would supply some 12% of projected water demand.63/

There are few structural measures that can be used to mitigate the impact of tropical cyclones. Structural protection can be provided against the storm surge and flooding (for example, the most important port of the Dominican Republic --Haina-- is protected from cyclone induced storms by breakwaters erected in 1951 and currently under reconstruction),64/ while breakwaters and sea-walls can also slightly mitigate the impact of tsunami.

Structural measures are usually highly capital-intensive, partly because they must be designed on the basis of the expected maximum event. Generally, such investments are considered worthwhile; for example, it is estimated that losses caused by floods on the river Mapocho, Chile (which return every 5-10 years) are approximately 20 times higher than the cost of investment required to prevent them.65/ At the same time, however, it should be taken into account that some natural disasters have a very long return period --e.g., it is estimated that the flooding that affected Guayaquil, Ecuador, in 1982-1983 has an average period of return of approximately 500-1000 years-- so that in purely economic terms the construction of the required works may not be justified. Moreover, many structures have only a relative short useful life (25-50 years).

2. Non-structural measures.

Non-structural measures for reducing the damage caused by natural hazards include all efforts to reduce damage other than the building of protective structures. The range of such measures is very large but it is possible to classify those most commonly applied in Latin America and the Caribbean into the following groups: warning systems, emergency measures, land-use controls and building regulations.

(a) Warning systems

A natural hazard warning system is indispensable for effective action to mitigate a disaster. Warning systems are most effective with natural hazards that can be detected at an early stage of their existence and whose subsequent history can be monitored with a reasonable degree of accuracy. This is the case with some floods and tropical cyclones, when the expected arrival time and force can be accurately predicted within 24 hours of their appearance. Warning systems are particularly important for tsunamis, as there are no known means of prevention.

Forecasting, prediction and warning measures in Latin America and the Caribbean are usually undertaken by national meteorological networks and

civil defence organizations. Some countries have fairly sophisticated warning and forecasting systems; for example, a real time flood forecasting system, including a telemetering network and a computerized model, was implemented in 1985 in the Yaque del Sur River Basin (Dominican Republic) and a real time hydrological forecasting system, including a satellite based telemetry network and a computerized forecasting model, has been installed in the Bayano River (Panama).66/ However, a good forecasting system is not in itself sufficient to prevent a disaster when warnings and forecasts are prepared they must be efficiently disseminated. This was tragically demonstrated in November 1985, when eruption of the Andean volcano Nevado del Ruiz (Colombia) sent a tide of mud and melted snow into Armero, the population of which had been advised by a government radio station that there was no reason for concern and no need to leave home.67/

Regional forecasting and warning measures are particularly important in the Caribbean and Central America, where the Hurricane Committee, under the auspices of the World Meteorological Organization, co-ordinates national and regional activities related to early hurricane warning and flood forecasting. In South America co-ordination and co-operation in flood forecasting is maintained mainly in the area of the River Plate basin, where Operational Hydrological Alert Centers have been set up in Buenos Aires, Asunción and Brasilia, to provide the information needed for forecasting floods on the rivers Paraná, Paraguay and Uruguay.

In the case of drought forecasting, apart from forecasts prepared by national meteorological services the United States Agency for International Development (USAID) provides bi-weekly drought and crop condition assessments throughout Central and South America and the Caribbean Basin in co-operation with the National Oceanic and Atmospheric Administration (NOAA).68/

As for tsunamis, the permanent tsunami warning system is operated by the United States National Weather Service, based on the work of the Tsunami Warning Centre in Honolulu, Hawaii. This centre operates under the auspices of the Intergovernmental Oceanographic Commission which set up an "International Co-ordination Group for the Tsunami Warning System in the Pacific" in which Chile, Ecuador, Guatemala and Perú participate.69/

(b) Emergency measures

The emergency measures developed to reduce the impact of hazards include the preparation of emergency plans (including plans for provision of emergency assistance to and from neighbouring countries), construction of Disaster Centres (stocked with food, tents, equipment, medical supplies including vaccines, etc.), Disaster Administration, development of emergency legislation, preparation of priority lists of water users, evacuation, development of emergency communication systems, etc. Emergency measures acquire particular importance when they are the only measures available for reducing the impact of natural disasters.

Such measures can also significantly reduce damage from droughts, and from floods that build up gradually, such as those in the River Plate basin in Paraguay and Argentina. At the same time, emergency measures can mitigate the impact of rapidly developing disasters such as flash floods, tsunamis,

tropical cyclones and avalanches: for example, rapid response in Santiago, Chile to an unexpectedly severe flash flood in 1982 prevented loss of life and the casualties from the hurricane Alberto that struck Cuba in November 1985 were kept low (only 3 lives were lost) due to prompt action by the defence committees in organizing the evacuation of some 715 000 people.70/

Emergency measures are usually undertaken either by specialized organizations in charge of response to all natural disasters or by civil defence organizations. In some countries, such as Antigua and Guyana, organizations subordinated to the Ministry of Health are in charge of response to natural disasters. A list of national organizations in the field of disaster management for Latin America and the Caribbean is given in Annex 2.

(c) Land-use controls

The restriction of human settlements to low risk areas is known to offer enormous advantages, and in distinction from other nonstructural measures it is of high effectiveness in reducing property loss and economic disruption. On the whole, in Latin America and the Caribbean land use planning measures are applied only in isolated cases within urban areas, although their use is growing. For example, the prevention activities of the Pan-Caribbean Disaster Preparedness and Prevention Project (PCDPPP) are geared to supporting the efforts of the Caribbean countries to determine areas of high risk from tropical cyclones, floods and other natural disasters.71/ In Jamaica a project to produce a spatial analysis of natural hazards has been carried out, and in other Caribbean islands disaster controllable areas have been identified so as to improve protection systems. The adoption of land use regulation as a flood damage mitigation recourse has been proposed in Argentina, prevention of flood hazards through land use planning has proved successful in urban areas of Mexico,72/ and resettlement of population as a means of reducing losses from drought has been undertaken in the north-east of Brazil.

Attention has also been paid not only to land use planning in its narrow sense (the restriction of certain activities in high risk areas) but also to attempts to establish new uses for these areas which will not be affected by natural disasters. One example of such a policy is afforded by the Atacama desert in northern Chile, where 18 000 hectares of Prospis tamarugo and algarroba (mesquite), which tap moisture from the atmosphere, have been planted to serve as cattle fodder.73/ In the Northeast of Brazil industrial development is being stimulated with the aim of reducing the heavy dependence of affected regions on drought sensitive agriculture.

(d) Building regulation

Prevention of building collapse and damage, particularly of buildings intended as public shelters, substantially reduces human death and suffering, limits property losses and supports post disaster emergency activities. Building regulations are an important means of controlling losses in the case of floods, tropical cyclones and other natural hazards which imply added loads for the building structure. It should be noted, however,

that building regulations that can prevent damage from earthquakes and those designed to protect against tropical cyclones or floods do not necessarily coincide.

The application of building regulations is usually considered to be expensive, but the experience of Latin American countries shows that less expensive measures can be equally effective: for example, such simple preventive measures as anchoring roofs securely to buildings and providing strong shutters for glass windows can reduce damage from tropical cyclones.74/

The use of building regulations for mitigation of natural disasters is growing in the region, most notably perhaps in the Caribbean where the adoption of building techniques and codes that can reduce damage to buildings from tropical cyclones and other natural disasters is promoted by the PCDPPP.75/ In 1982 the Caribbean Community Secretariat, with assistance from various other organizations, embarked on the development of a Caribbean Uniform Building Code which it is believed, is the single action that can perhaps do most over the next decade to reduce damage to structures in the subregion.76/

Building regulations are equally important in the case of hazard mitigation structures (dams, flood walls, auxiliary water supply systems, etc.), since the failure of these during a natural disaster can substantially increase damage. The importance of strict building regulations was demonstrated during the flood that affected Santiago, Chile in June 1982, when many old structures remained intact because of strict building norms.77/

Apart from the hazard mitigation measures described above, the use of more sophisticated techniques, frequently related to climate modification, is also developing in the region. Thus, in July 1985 a drought in the Dominican Republic was ended when rain and showers were provoked by bombarding clouds with granulated salts from an aircraft.78/

Part B

WATER-RELATED NATURAL DISASTERS IN SOUTH AMERICA, CENTRAL AMERICA AND THE CARIBBEAN (1979-1986)*/

*/ Based on information from selected issues of UNDRO News; Annual Reports of the Inter-American Development Bank; The Natural Disasters of 1982-1983 in Bolivia, Ecuador and Peru (E/CEPAL/G.1274, 27 December 1983) and other sources.

Table 1

NATURAL DISASTERS INCLUDED IN THE LIST, BY TYPES

Type	South America	Central America and the Caribbean	Total	%
Droughts	3	6	9	7
Floods	52	14	66	55
Landslides a/	16	1	17	14
Storms	4	8	12	10
Tropical cyclones	-	17	17	14
Total	75	46	121	100

a/ Include mudslides.

Table 2

DAMAGE CAUSED BY NATURAL DISASTERS INCLUDED IN THE LIST, BY YEARS

(Millions of US dollars at 1985 prices)a/

Year	Damage	Events on which information is available, as % of all events included in the list	Events during year, as a percentage of events during whole period
1979	2 419,12	25	10
1980	-	-	8
1981	12,52	19	9
1982	2 897,06	31	22
1983	1 884,91	16	13
1984	414,25	21	12
1985	3 305,40	30	14
1986(Jan.-Sep.)	61,67	27	12
Total	10 994,93	23	100

a/ The reported amount of damage has been inflated/deflated by the United States Capital Equipment Price Index.

Table 3

NUMBER OF CASUALTIES AND OF PERSONS AFFECTED BY NATURAL DISASTERS INCLUDED IN THE LIST

Type	Casualties		Affected	
	Total	Events on which information is available as % of all events included in the list	Total	Events on which information is available as % of all same type of events included in the list
Droughts	20	11	2 080 000	33
Floods	4 942	67	3 568 500	29
Landslides[a/]	29 002	88	-	-
Storms	579	83	250 000	8
Tropical cyclones	14 089	65	2 476 891	12
Total	48 632	67	8 375 391	21

a/ Includes mudslides.

Table 4

NUMBER OF HOMELESS AND EVACUATED AS A RESULT OF NATURAL DISASTERS INCLUDED IN THE LIST

Type	Homeless		Evacuated	
	Total	Events on which information is available as % of all same type of events included in the list	Total	Events on which information is available as % of all same type of events included in the list
Droughts	-	-	-	-
Floods	2 080 300	41	340 500	15
Landslides[a/]	4 366	12	-	-
Storms	84 000	17	51 000	25
Tropical cyclones	512 000	18	105 000	6
Total	2 680 666	28	496 500	12

a/ Includes mudslides.

I. WATER RELATED DISASTERS IN SOUTH AMERICA (1979-1986)

A. Droughts

1. Bolivia
   1982-1983

Affected area:	departments of Potosi, Oruro, La Paz, Cochabamba, Chuquisaca, Tarija and Santa Cruz
Affected:	1 600 000 people
Damage:	US$ 836 500 000 (with 1982-1983 floods); 1 600 000 peasants completely or partly lost their crops and livestock; 35% of the country was affected
Cause:	associated with "El Niño"
Details:	extreme drought which affected 380 000 sq. km; can be compared only to 1978/1979 and 1941/1943 droughts

2. Brazil
   December 1983

Affected area:	north-east
Casualties:	20 people; severe famine threatens thousands of people

3. Peru
   1982-1983

Affected area:	departments of Puno, Cuzco, Apurimac, Ayacucho, Huancavelica, Arequipa, Moquegua and Tacna
Affected:	460 000 people
Damage:	US$ 2 001 800 000 (with 1982-1983 floods); 460 000 peasants completely or partly lost their crops and livestock; 20% of the country was affected
Cause:	associated with "El Niño"

B. Floods

1. Argentina
   May 1979

Affected area:	northern regions
Worst affected:	provinces of Formosa and Misiones
Evacuated:	7 500 people

2. Argentina
March 1980

Affected area:	north-west
Casualties:	30 people
Evacuated:	4 000 people
Cause:	heavy rains
Details:	the San Lorenzo river overran its banks

3. Argentina
May 1980

Affected area:	province of Buenos Aires
Casualties:	31 people
Evacuated:	36 000 people
Cause:	9 days of heavy rain
Details:	an area of 10 000 000 acres was flooded

4. Argentina
December 1982

Affected area:	northern provinces (Formosa, Chaco, Santa Fe, Corrientes, Entre Rios and Buenos Aires provinces)
Affected:	50 000 people
Damage:	large areas were inundated, water was contaminated
Cause:	Anomalous, atypical and extraordinarily heavy precipitation

5. Argentina
February 1983

Affected area:	along the Parana river (north-east)
Evacuated:	30 000 people
Cause:	heavy rains
Details:	the Bermejo and Pilcomayo rivers also flooded

6. Argentina
February-March 1984

Affected area:	north-west
Damage:	many killed and thousands made homeless
Cause:	heavy rains

7. Argentina
May 1985

Affected area:	Buenos Aires and surrounding areas
Casualties:	15 people
Evacuated:	100 000 people
Cause:	heavy rains for 24 hours

8. Argentina
November 1985

Affected area:	Buenos Aires
Casualties:	13 people
Homeless:	22 000 people

9. Argentina
November 1985

Affected area:	pampas
Casualties:	14 people
Homeless:	50 000 people
Damage:	US$ 1 500 000 000; 1 500 000 ha were under water, damage was caused to crops, roads, homes, farm equipment

10. Argentina
April-March 1986

Affected area:	northern region - provinces of Chaco and Formosa
Worst affected:	province of Chaco
Casualties:	2 people
Homeless:	60 000 people
Evacuated:	55 000 people
Damage:	in Chaco 1/3 of territory was under water; several hundred thousand tons of crops were lost, 12 000 houses were destroyed, considerable livestock losses, damage to schools and health posts
Cause:	uninterrupted rain for 1 week (1 000 mm of rain within 48 hours) fell on 60% of Chaco province
Details:	accompanied by a landslide

11. Bolivia
January 1979

Affected area:	south-eastern region (between San Jose de Chiquitos and Puerto Suarez in the department of Santa Cruz)
Casualties:	25 people
Homeless:	8 000 people
Affected:	16 500 people
Damage:	railways, crops, cattle

12. Bolivia
1982-1983

Affected area:	eastern and northern departments of Santa Cruz, Beni and Pando
Affected:	700 000 people
Damage:	US$ 836 500 000 (with 1982-1983 drought); damage was caused to transport, buildings, infrastructure, agriculture; 150 000 sq. km were affected
Cause:	associated with "El Niño"; torrential rains

13. Bolivia
January 1984

Affected area:	various departments including the capital, La Paz
Affected:	3 000 people
Damage:	roads, bridges, houses, fields, livestock
Cause:	continuous rain, at times of torrential intensity

14. Bolivia
February 1985

Affected area:	Bermejo and Tarija departments 1 500 km south of La Paz
Damage:	several killed; damage to crops, water systems, communications, transport; 100 houses destroyed

15. Bolivia
January-March 1986

Affected area:	the central provinces of Cochabamba and La Paz
Worst affected:	province of Cochabamba
Casualties:	30 people
Homeless:	30 000 people
Affected:	250 000 people
Damage:	US$ 50 000 000; 2 000 houses were destroyed, 8 000 ha of farmland were flooded, damage was caused to crops, houses and roads; hundreds of thousands were left homeless
Cause:	heavy rains and snowmelt
Details:	the water level of lake Titicaca rose by 2.7 m; possibly the worst flooding in a century; mudslides and landslides

16. Bolivia
March 1982 (Note: part of the 1982-1983 flood)

Affected area:	north-eastern region
Worst affected:	provinces of Beni and Santa Cruz
Affected:	40 000 people
Damage:	US$ 400 000 000; damage to crops; livestock and infrastructure; 400 000 head of cattle died; 170 000 sq. km were flooded
Cause:	exceptionally heavy rains

17. Bolivia
February-March 1983 (Note: part of the 1982-1983 flood)

Affected area:	northern region (Santa Cruz department)
Casualties:	100 people
Homeless:	15 000 people
Affected:	50 000 people
Damage:	12 000 houses were damaged; 25 000 ha of arable and pasture land were flooded; 64 km of highway were washed away
Cause:	torrential rains; associated with "El Niño"
Details:	the Pirai river flooded parts of Santa Cruz city and surrounding areas; accompanied by flash floods

18. Brazil
February 1980

Affected area:	seven northern and central states
Worst affected:	the states of Maranhao, Para and Goias
Casualties:	50 people
Homeless:	270 000 people
Damage:	crops, roads, communication systems
Cause:	severe seasonal rains
Details:	the major Amazon tributary Tocantins burst its banks

19. Brazil
January 1980

Affected area:	Minas Gerais state (banks of the Sao Francisco river)
Casualties:	17 people
Damage:	thousands homeless, hundreds evacuated
Cause:	heavy rains

20. Brazil
April 1981

Affected area:	north-eastern region
Casualties:	30 people
Homeless:	50 000 people
Damage:	cities flooded, damage to crops; intense rain caused failure of six small upstream dams and the Mae D'Agua Dam - this caused flooding of Santa Cruz (damage to buildings and 5 000 homeless)
Cause:	10 days of uninterrupted rain

21. Brazil
December-January 1981-1982

Affected area:	near Rio de Janeiro
Casualties:	58 people
Homeless:	700 people
Cause:	heavy rains
Details:	accompanied by landslides

22. Brazil
February 1983

Affected area:	along the Parana river (Southern region)
Casualties:	9 people
Homeless:	17 000 people
Cause:	3 months of exceptional rainfall
Details:	the Parana river widened up to 60 km in some places

23. Brazil
January 1983

Affected area:	south-eastern region - around the town of Belo Horizonte in Minas Gerais state 350 km north of Rio de Janeiro
Casualties:	51 people
Homeless:	2 000 people
Cause:	torrential rains
Details:	flash floods

24. Brazil
April 1984

Affected area:	cities of Recife and Salvador in north-east
Casualties:	30 people
Homeless:	50 000 people
Cause:	torrential rains
Details:	accompanied by landslides

25. Brazil
August 1984

Affected area:	Santa Catarina state
Casualties:	4 people
Homeless:	100 000 people

26. Brazil
December 1984

Affected area:	Belo Horizonte in the south-eastern state of Minas Gerais
Casualties:	11 people
Damage:	houses, bridges, roads
Cause:	torrential rains
Details:	mudslides

27. Brazil
May-June 1984

Affected area:	states of Rio Grande do Sul (South) and Paraiba (North East)
Casualties:	23 people
Homeless:	11 100 people
Cause:	72 hours of uninterrupted rains (in Paraiba)
Details:	landslides

28. Brazil
December 1985

Affected area:	Bahia state
Casualties:	1 person
Homeless:	10 000 people
Cause:	heavy rainstorms

29. Brazil
January-March 1985

Affected area:	states of Minais Gerais, Espirito Santo and Rio de Janeiro
Casualties:	200 people
Homeless:	60 000 people
Cause:	torrential rains
Details:	mudslides and landslides

30. Brazil
March-April 1985

Affected area:	north-east (states of Maranhao, Ceara, Piaui and Rio Grande do Norte)
Casualties:	100 people
Homeless:	800 000 people
Damage:	US$ 200 000 000; public centres, health posts, schools, bridges and roads in the affected regions were wiped out
Cause:	heavy rains (over 30 inches in less than a month)

31. Chile
June 1982

Affected area:	areas adjacent to Mapocho river and its tributaries the Zanjon de la Aguada and Canal San Carlos
Evacuated:	8 000 people
Cause:	strong rainstorms (uninterrupted rain for 72 hours) and snowmelt
Details:	can be compared only to the 1953 flood

32. Chile
June 1986

Affected area:	central part of the country - Santiago and regions IV to VIII
Worst affected:	VI region
Affected:	80 000 people
Damage:	US$ 3 700 000; millions were affected by lack of drinking water and damage was caused to buildings, roads, bridges, water supply systems, farmland, etc.
Cause:	heavy rains and snowmelt
Details:	rivers Mapocho, Maipo, etc. burst their banks

33. Colombia
October 1979

Affected area:	north-eastern region
Casualties:	182 people

34. Colombia
April 1981

Affected area:	northern region
Casualties:	65 people
Homeless:	14 000 people
Cause:	heavy rains
Details:	accompanied by landslides

35. Colombia
August 1981

Affected area:	eastern region
Casualties:	150 people
Damage:	US$ 500 000
Details:	the Salamina river inundated the town of Saravena

36. Colombia
January 1982

Affected area:	south western region (Narino province)
Casualties:	90 people

37. Colombia
November 1984

Casualties:	55 people
Affected:	194 000 people
Damage:	US$ 400 000 000; damage to crops and property: almost 1/3 of the country was affected
Details:	worst floods for more than a decade

38. Colombia
July 1986

Affected area:	regions of Aranca and Meta
Damage:	crops, roads in nearly 50% of the country; thousands were affected, and there was a threat of an epidemic
Cause:	torrential rains
Details:	rivers burst their banks

39. Ecuador
1982-1983

Affected area:	coastal region - the provinces of Esmeraldas, Manabi, Guayas, El Oro, Loja, Los Rios and Azuay
Worst affected:	the Guayas river basin up to province of Los Rios
Casualties:	30 people
Affected:	950 000 people
Damage:	US$ 640 600 000; towns, roads, and farmland were inundated over large areas, evacuation problems; shortages of staple crops and drinking water, 13 700 houses, 10 bridges and 1 800 km of highway were damaged or destroyed
Cause:	nearly 2 months of exceptionally heavy rains (in some places the rainfall was more than 4 000 mm). Period of return of more than 500 years
Details:	unusually high tides along the coast, land/mudslides

40. Paraguay
March-September 1979

Affected area:	northern region (including Asuncion)
Homeless:	120 000 people
Damage:	damage to crops; the capital was flooded up to a depth of 8 m (record)
Cause:	continued heavy rainfall

41. Paraguay
May-June 1982

Affected area:	areas around river Paraguay from Bahia Negra in the North to Pilar in the South (over 1 100 km)
Affected:	100 000 people
Evacuated:	60 000 people
Damage:	diseases due to cold and damp weather
Cause:	seasonal rains

42. Paraguay
January-March 1983

Affected area:	along the Parana and Paraguay rivers
Damage:	populated centres; agriculture; roads; mines; infrastructure
Cause:	heavy rainfall
Details:	10 000 sq. km were affected

43. Paraguay
August 1986

Affected area:	eastern region
Worst affected:	Rocha Department
Affected:	2 000 people
Cause:	torrential rains

44. Peru
April 1980

Affected area:	eastern region
Casualties:	70 people
Damage:	36 000 people were isolated in the Cuzco region and in the Merced and Satipo valleys
Cause:	heavy rains
Details:	accompanied by landslides

45. Peru
March 1981

Affected area:	the central mountains and along the north coast
Casualties:	70 people
Damage:	US$ 6 000 000; 5 000 families were made homeless
Cause:	torrential rains
Details:	several rivers burst their banks; accompanied by landslides

46. Peru
1982-1983

Affected area:	departments of Tumbes, Piura, Libertad, Lima, Ancash
Affected:	830 000 people
Damage:	US$ 2 001 800 000 (direct and indirect damage) (with 1982-1983 drought); damage was caused to infrastructure and agriculture

47. Peru
January-March 1986

Affected area:	Puno, Huanuco and Ucayali
Worst affected:	Puno
Casualties:	40 people
Homeless:	10 000 people
Affected:	300 000 people
Damage:	US$ 8 000 000; crops were damaged and some 85 000 ha of cultivated land, 51 km of roads and 20 km of railway were destroyed
Cause:	continuous torrential rainfall and snowmelt
Details:	mudslides; avalanches; rivers and Lake Titicaca burst their banks; accompanied by landslides

48. Peru
April 1982 (Note: part of the 1982-1983 floods)

Affected area:	Cuzco province
Casualties:	220 people
Cause:	heavy rains
Details:	accompanied by landslides

49. Peru
April 1982 (Note: part of the 1982-1983 floods)

Affected area:	along both sides of the Ucayali river between the cities of Atalaya and Contamana in the north-east
Affected:	30 000 people
Damage:	crops, houses

50. Peru
January 1982 (Note: part of the 1982-1983 floods)

Affected area:	the Huallaga valley north-east of Lima and south-eastern province of Cuzco
Casualties:	700 people
Evacuated:	20 000 people
Damage:	extensive damage to crops, heavy damage to the town of Uchiza (in the north-east)
Details:	flash floods

51. Peru
January-March 1983 (Note: part of the 1982-1983 floods)

Affected area:	northern coast - departments of Piura, Lima, Tumbes, Sullana and Ancash - close to the border with Ecuador
Casualties:	270 people
Homeless:	200 000 people
Affected:	200 000 people
Damage:	infrastructure, roads, bridges, properties; water supplies were contaminated, crops were destroyed, dozens of villages were buried by landslides, and numerous people were injured
Cause:	heavy rainfall; associated with "El Niño"
Details:	landslides in Matucana, Lima department, up to 184 mm of rainfall was recorded over 17 hours

52. Venezuela
December 1985

Affected area:	Caracas and nearby coastal areas
Casualties:	38 people
Homeless:	15 000 people
Cause:	storms which brought heavy rains
Details:	accompanied by landslides

C. Landslides

1. Argentina
March 1984

Affected area:	town of Vespucio in north near the Bolivian border
Casualties:	24 people
Damage:	a dozen houses were buried
Cause:	torrential rains

2. Brazil
December 1983

Affected area:	region of Rio de Janeiro
Casualties:	53 people
Cause:	torrential rains

3. Colombia
January 1982

Affected area:	near the city of Manizales (in the western part of the country)
Casualties:	30 people
Cause:	heavy rains
Details:	a major landslide

4. Colombia
November 1985

Affected area:	the town of Armero (Central Colombia) and the Chinchina coffee-growing area
Casualties:	28 000 people
Damage:	US$ 400 000 000; 4 000 homes were destroyed, damage was caused to roads, bridges and houses; volcanic ash covered some 3 000 ha of farm land and destroyed cattle grazing
Cause:	mudslide - result of eruption of the Nevado del Ruiz volcano

5. Colombia
April 1986

Affected area:	regions of Boyaca, northern Cundinamarca (about 80 km north of Bogota) and Muzo
Casualties:	31 people
Cause:	rains

6. Peru
December 1981

Affected area:	near the town of Yanacocha (north-east of Lima)
Casualties:	70 people
Details:	a major landslide

7. Peru
March 1984

Casualties:	7 people
Damage:	US$ 3 000 000; Lima was cut off from central and northern areas of the country
Cause:	torrential rains
Details:	giant mudslides

8. Peru
April 1985

Affected area:	an Andean village in the Colcabamba district 500 km south-east of Lima
Casualties:	150 people
Homeless:	4 000 people
Damage:	over 100 houses were destroyed
Details:	there were 2 successive landslides

9. Peru
February 1985

Affected area:	eastern region - 570 km east of Lima
Casualties:	13 people

10. Peru
June 1985

Affected area:	la Hoyada region near the Ucayali river
Casualties:	Several scores of people were buried by landslide and were feared dead
Details:	massive landslide

11. Peru
January 1986

Affected area:	Capilluchari - a village 200 miles east of Lima
Casualties:	13 people
Damage:	one house was buried
Details:	landslide of mud and rocks

12. Peru
March 1986

Affected area:	2 Northern villages 400 km north of Lima
Casualties:	40 people
Homeless:	366 people
Damage:	roads, crops
Details:	avalanche was caused by heavy rains

13. Peru
March 1982 (Note: part of the 1982-1983 floods)

Affected area:	near Tocache, 700 km north-east of Lima
Damage:	many casualties
Details:	a major landslide

14. Peru
November 1982 (Note: part of the 1982-1983 floods)

Affected area:	remote Amazonian village of Chazuta
Casualties:	13 people
Damage:	road links were cut

15. Peru
March 1983 (Note: part of the 1982-1983 floods)

Affected area:	villages of Yautan and Cashipampa in the north of the country
Casualties:	532 people
Details:	up to 15 m of mud

16. Venezuela
September 1986

Affected area:	Caracas (district of La Vega)
Casualties:	16 people
Damage:	some 50 houses were buried by this landslide

D. Storms

1. Argentina
September 1986

Affected area:	Buenos Aires and surrounding areas
Worst affected:	locality of Isidro Casanova
Casualties:	1 person
Evacuated:	5 000 people
Details:	rain, strong wind, hailstorms; rivers and streams overflowed their banks

2. Brazil
June 1982

Affected area:	Parana state in the South (northern and eastern areas of the state)
Casualties:	333 people
Homeless:	4 000 people
Damage:	damage was done to property and bridges, and water and power supplies were cut
Details:	gale force winds of up to 150 km/h

3. Chile
July 1984

Affected area:	most of the country
Worst affected:	Andean region 120 km north-east of Santiago
Casualties:	50 people
Homeless:	80 000 people
Damage:	roads, railways, bridges were cut
Details:	snowstorms, heavy rains and high winds produced avalanches, floods and landslides

4. Chile
May 1986

Affected area:	southern and central areas of the country
Worst affected:	Valparaiso and San Antonio
Casualties:	9 people
Damage:	US$ 1 000 000; buildings, vehicles
Details:	strong winds, heavy rains (Santiago 40.2 mm, Valparaiso 51.0 mm and Curico 95.0 mm during 24 hours)

7. Honduras
November 1979

Affected area:	northern region
Casualties:	10 people
Affected:	13 000 people
Damage:	damage of several million dollars was caused
Cause:	heavy rains
Details:	strong winds

8. Jamaica
April 1979

Affected area:	north-west
Cause:	heavy rains

9. Jamaica
June 1979

Affected area:	western part of the country
Casualties:	40 people
Homeless:	35 000 people
Damage:	US$ 82 000 000; 2 525 km2 were affected, buildings, surface communications, power distribution systems, etc. were damaged
Details:	exceptionally severe flooding, very heavy rains

10. Jamaica
December 1985

Casualties:	7 people
Damage:	damage of millions of dollars to crops, roads and livestock
Cause:	floods due to heavy rains

11. Mexico
November 1980

Affected area:	south-east of the country
Casualties:	4 people
Homeless:	100 000 people
Damage:	large areas of agricultural land were flooded and damage was caused to rice, maize and sugar cane plantations

12. Mexico
November 1982

Affected area:	Port of Manzanillo
Casualties:	21 people
Homeless:	5 000 people
Cause:	heavy rains
Details:	accompanied by mudslides

13. Mexico
September 1986

Affected area:	Monterrey (state of Nuevo Leon), in the north of the country
Casualties:	13 people
Homeless:	500 people
Damage:	thousands were affected
Cause:	torrential rains (rainfall of 135 mm)

14. Nicaragua
December 1979

Affected area:	north-eastern region of the country
Homeless:	25 000 people
Affected:	30 000 people
Damage:	plantations
Cause:	18 days of continuous rain

C. Landslides

1. Mexico
February 1982

Affected area:	near Mexico City
Casualties:	10 people
Details:	mudslide

D. Storms

1. Cuba
November 1980

Damage:	destroyed 2 000 ha of tobacco plantations
Details:	tropical rains

2. Cuba
June 1986

Affected area:	central and eastern regions
Casualties:	8 people
Evacuated:	36 000 people
Details:	torrential rains; partially helped to alleviate prolonged drought

3. Dominican Republic
June 1981

Casualties:	20 people
Damage:	30 000 families were affected, serious damage was caused to 7 500 ha of rice plantations and other crops
Details:	heavy rains

4. Mexico
February 1982

Affected area:	near Mexico city
Casualties:	8 people
Details:	severe hailstorm

5. Mexico
September 1982

Affected area:	Pacific coast
Casualties:	6 people
Damage:	all Pacific ports were closed
Details:	heavy rains

6. Mexico
January 1984

Affected area:	11 states
Casualties:	140 people
Affected:	250 000 people
Damage:	30 000 ha of cereals and pasture lands were damaged and dozens of cattle died
Details:	heavy snowfall and blizzards

7. Mexico
September 1984

Affected area:	area around Acapulco, west coast
Casualties:	4 people
Evacuated:	10 000 people
Damage:	thousands homeless
Details:	in the area of Acapulco there were 2 weeks of torrential rains, while the eastern coast was threatened by tropical storm "Edward"

8. St. Lucia
September 1983

Damage:	US$ 1 290 000; banana plantations, livehood of 3 000 families, were destroyed
Details:	gale force winds

E. Tropical cyclones

1. Cuba
August 1981

Affected area:	western region
Details:	Tropical storm "Dennis"; heavy rains

2. Cuba
June 1982

Affected area:	western part of the country (Havana and Pinar del Rio provinces)
Worst affected:	province of Pinar del Rio
Casualties:	40 people
Evacuated:	105 000 people
Damage:	US$ 85 000 000; housing, infrastructure, railroads, roads,dams, bridges and electrical network were damaged, 15 000 houses were destroyed, heavy damage was caused to agriculture (137 000 ha of crops lost or damaged)
Details:	there were 2 hurricanes (one - "Alberto"), local record of 2.4 mm of rain per minute, total rainfall (9 days) was 80 cm

3. Cuba
November 1985

Casualties:	4 people
Affected:	476 891 people
Damage:	US$ 1 200 000 000; sugar cane crop and other crops, agricultural and industrial installations and 65 000 houses were damaged, 4 000 houses were destroyed
Details:	Hurricane "Kate"; wind speeds of up to 100 miles per hour

4. Dominica
August-September 1979

Worst affected:	southern part of the country including Roseau (capital)
Casualties:	7 400 people
Homeless:	260 000 people
Damage:	US$ 830 000 000; virtually all agriculture was destroyed; damage was caused to roads, bridges, power and telephone lines; 629 fishing boats were lost
Details:	Hurricanes "David" and "Frederic" (unequalled in the century). "David" brought winds of up to 240 km/h and heavy rainfall

II. WATER-RELATED NATURAL DISASTERS IN CENTRAL AMERICA AND THE CARIBBEAN (1979-1986)

A. Droughts

1. Antigua and Barbuda
   April 1984

   Affected: 20 000 people
   Damage: 20 000 left without drinking water because of the drying up of the main reservoir

2. Cuba
   February 1981-1983

   Affected area: eastern region of the country
   Damage: serious water shortages

3. Cuba
   1984-1985

   Damage: the water supply and sugar crops were affected: the 1986 crop was expected to be 12% lower than planned (8,5 mn tons) because of the drought

4. El Salvador
   July-August 1982

5. Haiti
   February 1981-1983

   Affected area: south-west region of the country
   Damage: serious water shortages

6. Jamaica
   February 1981-1983

   Damage: serious water shortages

B. Floods

1. Barbados
   May 1981

   Damage: sugar cane crop
   Cause: heavy rains

2. Cuba
February 1983

Affected area:	6 provinces
Worst affected:	Pinar del Rio and Havana in the west
Casualties:	8 people
Damage:	US$ 60 000 000; nearly 2 000 homes in Santiago de Cuba province, in the worst hit provinces 30% of tobacco crop was lost and other crops were seriously damaged
Cause:	torrential rains

3. El Salvador
September 1982

Affected area:	coastal and inland regions
Worst affected:	Pacific and Northern provinces
Casualties:	2 000 people
Affected:	50 000 people
Evacuated:	20 000 people
Damage:	US$ 280 000 000; 15 500 houses were completely or partially destroyed, 30% of crops were ruined and 14 000 km2 of land were under water; power production was affected
Cause:	torrential rains for 4 days

4. Guatemala
September 1982

Damage:	US$ 100 000 000; 60 000 km2 were affected by floodwater, 30 bridges collapsed, roads, water supply systems, communications and hydroelectrical power plants were damaged
Cause:	torrential rains

5. Guyana
December 1985

Damage:	rice crops
Cause:	heavy rains

6. Haiti
February 1981

Affected area:	south-west and north-west
Casualties:	15 people
Damage:	villages, crops and livestock

5. Dominica
November 1984

Casualties:	2 people
Damage:	US$ 2 000 000; left at least 10 000 stranded, dozens of families were made homeless, mudslides blocked access to several villages
Details:	Tropical cyclone "Klaus"; mudslides

6. Dominican Republic
August-September 1979

Worst affected:	central and southern regions of the country
Casualties:	6 000 people
Affected:	2 000 000 people
Damage:	US$ 830 000 000; 125 000 families were made homeless; damage was caused to buildings, infrastructure, crops, dams, irrigation network and drinking water supply systems, and hydroelectric and crude oil plants; floods
Details:	Hurricanes "David" and "Frederic"

7. Guadaloupe
August-September 1979

Details:	Hurricanes "David" and "Frederic"

8. Haiti
August 1980

Casualties:	200 people
Homeless:	200 000 people
Details:	Hurricane "Allen"

9. Honduras
April 1982

Damage:	US$ 101 000 000; 1 100 dwellings, 21 bridges, 500 km of secondary roads, 40 km of highway, 2 400 ha of pasture land and 10 500 ha crops were destroyed; 5 000 head of cattle were lost; 4 dams burst
Details:	landslides; rainfall was 600 mm in 3 days; widespread flooding

10. Jamaica
August 1980

Affected area:	north coast
Damage:	fishing and poultry industries, banana crops
Details:	Hurricane "Allen"

11. Jamaica
November 1985

Casualties:	7 people
Damage:	US$ 5 400 000; infrastructure, agriculture
Details:	Hurricane "Kate" caused landslides and heavy rainstorms

12. Martinique
August-September 1979

Details:	Hurricanes "David" and "Frederic"

13. Mexico
September 1982

Affected area:	North Pacific coast
Casualties:	225 people
Damage:	US$ 30 000 000; thousands were made homeless, 1 000 houses were flattened, power and water were cut off
Details:	Hurricane "Paul"; violent winds, heavy rains, flooding

14. Mexico
October 1983

Affected area:	western coast at Mazatlan (1 000 km north-west of Mexico City), town of Concordia
Casualties:	135 people
Damage:	tens of thousands were made homeless, several ships were damaged, 40 000 ha of standing crops were flattened
Details:	Hurricane "Tico"; winds of up to 250 km/h

15. Mexico
September 1986

Affected area:	southern part of the coast
Details:	hurricane "Newton"

16. Nicaragua
April 1982

Affected area:	West, North, South and Central regions
Worst affected:	Leon, Corinto, Chinandega and Managua
Casualties:	70 people
Homeless:	52 000 people
Damage:	US$ 356 000 000; the most costly damage was caused to agricultural and transportation sectors; 28 bridges and 4 500 homes were destroyed, 45% of paved roads were washed away, 6 000 livestock were killed, etc.
Details:	exceptionally heavy rains (44 cm in Managua, 86 cm in Chinandega) and strong winds (tropical storm "Alletta")

17. St. Lucia
August 1980

Casualties:	6 people
Damage:	several hundred were injured, 400 homes were destroyed and 1 100 seriously damaged, agriculture and fishing were worst hit, 9 500 families lost their means of livehood
Details:	this island was the worst affected by the hurricane "Allen"

Notes

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Annex 1

NATIONAL ORGANIZATIONS FOR DISASTER MANAGEMENT IN LATIN AMERICA AND THE CARIBBEAN a/

Country	Organization
1. Anguilla	National Disaster Committee (under the chairmanship of the Governor)
2. Antigua	National Disaster Committee (under the chairmanship of the Minister of Health)
3. Argentina	(a) Dirección Nacional de Defensa Civil (Ministerio de Defensa) (b) Dirección Nacional de Emergencias Sociales (DINES) (Ministerio de Salud y Acción Social)
4. Bahamas	Civil Defence Department
5. Barbados	Central Emergency Relief Organization (Prime Minister's Office)
6. Belize	Central Emergency Organization (Office of the Premier)
7. Bermuda	Police Headquarters
8. Bolivia	Dirección General de Defensa Civil (Ministerio de Defensa Nacional)
9. Brazil	(a) Grupo Especial para Asuntos de Calamidades (GEACAP) (Ministry of the Interior) (b) Fondo Especial para Calamidades Publicas (FUNCAP) (Ministry of the Interior) (c) Civil Defence (Ministry of the Interior) (d) Defensa Civil do Estado de Sao Paulo
10. Chile	Oficina Nacional de Emergencia (ONEMI) (Minis-

Country	Organization
11. Colombia	Dirección Nacional de la Defensa Civil
12. Costa Rica	(a) Civil Defence (b) National Emergency Commission (Health Sector) (CONESS)
13. Cuba	Civil Defence of Cuba (section responsible for the management of natural disasters and pre-disaster planning) (Ministry of the Interior)
14. Dominica	National Emergency Planning Organization (Office of the Prime Minister)
15. Dominican Republic	(a) National Civil Defence (b) Secretariat of Public Health and Social Welfare
16. Ecuador	(a) Civil Defence (b) Dirección de la Unidad Ejecutora de Obras Emergentes (Presidencia de la República)
17. El Salvador	Comité de Emergencia Nacional (Ministerio del Interior)
18. Grenada	Office of Disaster Preparedness (Ministry of Information and National Security)
19. Guatemala	Comité Nacional de Emergencia (CONE)
20. Guyana	Civil Defence Commission (under the chairmanship of the Minister of Health and Public Welfare)
21. Haiti	(a) La Commission Nationale de Coordination (president: le Secretaire d'Etat de la Sante Publique et de la Population)

Country	Organization
22. Honduras	Consejo Permanente de Emergencia Nacional (COPEN) (Dirección de Asuntos Civiles)
23. Jamaica	Office of Disaster Preparedness and Emergency Relief Co-ordination (ODIPERC) (Office of the Prime Minister)
24. Martinique	Direction Departementale de la Securite Civile
25. Mexico	(a) Subsecretaría de Asentamientos Humanos Dirección General de Prevención y Atención de Emergencias Urbanas (SAHOP) (b) Centro Médico de la Universidad Autónoma (c) Fondo Nacional para Actividades Sociales (FONAPAS)
26. Nicaragua	(a) Comité Nacional de Emergencia Frente al Desastre (b) Defensa Civil Nacional (Ministerio de Defensa)
27. Panama	Sistema Nacional de Protección Civil para Casos de Desastres (SINAPROC) (Ministerio de Gobierno y Justicia)
28. Paraguay	Civil Defence Organization (Ministry of the Interior)
29. Peru	(a) Comité Nacional de Defensa Civil (b) Division of Emergencies and Catastrophes, Department of Epidemiology (Ministry of Health)
30. Puerto Rico	Oficina de Defensa Civil (Oficina del Gobernador)
31. Saint Vincent and the Grenadines	Central Emergency Relief Organization

Country	Organization
32. Trinidad and Tobago	National Emergency Relief Organization (Ministry of National Security)
33. Uruguay	Comité de Asistencia
34. Venezuela	National Civil Defence (Ministry of the Interior)