III. CATEGORIES OF WATER-RELATED NATURAL DISASTERS

A. Introduction

The occurrence of water related natural disasters is common in the ESCAP region and their impact is becoming more devastating. Increasing populations and the denser occupation of hazard-prone areas contribute to the growing costs of damage and disruption resulting from such disasters. Unwise land-use is a significant factor in these escalating costs.

A collation and description of the major categories of water-related natural disasters which afflict the region is presented in the following sections.

B. Tropical cyclones

Tropical cyclones are intense low-pressure rotating wind systems, which develop over warm oceans in low-latitudes and move onto adjacent land masses, where they may have tremendous destructive potential. In the ESCAP region, such phenomena are called "typhoons" in the north-west Pacific and the South China Sea, or "tropical cyclones" in the Indian Ocean, the Arabian Sea, the Bay of Bengal, the northern coasts of Australia and the South Pacific. In North and Central America and the Caribbean they are called "hurricanes". All these terms are taken to be synonymous in this document.

A major tropical cyclone may affect an extensive area for a period from a few days to a week or more. Its passage is associated with extremely heavy rainfalls and extremely high velocity winds which can lead to major and extensive flooding, enormous property damage, human injury and heavy loss of life. During its life it may vary in intensity and destructive power and move along a variable path, affecting a number of countries.

The tropical cyclone cell is a circulatory wind system having an intense low pressure core. Wind circulation around the cell is clockwise in the Southern Hemisphere and anti-clockwise in the Northern Hemisphere. The diameter of a mature tropical cyclone varies from as little as 100 - 200 km to as much as 1000 km in a large system. Wind velocities around its centre may exceed 200 km/h.

A tropical cyclone forms over the open sea where the surface temperature is 26.5° C or more and the latitude about 5° to 20°. Its movement is generally along a curved westerly and polewards track. Once over land its power dissipates as a consequence of the lack of moisture supply and the friction due to the land's roughness, and it eventually deteriorates into a tropical rain depression. The time from its detection to its disappearance is commonly around 5-6 days.

Tropical cyclones are classified according to their intensity. The World Meteorological Organization (WMO) provides the following classification table:

CLASSIFICATION		MAXIMUM SUSTAINED WINDS		
		mps	knots	kph
(a)	Tropical depression	up to 17.2	up to 34	up to 62
(b)	Tropical storm	17.2 - 24.4	34 - 47	62 - 88
(c)	Severe tropical storm	24.5 - 32.6	48 - 63	89 - 117
(d)	Typhoon / tropical cyclone	32.7 or more	64 or more	118 or more

(*Source* WMO Guide to Marine Meteorological Sciences (WMO-No 471) and WMO Manual on Marine Meteorological Services (WMO-No 558))

Tropical cyclones occur more frequently in Asia, and particularly in the Northwest Pacific, than in any other part of the world. In the ESCAP region, the most frequent source for the formation of tropical cyclones is just east of the Philippines, where the main tropical cyclone season extends from July to October and the frequency of occurrence in those months is about five cyclones per month.

Tropical cyclones spawned in this region generally track westward and may later turn north-west, first affecting the Philippines and then moving on to the Asia mainland or recurving north-eastward towards Japan.

Those tropical cyclones which move westward across Indochina tend to lose their intensity after crossing the coastline. They may redevelop, however, over the Bay of Bengal and continue to move westwards over India or recurve northwards towards Bangladesh or Myanmar.

In the Bay of Bengal, in addition to those cyclones originating in the Northwest Pacific, tropical cyclones commonly develop over the southern section of the Bay and move in either a westerly or northerly direction to affect India, Bangladesh or Myanmar. These cyclones are more likely to occur before April/May or after October/November and may be accompanied by storm surges.

Some tropical disturbances track across India or develop over the Arabian Sea and more towards Pakistan, the eastern part of the Islamic Republic of Iran or the Sultanate of Oman. The occurrence of damaging tropical cyclones which affect these countries is infrequent

Tropical cyclones originating within the Southern Hemisphere zone of the ESCAP region have an extensive spawning area which includes the Indian Ocean, the Timor Sea, the Arafura Sea, the Gulf of Carpentaria, the Coral Sea and the South Pacific. Within this region, the frequency of occurrence of tropical cyclones is about half that which is experienced to the north of the Equator and the tropical cyclone season is restricted to the period December to April. These Southern Hemisphere disturbances tend to have more erratic tracks and slower travel speeds that those formed in the Northern Hemisphere, although their destructive effects may be just as severe.

C. Floods

1. The nature of flooding

A flood can be defined as an excess flowing or overflowing of water, especially over land which is not normally submerged. The source of the flow of water which produces disastrous flooding can have various origins, which include intense and prolonged rainfall, snowmelt, the downstream blocking of river channels by landslides or avalanches, the upstream failure of dams or river blockages, storm surges, abnormally high tides, and tidal waves.

Within the ESCAP region, the extent and cost of disastrous flooding has been intensifying as a consequence of increasing populations, denser occupancy of floodplains and other flood-prone areas, and the expansion of adverse forms of watershed land use. Within this region, floods are the most frequently occurring and the most destructive of all the forms of natural disaster which affect the area, although tropical cyclones have caused heavier loss of life. The most serious flooding experienced in the region comes from intense rainstorms associated with tropical cyclones or widespread and prolonged heavy rainfall associated with monsoonal depressions. Cyclonic storms may occasionally produce more than 1000 mm of rainfall per day and monsoonal flood rains may persist for many days. The resulting floods may produce inundation over periods lasting from a few hours to three weeks or more, depending upon the size of the catchment and the characteristics of the river channel and its floodplain.

Flooding is a natural phenomenon which occurs inevitably from time to time in a river or drainage basin and cannot be prevented. The problems associated with disastrous flooding arise because of man's deliberate occupancy of flood-prone areas, undertaken for a variety of good reasons. These include the suitability of flood plains and river banks for agriculture and other forms of primary production, for convenience for transport and navigation, for appropriate topography for towns and cities, and for proximity to domestic, industrial and irrigation water supply. The very existence of the flood plain is, however, clear evidence that floods will occur and flooding cannot be avoided. There can be no such thing as flood prevention: the best that can be expected is flood damage mitigation, which can be achieved only to the extent that the community is prepared to meet the costs incurred.

The important characteristics of floods, which determine the magnitude and cost of their disastrous effects, comprise the following:

(a) The peak depth of inundation, which determines the extent and cost of damage to buildings and crops and the cost and feasibility of mitigation measures;

(b) The areal extent of inundation, which determines similar factors;

(c) The duration of flooding, which is an important factor in determining the degree of damage and inconvenience caused;

(d) The rate of rise of the flood event, which determines the effectiveness of flood warning and evacuation procedures;

(e) The velocity of flood flow, which determines the cost of flood damage and the feasibility and design of levees and floodproofing structures;

(f) The frequency of flooding, which expresses the statistical characteristics of flood events of a given magnitude and determines the long-term average costs and benefits of flooding and flood mitigation;

(g) The seasonability of flooding, which determines the cost of flood damages, particularly when agricultural areas are inundated.

To understand the nature of flooding, and to provide a basis for assessing the likely effects of different forms of land use on flood behaviour, it is necessary to consider briefly the mechanics of the run-off process. This is a complex hydrological process in which many variable factors and influences may be at work. Its complexity increases with the size of the catchment under consideration, so that the flood behaviour of a small upland watershed may be entirely different from that of a large river basin of which it is a part, even though they are both subject to the same flood-producing storm rainfall conditions.

When heavy storm rainfall occurs, the precipitation will initially be intercepted on vegetation or infiltrated into the soil, where it will build up soil moisture levels and reduce infiltration capacity. When this capacity is exceeded, overland flow will commence and a build-up of surface run-off, flowing towards the nearest watercourse, will commence. Once this run-off reaches a watercourse, the rate of streamflow will commence to increase and, if the supply of run-off continues, to cause the stream to rise and perhaps overflow its banks. At the same time, precipitation which has infiltrated into the soil may move laterally as interflow or, at a deeper level, as groundwater flow, and eventually enter the watercourse and supplement the flood streamflow.

In a large valley, this process will be repeated on many sub-catchments, all of which may contribute surface and groundwater run-off to channel flow. A combined flood wave of increasing magnitude will move downstream through tributaries to the main river channel, where it may eventually exceed the capacity of the river channel and overflow its banks to inundate the flood plain.

A significant and fundamental aspect of this process is that at every stage and in every component of it, there are various forms of temporary storage through which the water must pass as it moves through the catchment. Examples of such storage include interception storage, soil moisture storage, groundwater and interflow storage, surface depression and detention storage, channel storage and floodplain storage. As it fills and subsequently empties, the effect of each component of the catchment storage is to delay and attenuate the flow of flood water, so that the peak of the flood hydrograph occurs some time after the peak rate of the storm rainfall which produced the flood flow. On very small watersheds, this delay may be a matter of minutes or at worst a few hours; on large river basins it may be several weeks and in extreme examples, as on very long, low-gradient inland rivers in some parts of the region, several months.

As a flood moves down a large valley, storage effects in the river channel system become increasingly dominant in the determination of the magnitude and time distribution of the flood wave. As the contributing catchment area increases, the peak rate of flow may be expected to increase but the rate of run-off per unit of contributing catchment area can be expected to decrease. The shape of the flood hydrograph will become increasingly attenuated as the flood wave moves down-catchment and the effects of variations in such contributing factors as the intensity and time-distribution of the storm rainfall, the nature of the vegetative cover and land use on the upper catchment, or the extent and effectiveness of upstream flood control measures such as soil conservation works or small detention reservoirs will become increasingly less significant. This is primarily because the channel storage effects become increasingly more significant and eventually, as the catchment size and the storage capacity of the channel system increase, become totally dominant in determining the shape of the flood hydrograph.

The importance of the relative storage effects to the mechanics of the run-off process is such that it is possible to classify catchments according to the level of their significance. Small watersheds are highly sensitive to changes in rainfall intensity and duration, the effects of changes in land use and the effects of other factors which determine overland flow characteristics. As the size of the watershed increases, the effects of channel flow and basin storage become increasingly dominant and sensitivities to variations in rainfall, interception or infiltration become increasingly suppressed Thus it is possible to classify a "hydrologically small" watershed as one so small that its sensitivities to short-term variations in rainfall intensity and changes in land use are not suppressed by its channel storage characteristics. A "hydrologically large" watershed can be classified as one in which the channel storage effects are dominant in determining flood behaviour and the sensitivities to rainfall and land use are largely suppressed. In terms of actual area, the upper limit for an "hydrologically small" watershed may vary considerably according to a variety of catchment characteristics, but is likely to be in the range of hundreds of hectares to a hundred or more square kilometres.

If the run-off behaviour of a watershed is such as to bring it within the hydrologically small category as defined above, the application of appropriate forms of land use can be expected to be a particularly effective method of flood mitigation. On the other hand, if a catchment falls clearly into the hydrologically large category, there will be substantial limitations upon the effectiveness of such measures for major flood disaster reduction, at least over the lower reaches of the river basin and particularly on the flood plain.

This is not to suggest, however, that land-use management on the upper watershed should not be undertaken. First of all, such management is of substantial value for direct flood mitigation in upper watershed locations. Further downstream, whilst it might not substantially reduce major flood peaks, it may be of significant value in reducing catchment and streambank erosion and reducing the transport of sediment downstream. Watershed management on the upper catchment may be seen to have a range of other advantages, which include maintaining the integrity and productivity of the catchment soils, maintaining the productivity and sustainability of forestry and agriculture, preserving the integrity of natural vegetation and wildlife habitat, maintaining the quality of the catchment ecosystem and the catchment environment, and improving the quality of life of the catchment community. Furthermore, upper watershed land-use control and management may have very significant effects in terms of the maintenance or improvement of water quality throughout the entire river system, and may be desirable for this purpose alone.

2. Riverine flooding

Riverine flooding occurs when the flow in a river channel exceeds its bankfull capacity, overflowing the normal banks and inundating the adjacent floodplain. It is a phenomenon associated with hydrologically large catchments and its most significant effect is the widespread, comparatively shallow inundation of large expanses of flat terrain.

The most important factors determining the magnitude and severity of riverine flooding are the total depth of the excess rainfall producing the flood in question, the total area of the contributing catchment, and the lag or delay time between the occurrence of the storm peak and the passage of the flood hydrograph peak. The factors will particularly affect the depth and areal extent of flooding, matters which will also be determined by the topography of the inundated areas and particularly the lateral slope and width of the floodplain. The duration of the flood-producing rainfall, as well as the catchment lag characteristics, will also affect the duration and time distribution of the flood event.

Within the ESCAP region, riverine flooding is a common occurrence which involves substantial average annual flood damage costs. In this region, a very high proportion of the community in many countries occupies floodplain sites which experience frequent and devastating flooding. The most common cause of disastrous riverine flooding is prolonged intense rainfall, although is some parts of the region, in the Himalayas or at higher latitudes, snowmelt may be a contributing factor.

The most severe flooding experienced in the region is caused by very intense rainfall associated with major tropical cyclones, particularly where the influence of the cyclone extends over a considerable area. Intense long-duration rainfall associated with monsoonal depressions is also an important cause of serious riverine flooding.

In the large river basins of the region, such as the Ganges, the Mekong and the Yangtze, flooding is usually seasonal and may last for many weeks. These basins are subject to continual rainfall during the wet season and exhibit a long high water period, with a comparatively slow rise and fall, during this season Major flooding can result if intense storm rainfall occurs during such conditions On smaller drainage basins, on rivers such as those of north China, Japan and the Republic of Korea which are subject to occasional tropical cyclones and intense convective storm activity, basin lag times are shorter and marked fluctuations of river level can occur during wet season conditions.

There is a variety of techniques which can be used to mitigate the damage caused by riverine flooding, and these are discussed in Chapter VI. Because this kind of flooding is a feature of river basins which are hydrologically large, there are limitations upon the extent to which the use of land-use practices and land-use control measures on the upper watershed can reduce the magnitude of disastrous riverine flooding. Within the floodplain areas subject to inundation, however, land-use management practices, and specifically land-use control by zoning, may be an important aspect of flood mitigation and a key component of the overall integrated watershed management programme for the river basin concerned.

3. Flash flooding

Flash flooding is a phenomenon principally associated with watersheds which are hydrologically small. It is commonly caused by intense convective storms of comparatively short duration but producing highly intense rates of rainfall. The severity of flooding is increased if the watershed is steep and its surface has low infiltration capacity. The duration of the flooding is short but the depth of flooding can be considerable and very extensive damage may result. Because they occur very rapidly and with little warning, flash floods can cause substantial injury and loss of life.

In the ESCAP region, flash flooding can be experienced wherever high intensity thunderstorms are common during the summer months or wherever intense thunderstorm activity associated with the passage of strong monsoonal depressions can be expected. It is most damaging in mountainous areas on small, steeply sloping catchments which have been cleared of protective vegetation. This type of flooding appears to be becoming more prevalent and more costly in terms of life and property because of increasing population density in districts subject to deforestation.

Because flash flooding is a phenomenon which is principally associated with watersheds which are hydrologically small, changes in land-use practices and the use of land-use controls can be effective means of flood mitigation. Such land-use practices as forest revegetation or the use of farming techniques such as terracing or strip cropping can substantially reduce flood damage and corresponding land degradation.

Land-use controls, such as the zoning of flash flood prone lands to prohibit village occupancy, can also be most effective.

4. Urban flooding

Urban flooding can be experienced in watersheds of all sizes, wherever the community has occupied locations which are susceptible to inundation by floodwater. In watersheds which are hydrologically small, it results from cyclonic or storm rainfalls falling on local areas, within or adjacent to urban settlements, where the process of urban development itself has dramatically altered the run-off-producing characteristics of the catchment. In watersheds which are hydrologically large, it is essentially an aspect of riverine flooding, which occurs because of overbank flow from major rivers onto floodplains which have been intensely developed for urban settlement.

When a catchment becomes wholly or partially occupied by urban development, this development can increase the volumes and rates of run-off from storm rainfall dramatically, partly because of the extent to which it decreases surface infiltration capacity and partly because of the extent to which it reduces times of concentration. In a dense urban environment, as compared with a natural rural environment, the enormous increase in impervious roofing surfaces and sealed pavement surfaces such as roads and parking areas results in much reduced infiltration of rainwater and a much greater volume of run-off.

The increase in paved ground surfaces, together with the installation of a more efficient drainage system, greatly reduces surface depression and detention storage, reduces the time of concentration and delivers run-off to the nearest watercourse in a fraction of the time that this would have taken prior to urbanization. The result is a much sharper rise in the rate of flood run-off, which greatly increases the peak discharge rate from the catchment and substantially increases the subsequent depth and severity of flooding. For these reasons, urbanization can significantly increase the peak discharges in smaller, comparatively frequent storms. Even in larger, rarer storms the peak discharges can be double those of an equivalent rural catchment.

For urban development on upland areas away from the floodplain, where the urbanized catchment behaves as an hydrologically small watershed, the extent to which land-use planning and management can be utilized to assist in flood mitigation is limited. Zoning of the urban area to provide adequate flood disposal waterways, to provide flood run-off detention storage sites and to prohibit residential development in highly flood-prone areas are some of the measures commonly adopted.

For intensely developed urban areas on floodplains, where there is a high risk of disastrous flooding, land-use planning and control measures have an important role to play in any flood mitigation strategy. In particular, land-use zoning to restrict or prevent housing development in areas subject to deep or high-velocity flooding is a widely-used technique under such conditions.

5. Coastal flooding

Coastal flooding can be caused by a number of factors. In the ESCAP region, the most serious forms of coastal flooding may be due to storm surge, storm tides or tidal waves (tsunami).

Storm surge flooding occurs when a tropical cyclone approaches a coastline. The low atmospheric pressure at the centre of a tropical depression causes the water surface below it to become elevated above the level of the surrounding ocean. As the cyclone approaches the coast, strong winds may pile up the already high sea waters against the shoreline, thus aggravating the rise in water level. The combined effect can produce serious flooding in low-level coastal areas.

A storm surge can be expected to be accompanied by high winds, wave action, intense rainfall and major flooding. Although its effects are restricted to a relatively narrow strip of coastline, it has the potential to cause substantial loss of life and property damage, particularly in coastal regions which are heavily populated.

When the landfall of a tropical cyclone coincides with a high tide, the depth of the storm surge is augmented by the tidal rise and the rise in sea level may exceed several metres above normal. The combined effect is termed a "storm tide". This phenomenon can be particularly devastating.

A tsunami is a different form of coastal flooding, generated by a submarine earthquake which causes a travelling ocean wave. As this wave approaches the coast its height increases rapidly and it can become very destructive as it inundates the shoreline zone.

Within the ESCAP region, many of the most severe disasters associated with tropical cyclones have involved storm surges. These phenomena are most severe in coastal regions within the tropical cyclone belt, although coastal flooding can also occur in extra-tropical and temperate regions. Countries or areas which are particularly susceptible to storm surge disaster include Australia; Bangladesh; China; the Philippines; Hong Kong, China; the Republic of Korea; Thailand; and the Pacific island countries. The northern sector of the Bay of Bengal, where the coast geometry exacerbates the phenomenon, is reported to be particularly at risk

Because the disasters resulting from coastal flooding are location-specific, land-use planning and management offers significant potential mitigation potential. In particular, zoning to limit or prohibit high-risk development in areas highly susceptible to storm surge flooding, if acceptable, is a highly effective mechanism.

D. Land instability

The term "land instability" is used here to apply to those kinds of disaster which involve the sudden movement of masses of earth and rock material down slopes and hillsides, principally as a consequence of heavy and prolonged rainfall. Such disasters include landslides, earth slips, mud flows, talus slides and detritus flows and in the context of this manual they are assumed to be associated with abnormal meteorological phenomena such as tropical cyclones, heavy thunderstorms, or intense and prolonged storm rainfall events associated with monsoonal fronts and extra-tropical cyclones. Land instability can also be initiated by earthquake action, which in some cases may aggravate the effects of rainfall saturation and gravity sliding.

The stability of a hillside or a man-made slope depends upon the weight of the overlying material, the steepness of the slope and the strength of the underlying layer or foundation. If the gravitational forces tending to cause sliding exceed the shearing strength of the underlying material along any potential failure surface, failure by slipping or sliding will occur.

When such instability does occur, the soil or rock material moves downwards and outwards – the upper part of the slide area, or *root*, subsides and the lower part, or *tongue*, bulges and extends outwards from the foot of the slope. In some types of slide, where the moving material is very soft and unstable or temporarily in a liquified condition, the tongue may move outwards for some hundreds of metres from the toe of the slope and completely block the valley floor

The area encompassed by an individual landslide is usually comparatively small and self-contained, although it may extend across many hectares. Even on relatively uniform slopes of great length and approximately uniform height, all subject to the same extreme weather conditions, slides usually occur only at a comparatively small number of isolated places, separated by considerable distances.

If the land surface overlying the slide area, or the land in the locality below the tongue of the slide, has been developed for forestry or agriculture or more seriously, is occupied by domestic or industrial development, the result of a major land instability event may be disastrous, causing serious loss of production and land productivity, dramatic damage to buildings and property, and potentially extensive injury and loss of life.

Disastrous land instability is generally a consequence of the presence of excess water in the sliding material and the underlying foundation. The source of this water may be infiltration, interflow or shallow groundwater consequent upon heavy or prolonged rainfall, and the condition is aggravated by poor drainage. The presence of excess water greatly reduces the stability of the slope for several reasons: it increases the weight of the overlying material; it increases the pore pressure in the underlying material; it lubricates the underlying failure surface; and it seriously reduces the shear strength of the material along the failure surface. In extreme cases, the presence of water may cause the complete liquefaction of the material on the slope, leading to the phenomena known as mud slides or flow slides.

The susceptibility of a given hillside or mountainside to sliding is dependent upon the nature of the overlying material and the geology of the underlying strata. The most common types of troublesome material include layers of weathered schists or shales, very loose water-bearing sands, homogeneous soft clay, stiff fissured clay, clay with sand or silt partings, and bodies of cohesive soil containing pockets or layers of water-bearing sand or silt. An underlying geological structure with slip or fissure planes lying approximately parallel to the slope offers particular problems. On natural slopes, the propensity to sliding may be aggravated by poor drainage conditions, works or land treatment measures which encourage the infiltration of surface water into the unstable material or its foundation, or the removal of vegetation, particularly large tree species which have extensive root systems capable of providing resistance to sliding forces. In developed regions, the existence of large engineering works such as quarries or road and railway cuttings is particularly likely to increase the risk of disastrous land instability unless appropriate and adequate engineering precautions are taken.

The term "landslide" is generally applied to the sudden movement of a large mass of soil and/or rock material down a steep slope, with the damage extending over a comparatively large area. "Landslips" are much smaller phenomena, although in country susceptible to landslip failure a great many individual slips may occur over a significant area in a short period of time. "Landcreep" failures, on the other hand, occur very slowly, allowing time for the taking of ameliorative or corrective measures.

"Mud flows" and "flow slides" occur when the overlying material is thoroughly saturated and, as a consequence of various initiating forces, becomes suddenly liquified. Failure occurs rapidly and the moving material travels a considerable distance outwards from the toe of the slope, causing extensive damage and devastation.

"River blockages" are a consequence of land instability, occurring when the outwards movement of material from the toe of a large landslide or flow slide completely blocks a river valley, forming a high dam behind which flood water accumulates to form a large reservoir. Such a dam is naturally unstable and extremely likely to fail suddenly, either by overtopping or by slumping, allowing the sudden release of a large volume of water and causing a flood wave to surge downstream. This may result in substantial injury and loss of life, serious property damage, damage to the river channel because of severe bank erosion and the destruction of any infrastructure, such as bridges, roads, or railways, which lies in the path of the wave.

In the ESCAP region, water-based disasters due to land instability are of widespread occurrence and periodically lead to significant damage and loss of life. They are particularly prevalent within the tropical cyclone belt, on steep hillside and mountain country which has been cleared of native vegetation and developed intensively for agriculture or rural village settlement. In more temperate regions, land instability can also be a serious problem in mountainous areas where intense and prolonged rainfall events can occur. For example, landslides are a common occurrence in the Himalayas, whilst extensive land slip disasters are occasionally experienced in other countries, such as Thailand.

Because the susceptibility of specific localities to land instability can usually be predicted and is generally well-known, land-use planning and management tools and techniques offer considerable potential for disaster mitigation. Where it is feasible, land-use zoning can be employed to prohibit or restrict human settlement or agricultural development in high-risk areas. Where the occupation of such areas is unavoidable, there is a variety of land-use control techniques, such as the restriction of logging or overgrazing or the application of precautionary land management practices, which can be utilized to assist in disaster prevention or mitigation.

E. Drought

Drought is a quite different form of water-based natural disaster from those previously described, because it is consequent upon a severe deficiency of water, not an excess of it. It can, however, be equally devastating in its effect, bringing severe economic and social consequences and resulting in serious loss of rural productivity and wide-spread and long-lasting degradation of land and other natural resources.

Drought might be briefly defined as a serious water shortage. This implies some specification of the amount of water required and the purpose for which it is to be used, both of which will determine whether a drought condition exists. What constitutes a drought for a given use in a given location may not be considered a drought elsewhere. By way of example, in Bali a drought is defined as a period of six days without rain, whereas in Central Australia an annual rainfall total of less than 200 mm might be considered normal and a severe drought may have a duration of several years.

It is generally accepted that there are at least three types of drought:

A "meteorological drought", which can be defined as a significant decrease in the normally expected seasonal rainfall, extending over a substantial area – the parameters used to measure and express its effect are the total rainfall depth and the duration of the drought period.

An "agricultural drought", which can be defined as a period during which the amount of rainfall and soil moisture content are inadequate for crop and pasture growth and animal production – the parameters used to express its severity are rainfall depth and soil moisture content.

An "hydrological drought", which can be defined as a period of below average water content in rivers, reservoirs, lakes, groundwater aquifers and soils – the parameters used to indicate its magnitude are given in terms of water storage volumes and available flow rates.

The adverse consequences of drought may be both short-term and long-term. Droughts produce immediate and relatively short-term disastrous effects upon a wide range of economic activities from crop and livestock production to water navigation and hydro-electric power production. In the longer term, droughts may result in significant loss in agricultural productivity, a forced move to less economic forms of land use, progressive land degradation or desertification, land abandonment, depopulation and the failure of communications.

A further consequence of prolonged drought, not normally expected, can be the severe increases in flooding and soil erosion which may occur if heavy storm rainfall occurs at the end of a drought, when protective vegetative cover has been lost and run-off rates may be substantially increased.

Because the nature and severity of a drought event is determined by weather conditions, it is difficult to predict its onset, its intensity or its likely duration. In the ESCAP region, this is particularly the case in higher latitude, continental regions which are outside the Tropics and away from monsoonal, trade wind or other seasonal rain pattern influences. There is increasing evidence, however, that in those parts of the region lying around the western Pacific rim, the occurrence of severe drought is associated with the El Niño phenomenon.

Drought is an intermittent problem in all the countries of the ESCAP region, even including the Philippines, Indonesia and the islands of the South Pacific. 1Major drought disasters are experienced from time to time in Australia, India and northern China, where the consequences of a drought event may be of very considerable significance to the national economy over a long period. Heavy loss of livestock, human disease and starvation, loss of wildlife and natural vegetation, and extensive and long-lasting land degradation, are all likely outcomes of drought disaster.

Land-use planning and management can provide a range of tools and techniques to assist in the mitigation of drought disaster. These include a wide range of special agricultural practices aimed both at improving preparedness for drought and managing drought conditions more effectively. Conservation farming practices are designed to increase the intake and storage of soil moisture, to reduce the rate of usage of soil moisture, and to mitigate the in-drought and post-drought effects of wind and water erosion. The conservation and storage of food, fodder and water and a variety of livestock management techniques are also employed both as drought survival tools and as safeguards against drought-induced land degradation.

Water conservation and the careful management of surface and underground water resources are key elements in any drought mitigation strategy. In drought-prone areas, the provision of adequate water storage and distribution systems and facilities for water supply and irrigation is essential, along with the careful and conservative development and husbandry of groundwater resources. Watershed management practices aimed at increasing and stabilizing the long-term supply of surface and groundwater and recharging groundwater aquifers have an important part to play in drought management practice.

F. The regional experience

Water-related natural disasters in the form of tropical cyclones, floods, landslides and mud flows are periodical occurrences in the majority of the countries of the ESCAP region. In many places land degradation, the consequence of poor land management, has served to aggravate the seriousness of such disasters. The available data indicate that, whilst not all the ESCAP countries are affected by tropical cyclones, very few of them are free from damaging flood events. These data also indicate that whilst tropical cyclones and associated storm surges are likely to cause the highest numbers of fatalities, floods are the most frequently occurring disaster events and the ones which cause the greatest total amount of damage. Tsunamis are also the cause of substantial destruction in coastal regions. Elsewhere, landslides and mud flows following very heavy rainfalls may cause considerable damage in both urban and rural communities. Droughts are a frequently occurring natural disaster in many countries, impacting particularly upon rural communities. Land degradation may exacerbate and prolong the adverse consequences of such events.

Cyclones, floods and drought are the worst forms of natural disaster to affect Bangladesh, although droughts occur only comparatively rarely. Tropical cyclones originating in the Bay of Bengal are usually associated with heavy rainfalls, strong winds and storm surges. Tidal waves often accompany cyclonic storm events. Tidal wave and storm surge conditions have from time to time been responsible for very heavy loss of life and extensive property damage. Severe flooding occurs along the main rivers in Bangladesh and smaller tributary streams may also experience serious flooding as a result of intense local rainstorms. Because Bangladesh has only a small area of hilly country, flash flooding or mass movement are not significant problems.

In Cambodia, major flooding can be caused by the Mekong River, as a consequence of heavy monsoon rainfalls over its upper catchment. Flash flooding is also common on smaller high-level watersheds across the country. Landslides caused by heavy rainfalls are also a common occurrence on upland watersheds.

Tropical cyclones can occur along the entire Chinese coast and the inland areas adjacent to it. The eastern and southern coastal regions are particularly vulnerable but all inland areas, with the exception of the north-western region, are within the range of cyclone damage. Most of the tropical cyclones affecting China approach from the China Sea. They may cause heavy damage along both large and small rivers, as well as along the coastline. Flooding may also be caused by heavy rainstorms, ice jams or landslides. Apart from these effects, landslides and mud flows can be problems across substantial areas of China. Many areas are also affected by droughts, often occurring sequentially, which result in severe impacts upon agricultural production and the overall national economy.

India has a long coastline which is exposed to tropical cyclones originating in the Bay of Bengal and the Arabian Sea. These cyclones are usually associated with high winds, torrential rains, flooding and storm surges. Elsewhere in India, flooding occurs during the monsoon season and is a consequence of heavy rainfalls associated with cyclone events, the monsoons, or intense tropical storms. Flash flooding is a problem on steep watersheds. Landslides are also a common and frequent form of natural disaster in India, a consequence of heavy rainfalls and land and soil degradation resulting from inappropriate human activities on steep country. The highest incidence of landslide disasters is to be found in the Himalayan region Many parts of India are also subject to severe drought events, a consequence of the erratic occurrence and behaviour of local rainfall conditions. It is estimated that 70 per cent of the agrarian districts of India are drought-prone

Climatic conditions in Indonesia are dominated by the tropical monsoon which extends from December to May each year. Flooding is the most frequently occurring natural disaster phenomenon, but tidal waves, landslide and droughts may have severe effects on local populations. The occurrence and severity of such events varies widely across the many island regions of which Indonesia is composed. Generally speaking, the upper watersheds of most large rivers are characterized by very steep slopes which are occasionally subject to very high intensity rainfall. Under such conditions, flash flooding and landslides are common occurrences On the coastal plains, extensive and protracted flooding occurs from time to time.

The major forms of water-based natural disaster to affect the Lao People's Democratic Republic are droughts and floods. Whilst tropical cyclones are not a direct threat, they can produce very heavy rainfalls leading to devastating flooding on the many smaller tributaries throughout the country. Flooding along the Mekong River results from heavy monsoon rainfalls during the period of August to September. Droughts may be experienced between May and July, before the arrival of the monsoon season.

On the east coast of Peninsular Malaysia, and along the coastline of Sabah and Sarawak, flooding is commonly associated with the north-east monsoon during the months of November to February. Intense, localized and short-duration thunderstorms are often the cause of flash flooding on the small but steep watersheds along the west coast of Peninsular Malaysia. In urban areas of Malaysia, intensive convective thunderstorms during the monsoon season are often the cause of flash flooding, particularly in Kuala Lumpur. Landslips or mudflows are an occasional consequence of heavy localized rainfall. Generally speaking, however, Malaysia is relatively free from massive flooding caused by severe tropical cyclones.

Along the coast of Myanmar, widespread damage can result when tropical cyclones coincide with storm surge conditions. Cyclones occur during the months of June to December. Severe tropical storms are also experienced during April, May, October and December. Flooding during the south-west monsoon may severely affect the lower reaches of the Ayeyawaddy River. Flash flooding is also experienced over upstream tributaries and smaller watersheds as a consequence of heavy rainfall. Damages from landslides, mudflows or droughts are essentially negligible by comparison with the severe damages that results from cyclone and flood events.

The climate of Nepal is largely controlled by the monsoon cycle. The principal flood season coincides with the period of maximum monsoonal rainfall, which usually occurs in August. High altitude watersheds are subject to major flooding from snowmelt. Flash flooding may also occur in the higher watersheds as a result of heavy rainfall. Glacial outburst floods may occur as a result of the sudden release of ponded glacial lakes and landsliding is also a common occurrence in high watersheds.

Pakistan does not suffer from the damaging effects of tropical cyclones, but is subject to devastating floods originating from monsoon rainfalls and snowmelt. The most widespread flooding occurs on the floodplains of the larger river systems, but upstream flooding resulting from landslides or the blocking of tributaries by glacial dams is also a common problem. Drought is a common feature of climatic conditions in the arid regions of Southern Pakistan and may have severe adverse effects, not only in economic and social terms but also in its land degradation consequences.

Water-related natural disasters are of common occurrence in the Philippines, where they may produce massive devastation. They include cyclones, floods, mass movement and drought. The severity of the impact from such disasters varies from region to region according to geographical location and topographical features. This country lies within the tropical cyclone belt and is affected by cyclones associated with the south-west monsoon during May-September and the north-east monsoon during November-February. Flooding is the most commonly occurring form of natural disaster and includes both riverine flooding and coastal flooding. Coastal areas are particularly susceptible to flooding from tsunamis, which may be aggravated at high tide periods. Floods often cause tremendous damage to prime agricultural lands and to government infrastructure such as roads, bridges, irrigation dykes and flood-control structures. Landslides are the most commonly-occurring form of mass movement disaster in the Philippines, and may affect pristine, disturbed or developed land areas.

The Republic of Korea is located in the temperate monsoon region. About two-thirds of the annual rainfall is received during the monsoon period from June to August. During these months, tropical cyclones and intense depressions bring heavy rainfall which often results in major flooding. Prior to the monsoon season, occasional droughts affect the agricultural and industrial sectors and impact upon rural communities. Tsunamis and landslides produce less frequent and less harmful natural disaster events.

Sri Lanka may be subject to a variety of natural disaster events, which include tropical cyclones, floods, droughts, landslides and coastal erosion. Heavy rainfalls occur during both the north-east monsoon period, from October to February, and the south-west monsoon period, from May to September. Tropical cyclones occur only rarely, but they can cause severe destruction and heavy loss of life. Floods are a common occurrence and they are often associated with landslips. Flash flooding is experienced on the high watersheds of the central mountain range and its slopes. Drought is also a common occurrence in the northern and eastern districts.

In Thailand, major natural disasters are mainly the consequence of flooding caused by heavy rainfalls associated with tropical cyclones. Landslides may also cause severe problems, whilst droughts are a common occurrence in the months preceding the rainy season. Tropical cyclones and deep tropical depressions may extend across Thailand between May and October. These are associated with very heavy rainfalls which can produce major and protracted flooding along the larger rivers and their flood plains. Destructive flash flooding is also a common occurrence on the smaller watersheds scattered throughout the country.

In Viet Nam, the northern and central regions are often affected by tropical cyclones during the rainy season, which occurs between July and October. Storm surges may also be a problem along the coastline. Flash flooding occurs on the many small, steep watersheds in the central region, whilst extensive and protracted flooding can be experienced in the Red River Delta region to the north Although tropical cyclone damage is rare in southern Viet Nam, the Mekong Delta region commonly experiences major flooding as a result of heavy rainfall on the upper catchment.