Day 1

Session/Activity		Activity time (minutes)	Cumulative time of session
Session 1: Introduction			
1.1	Registration	20	20
1.2	Opening ceremony	15	35
1.3	Mutual introductions	15	50
1.4	Participants' expectation survey	10	60
1.5	General introduction to the training objectives and programme schedule	10	70
1.6	Agreement on group rules and norms	10	80
1.7	Other issues (housekeeping)	10	90
Session 2: Flash Flood Hazards in the HKH Region			
2.1	Geographic setting of the region	10	10
2.2	Regional rainfall and temperature patterns	20	30
2.3	Physiographic features and runoff patterns of the major river basins	15	45
2.4	Major characteristics of flash floods in the HKH region	45	90
Session 3: Types, Causes, and Impacts of Flash Floods			
3.1	Types of flash flood	15	15
3.2	Identifying the causes of flash floods	10	25
3.3	Group presentation on activities 3.1 and 3.2	15	40
3.4	Outcomes and impacts of flash floods	20	60
Session 4: Flash Flood Hazard Analysis and Assessment			
4.1	Flash flood risks and hazards	30	30
4.2	Methods of hazard analysis and assessment	60	90

SESSION 1

Session 1 Introduction

Time: 90 minutes

Objectives

To introduce the participants, find out their expectations, and clarify the objectives of the training

- Introduction of participants, facilitator(s), trainer(s) and resource person(s)
- Discovery of participants' expectations
- Discussion of how the training objectives relate to the participants' expectations
- Setting the training norms and clarifying the logistics
- Discussion of any issues of concern raised by the participants

Materials

- One bag/file per participant containing a pen, writing pad, the training schedule, and relevant documents/materials
- Wall clock
- Different coloured meta cards
- General equipment and materials as described in the section 'How to use this Manual'

Activities

Activity 1.1: Registration

Time: 20 minutes

Registration is an informal activity to record the participants' names and addresses for future use and to distribute materials.

Distribute a registration form (see sample in 'Resource Materials' at the end of the session) to each participant and request that participants fill them out and return them.

A bag/file should be distributed to each participant at registration. The bag can containing any materials required during the training such as writing pads and pens, the training schedule, and documents required for the training sessions.

Suggestions for the facilitator

A simple attendance form can be used to record daily attendance at the training. This attendance form can be circulate at the beginning of each day or kept separately at the registration desk where the participants can sign it as they come in.

Activity 1.2: Opening ceremony

Time: 15 minutes

The opening ceremony which includes remarks by relevant speakers and VIPs marks the official launch of the training, it helps to set the tone for the session and can serve as a reminder of the broader issues which may not necessarily be touched upon in detail during the training.

Suggestions for the facilitator

Prepare a programme for the opening ceremony. Remember to be mindful of the protocol for the different speakers and VIPs. When inviting the speakers, acquaint them with the purpose of the training and inform them of how long they are requested to speak.

Activity 1.3: Mutual introductions

Time: 15 minutes

The facilitator asks participants, trainer(s) and resource person(s) to introduce themselves by stating their name, the country that they are working in, the organisation that they are affiliated with, and by giving a brief account of their expertise.

Suggestions for the facilitator

Introducing participants, trainer(s), and resource person(s) at the start of the training helps to create an environment of ease among all present. Make the introductions fun by using an icebreaker, which serves the dual purpose of making the session interesting and discovering the background of the participants. There are many possible icebreakers (e.g., West 1999).

Activity 1.4: Participants' expectation survey

Time: 10 minutes

The aim of the survey is to give the facilitator a better idea of the participants' expectations so that the course content can be fine-tuned to accommodate their needs (if possible).

Step 1 Distribute a blank meta card to each participant. Ask the participants to write down their expectations from the training on the meta card provided.

Step 2 Collect the completed meta cards. The facilitator goes through the meta cards and compiles a summary list of the expectations. The facilitator then communicates the participants expectations' to the programme coordinator and to the resource persons so they can address the relevant issues in their sessions.

Suggestions for the facilitator

It is strongly recommended that the facilitator go through the meta cards to compile the list and become acquainted with the participants' expectations from the training; the facilitator should then consider how to accommodate any need for changes to the content of the training.

Activity 1.5: General introduction to the training objectives and programme schedule

Time: 10 minutes

The facilitator makes a presentation:

- Outlining the training objectives
- Introducing the main topics/themes
- Relating the expectations of the participants (as per their feedback on the meta cards) to the topics that will be covered in the training programme.
- Introducing the programme schedule

Suggestions for the facilitator

Call attention to the programme schedule and briefly explain the content of the training and the way it is distributed over the days. When presenting the training objectives, make sure to correlate these with the expectations expressed by the participants. The comparison should give the participants an idea of the extent to which they already have a comprehensive, strategic overview of flood risk management and whether or not they have expectations outside the scope of the training. If some expectations are not covered in the objectives, make this clear. If the expectation is relevant but not explicitly covered, explain that it can be either discussed in private with the trainer or, if it is of general interest to this particular class, it can be discussed during a related session.

Activity 1.6: Agreement on group rules and norms

Time: 10 minutes

The facilitator discusses the rules and norms to be observed to ensure a good atmosphere for the training and inquires whether these are acceptable to the participants as is, or whether they need to be modified. The facilitator writes down the points raised on a flip chart or white board. These can be summarised on one sheet of paper and display on the wall throughout the training. Some typical ideas that might be included are listed below.

- Raise hand to ask a question
- One speaker at a time
- Respect for gender and culture. Do not use gender, racial, religious, or culturally sensitive words, or language.
- Respect starting and ending times
- Attend the sessions on time
- Inform when absent
- Switch off mobiles phones during the session
- Deal with things that disturb participants first. No question or observation is weird
- Responsible for your own learning
- Responsible for your 'yes' and 'no'
- Keep cases realistic

Suggestions for the facilitator

Use the parking lot – find time to answer all questions
During any given presentation the participants may raise issues that are relevant in the context of the session but which it is not possible to address or clarified at the moment due to time or resource constraints. Such issues can be 'parked' by writing them on the chart paper provided for this purpose. The 'parking lot' chart paper is displayed by the presenter's desk or in another convenient location. The trainer can then discuss these topics either one-on-one with the individual or with a group by arranging a mutually agreed time either during lunchtime or tea break or at the end of the day.

Activity 1.7: Other issues (housekeeping)

Time: 10 minutes

It is wise to keep aside some time to discuss any other issues that may need attention during the training. These issues may or may not be related to the technical aspects of the training. Letting participants know that any issues that are important to them will be looked after is reassuring and is a way of making participants feel comfortable and engaged. The facilitator may ask about time schedules, logistics, or any other issue. If a participant raises an issue, the facilitator should seek a solution by discussing with the group. The important thing is to assure participants that their needs will be taken into consideration. Items that may be of concern to the participants can include, for example:

- Resource materials and data
- Information regarding transportation from the place of residence to the training venue
- Places for phone communication, internet access, etc.
- Nearby market places for general shopping
- Traffic and security regulations
- Emergency contact person(s) and contact details

After this discussion, the facilitator can continue with the next technical session.

Session 1 Resource Materials

RM1.1: Sample registration form format

Flash Flood Risk Management Workshop Registration Form

Date (fill in)	
Name:	
Country	
Representing organisation:	
Position:	
Postal address:	
Fax:	
Contact telephone number:	
Email address:	

Sample attendance sheet format

Flash Flood Risk Management Workshop Sign-Up Sheet

Date: (fill in)	
Name of participant (please print)	Signature

RM 1.5: Objectives of the training

The specific objectives of the Flash Flood Risk Management Training of Trainers (TOT) Workshop are:

- to understand the nature of flash floods, their types, causes and the impacts they can have;
- to better understand flash flood hazards, vulnerability and risk assessments, and management methods;
- to understand what role local knowledge and gender perspectives can play in flash flood risk management;
- to explore social hazard mapping techniques and processes and to learn to value community participation;
- to learn about the full range of flood and risk management measures for different types of flash floods;
- to explore different ways of transferring scientific information to local communities;
- to provide information on the various modelling tools and understand how these can be used in an integrated approach to flash flood risk management;
- to provide in-depth information on risk management measures that can be used before, during and after the flash flood; and
- to provide the necessary tools and materials so that the participants can replicate this training on their own.

Session 2 Flash Flood Hazards in the HKH Region

Time: 90 minutes

Objectives

To acquaint the participants with the general characteristics of flash floods and introduce why flash floods occur in the Hindu Kush-Himalayan (HKH) region, including:

- Highlights of the geographical setting of the region
- Rainfall and temperature patterns of the region
- Physiography of the major river basins and their runoff patterns
- How flash floods and riverine floods can cause loss of life and property

Activities

Activity 2.1: Geographic setting of the region

Time: 10 minutes

Introduce the geographical setting of the HKH region, review which countries are covered, and touch on the major geological formations, landform types, slope, and relief.

Activity 2.2: Regional rainfall and temperature patterns

Time: 20 minutes

Present a review of the rainfall and temperature patterns of the region; include the following information:

- Maps of rainfall variability by season; summer vs. winter precipitation patterns
- Explanation of the monsoon and westerly circulation changes and their geographical coverage and dominance
- Microclimatic features and specifically the role that high intensity rainfall plays in causing flash floods in HKH region
- Summer and winter temperature patterns and their variability
- The relationship between altitude and temperature

Activity 2.3: Physiographic features and runoff patterns of the major river basins

Time: 15 minutes

Review the following:

- Major rivers and river basins of the HKH region
- Monsoon and annual runoff patterns in the region
- Seasonal variation in the runoff patterns of selected major rivers in the region

Activity 2.4: Major characteristics of flash floods in the HKH region

Time: 45 minutes

Step 1 Introduce the following:

- Major flood events in the region and loss of life and property
- The difference between flash floods and riverine floods

Open up a discussion on the difference between flash floods and riverine floods. Present the major differences between the two types of floods and compare the extent of losses that can be caused by each type.

Step 2 Present a short video on flash floods. Possible examples can include the extreme weather events of 1993, and/or the Bagmati flood or Koshi Flood that took place in Nepal in 2008. Discuss the nature of the flood and discuss the extent of the damage that it caused in terms of the loss of life and property.

Session 2 Resource Materials

RM 2.1: Geographical setting of the region

The HKH region extends 3,500 km in length and covers all or part of eight countries, namely, Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. The region encompasses some of the highest mountain chains in the world and the world›s two highest mountain peaks, Mt. Everest (8,850 m, Nepal) and K2 (8,611 m, Pakistan).

The mountain chains of the HKH region are the youngest on earth and are still tectonically active. They are still undergoing uplift and consequently the region is characterised by steep slopes and a high rate of surface erosion. These ranges contain rock series from all the major geologic periods. The central Himalayan zone has predominantly crystalline and metamorphic rocks which date from the Tertiary Period (which started before 65 million years ago and ended 1.6 million years ago) whereas the Eastern Himalayas have more examples of Archaean basement gneiss which date to more than 2.5 billion years ago. The lower ranges, along the southern flank of the Himalayas, consist of a complex set of younger Tertiary sedimentary deposits including riverine deposits left behind by rivers originating in the Himalayas.

RM 2.2: Rainfall and temperature in the HKH

The climate in the Himalayas, as in the other parts of South Asia, is dominated by the Monsoon. The summer monsoon originates in the Bay of Bengal and the amount of monsoon precipitation it deposits decreases from east to west. The Monsoon season is much longer in the Eastern Himalayas (e.g., Assam), where it lasts for five months (June-October), than in the central Himalayas (Sikkim, Nepal, and Kumaon) where it lasts for four months (June-September). In the Western Himalayas (e.g., Kashmir) the Monsoon lasts for only two months (July-August) (Chalise and Khanal 2001); however, this area also receives significant precipitation from winter westerlies. Winter precipitation is greater in the western parts of the region and less in the eastern parts. Summer precipitation is greater on the windward side of the Himalayas owing to the orographic effect and the leeward side receives less rain. Annual precipitation decreases from southeast to northwest: from about 800 mm at Markam and Songpan in western Sichuan to 400-500 mm at Lhasa, 200-300 mm at Tingri, and less than 100 mm at Ngari Prefecture (Mei'e et al. 1985).

Temperatures in the HKH vary inversely with elevation at the rate of about 0.6°C per 100 m but, due to the rugged terrain, temperatures vary widely over short distances. Local temperatures also vary according to season, aspect, and slope (Zurick et al. 2006). Owing to the thin atmosphere above the Tibetan Plateau and ample and intense radiation, the surface temperature has a large diurnal variation, although its annual temperature range is relatively small. The diurnal variation of temperatures in the northern mountainous region of Pakistan and Afghanistan is also considerable, and the annual temperature range is large. In Chitral (1450 masl), for example, in the course of a year temperatures can climb to as high as 42°C and can plunge to as low as -14.8°C (Shamshad 1988).

High-intensity rainfall is a characteristic microclimatic feature of the region (Domroes 1979). Such high-intensity rainfall has important implications for the flash floods known as intense rainfall floods (IRFs) which are common throughout the HKH.

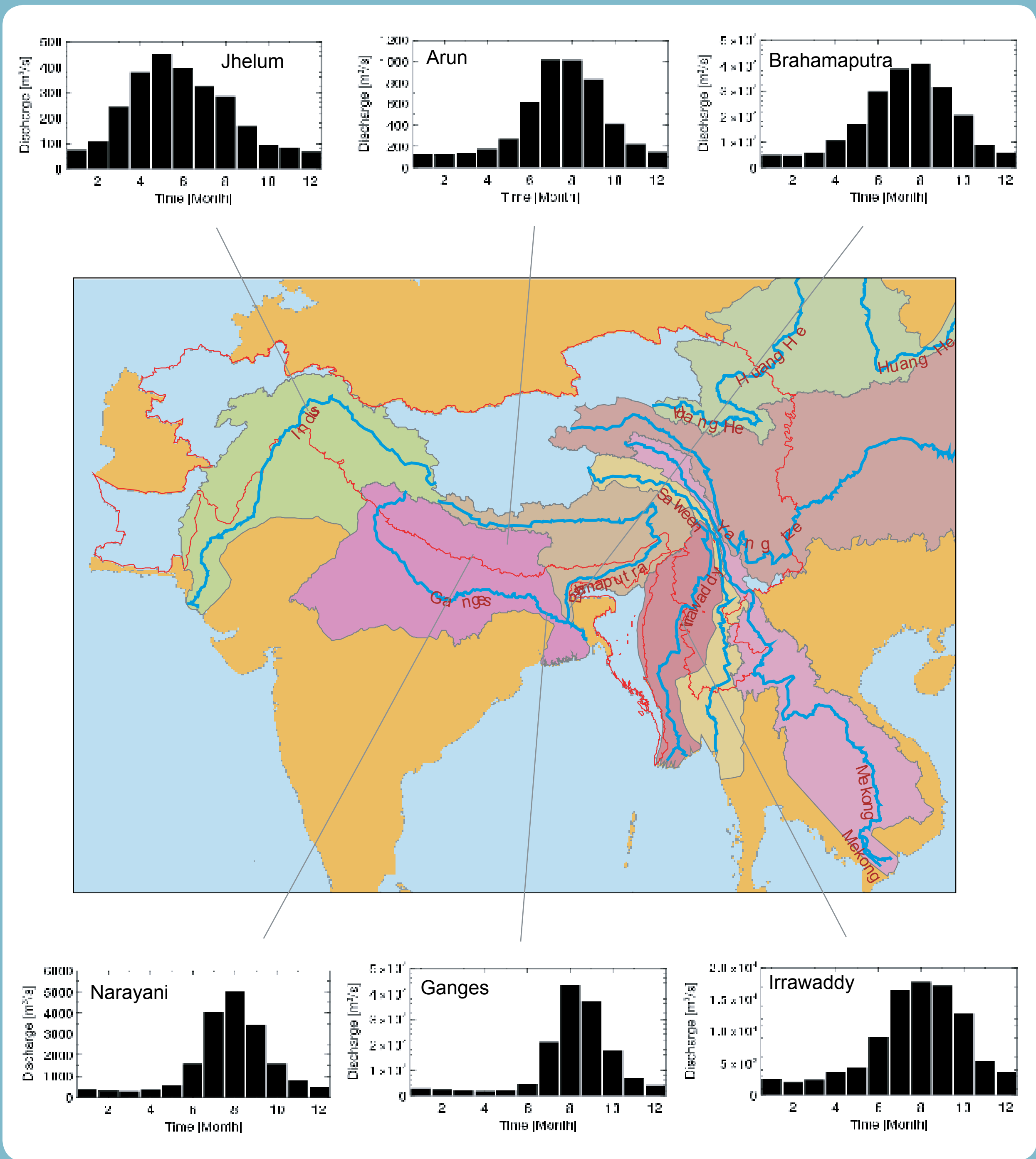
The Western Himalayas, Karakoram and Hindu Kush can receive large amounts of snow during the winter. This precipitation is caused by westerly disturbances from the Mediterranean. These intense snowfalls can affect livelihoods not only by causing avalanches, which often block transport routes, but also by causing flash floods when rapid snowmelt is triggered by fast warming in the spring.

RM 2.3: Major river basins and their runoff pattern

Ten major rivers originate in the Himalayan range – the Amu Darya, Brahmaputra, Ganges, Indus, Irrawaddy, Mekong, Salween, Tarim, Yangtse, and Yellow Rivers.

All of these rivers are an important source of runoff, and in all cases the runoff is significantly higher in the summer than in the winter (Figure 1). In spite of the fact that the river basins of these rivers are situated in widely different locations, their flow hydrographs generally peak during spring or summer, a fact that accentuates the importance of summer precipitation in runoff generation.

Figure 1: **Major river basins in the HKH and seasonal variation in the flow of selected rivers**



Source: ICIMOD archive

RM 2.4: Flash floods in the HKH region and their major characteristics

The frequency with which flash floods occur differs in different areas. It is now widely held that the joint influence of global climate change and regional environmental degradation may compound to increase the frequency and the magnitude of water-induced hazards (including flash floods) and that mountainous regions, such as the HKH, are more susceptible to these changes. The main characteristics of flash floods are summarised in Box 1.

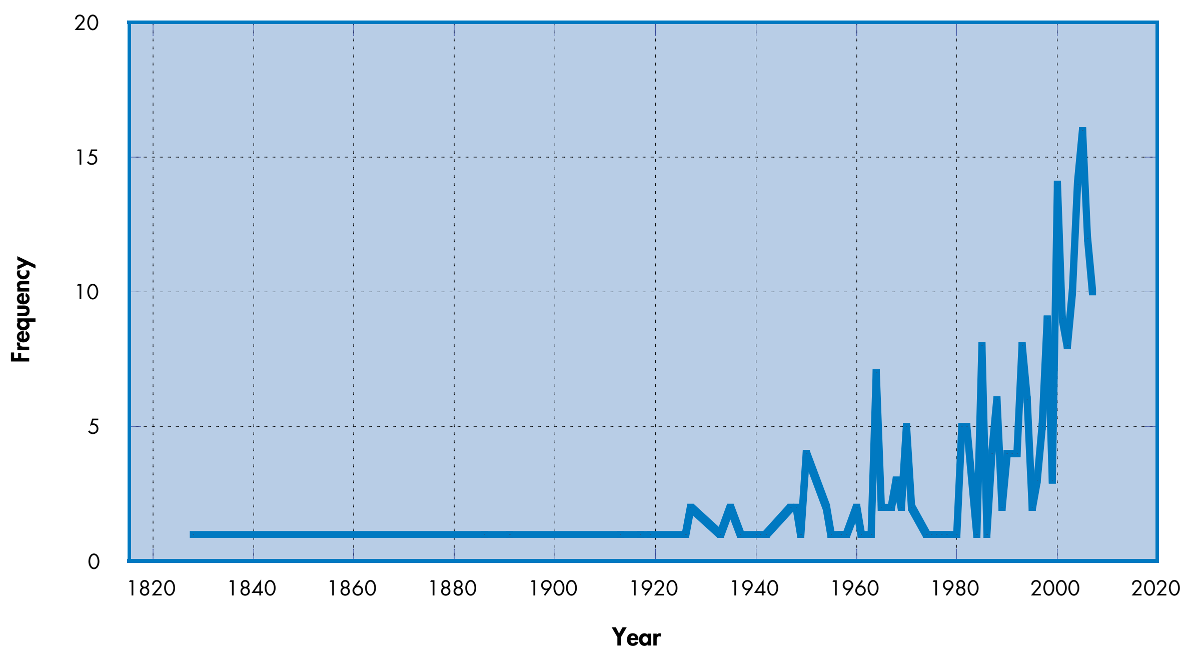
Box 1: Characteristics of flash floods

- Sudden and rapid events that travel like waves
- Sudden onset – little or no lead time
- Can occur at any time of the year
- Floods are localised
- No distinct flood path
- Flood waters travel at high speed
- Flood waters contain a high debris load

Figure 2 shows that the incidence of flash flood events has increased sharply since the 1980s. With 1985 as a baseline for study, the greatest number of flash flood events occurred during 2005 and 2006.

Every year in the HKH region, both hundreds of lives and billions of dollars worth of property and investments are lost, scarce agricultural lands are destroyed due to landslides, debris flows, floods, and flash floods. Statistics show that the number of people killed per event is significantly higher in Asia than elsewhere and that the number is higher for flash floods than for all other water-induced disasters. In the last decade of the twentieth century, floods killed about 100,000 people and displaced or otherwise affected an additional one billion people. There are indications that the number of flood events (and the number of related deaths) is increasing (Jonkman 2005, cited in Shrestha and Shrestha 2008). In China, 152,000 people were killed

Figure 2: **Flash flood trend in HKH region (based on data recorded from 1828 to 2007)**



Source: Shrestha and Shrestha (2008)

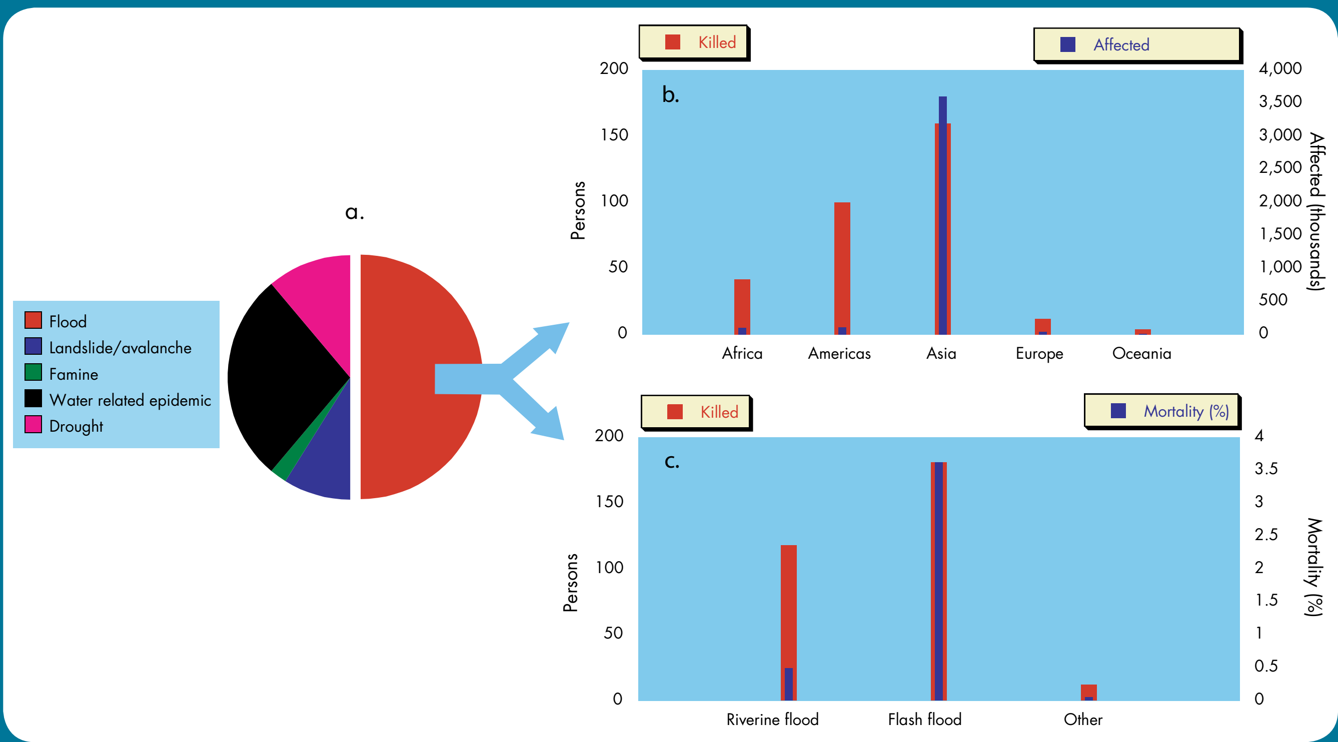
SESSION 2

Table 1: **Flash floods and riverine floods**

	Flash floods	Riverine floods
Features	Rapid water level rise above natural channels Reaches peak flow within minutes up to a few hours Rapid recession (within minutes to few hours) Often dissipate quickly Not necessarily related to base flow levels Short lag times	Slow water level rise beyond natural channels Reaches peak flow within days to weeks Slow recession (within days to weeks) Mostly coinciding with high base flow levels Medium to long lag times
Causes	Very high intensity rainstorms/ cloudbursts Rapid snow/glacial melt due to rapid increase in temperature Dam (both artificial and natural) breaks	Prolonged seasonal precipitation of low to high intensity Seasonal snow and glacial melt
Associated problems	Often carry high sediment and debris loads Very high hydraulic force and erosive power	Inundation
Frequency	Occasionally, any time during the year	Annually during rainy season
Affected areas	River plains and valleys Alluvial fans Mostly local extent Generally small to medium areas are affected	River plains and valleys Local to regional extent Large areas can be affected
Predictability	Very difficult to forecast	With appropriate technology and measures in place, forecasting is easily possible
Potential mitigation measures	Early warning systems Community preparedness and awareness Appropriate emergency measures	Real-time flood forecasting Community preparedness and awareness Appropriate emergency measures

Source: Xu et al. (2006)

Figure 3: **People killed and affected by floods: a) Types of water-related disasters; b) Number of people killed and affected by floods (disaggregated by continent); c) Number of people killed (disaggregated by flood type)**



Source: Based on Jonkman (2005); ICIMOD (2007) in flash floods during the period from 1950 to 1990, and accounted for about 67% of the total number of flood related deaths during the same period (Zhuo and Wan 2005, cited in Shrestha and Shrestha 2008). In Nepal, landslides, floods, and avalanches are annually responsible for about 300 deaths and the destruction of important infrastructure of estimated worth US$ 9 million (DWIDP 2005, cited in Shrestha and Shrestha 2008).

Flash floods and riverine floods differ in many respects (see Table 1). The numbers of people killed or otherwise affected is higher for flash floods than for riverine floods (Figure 3) (Jonkman 2005). The region's flash floods occur predominantly in the mountainous parts of South Asia, such as the greater Himalayan range, the Hindu Kush, the Karakorum, the Tien Shan, the Kun Lun, and the Pamir.

Session 3 Types, Causes, and Impacts of Flash Floods

Time: 60 minutes

Objectives

To understand the types, causes and impacts of flash floods, including:

- The different types of flash floods
- Identifying the causes of flash floods
- Understanding the impacts that flash floods can have from different perspectives

Methodology

This session uses group work to stimulate involvement and discussion. The participants are divided into groups where they discuss the assigned topic and record their findings. At the end of the allotted time each group shares their findings and the whole class participates in a group discussion.

Activities

Note to the trainer

The interactive format of this session provides the trainer with an opportunity to find out how much the class knows about flash floods. It is therefore necessary to encourage everyone to actively participate in the discussion.

Activity 3.1: Types of flash flood

Time: 15 minutes

Step 1 Depending on the number of participants, divide the class into 3-5 groups, each having 3-6 participants.

Step 2 Distribute Handout 3.1 to each group.

Step 3 Ask the groups to discuss the types of flash floods that can occur in the region and ask them to list the different types on Handout 3.1.

Step 4 When the participants have had a chance to complete their handouts, engage them in a short question and answer session. Add to the participants' understanding and correct common misconceptions. To make the definitions more vivid, show pictures of the various types of floods. It is important to intervene at this point because the groups need to have a clear understanding of the different types of flash floods before they go on the next activity which is about the causes.

Activity 3.2: Identifying the causes of flash floods

Time: 10 minutes

Step 1 Similar to Activity 3.1; this time, ask the groups to discuss the probable causes of flash floods.

Step 2 Continue with Handout 3.1, ask the groups to list the causes for each type of flash flood identified in the previous exercise.

Activity 3.3: Group presentation on Activities 3.1 and 3.2

Time: 15 minutes

Step 1 Ask each group to select a person to present the group's findings on the types and causes of flash floods.

Step 2 Comments on the similarities and differences in the list of 'causes' that each group presents. Uses this as a starting point to present the major causes of flash floods.

Step 3 Ask the groups to return the completed Handout 3.1. Review the returned handouts and mark the missing types of flash floods and their causes as compared to the list found in the resource materials. Use this feedback to gauge the participants' grasp of the subject matter. Make sure to notice if there are any new types and causes mentioned by the participants.

Activity 3.4: Outcomes and impacts of flash floods

Time: 20 minutes

Step 1 Continue with the same groups as were formed for Activity 3.2. Distribute Handout 3.4 to each group. Ask the participants to discuss the possible impacts of flash floods.

Step 2 Ask each group first to list the possible impacts of flash floods and then to complete the table by considering what type of impact each can have.

Step 3 Make sure that the participants are able to analyse the impacts from different perspectives. Discuss the types of impacts and review responses given in Handout 3.4.

Note to the trainer

The group exercise on the categorisation of flash flood impacts helps participants to understand the impacts from different perspectives. Guide the discussion by first highlighting what the impacts can be and then discuss each from different perspectives. For example, work through the example of a bridge damaged during a flash flood. In this case the physical loss of the structure is immediately evident and its effect on the transportation system is also quickly apparent. The loss of a bridge severely affects everyday life and disturbs the normal mobility pattern. Eventually, its devastating effects on the regional economy also become apparent. The economic consequences can be equally incapacitating. These can include, for example, impacts on tourism and travel through the area as alternative routes need to be taken. The point to emphasise is that impacts can be viewed from different perspectives e.g., physical, economic, and social. Discuss how the impacts can be quantified.

Session 3 Handouts

Handout 3.1: Types and causes of flash floods

List the types of flash floods and give their probable causes.

SN	Type of Flash Flood	Probable Causes

Handout 3.4: Inventory of flash flood impacts by type

List the possible losses or impacts caused by flash floods and place a tick mark in the appropriate column to indicate the type of impact that can be expected.

SN	List of possible losses or impacts caused by flash floods	Type of impact							
		Physical	Social	Direct	Indirect	Short term	Long term	Reversible	Irreversible

Session 3 Resource Materials

RM 3.1: Types and causes of flash floods

Based on the underlying processes causing flash floods, they can be categorised into three main types: intense rainfall floods, landslide dam outburst floods, and glacial lake outburst floods. In addition, flash floods can also be caused by bursting of artificial structures such as dams.

The causes of flash floods can be broadly classified into two main groups; these are either meteorological (intense precipitation) or geo-environmental.

Intense rainfall flash floods

Intense rainfall is the most common cause of flash flooding in the HKH region. It is associated with three meteorological phenomena: cloudbursts, stationary monsoon troughs, and monsoon depressions.

Cloudbursts. A cloudburst is an extreme form of precipitation, sometimes with hail and thunder, which normally lasts no longer than a few minutes but is capable of creating flood conditions. Cloudbursts occur when air masses are heated intensely and rise rapidly to form thunderclouds. When these clouds interact with the local topography, they often move upwards, especially if the atmospheric flow is perpendicular to the topographic features. Intense precipitation typically involves some connection to monsoon air masses, which originate in the tropics and are typically warm and heavily laden with moisture (Kelsch et al. 2001). A lack of wind aloft prevents the dissipation of thunderclouds and facilitates concentrated cloudbursts which typically deposit precipitation in a small localised area.

Monsoon trough. Intense rainfall can also be caused by the prolonged stationary positioning of an inter-tropical convergence zone (ITCZ), commonly called a monsoon trough. An ITCZ is an elongated zone or low pressure system which typically sits along the mountain range. This type of meteorological phenomenon was responsible for record precipitation in the upper region of the Mahabharat Range in the central part of Nepal on 19-20 July 1993. On 20 July, Tistung station measured a rainfall of 540 mm in 24 hours, and the gauge recorded a maximum rainfall of 70 mm in one hour (Shrestha 2008).

Monsoon depressions. Intense monsoon depressions seldom reach the mountain areas during the monsoon season. They are occasionally caused by strong westerly waves over northern Kashmir, which cause heavy to very heavy rainfall in the lower Kashmir and Jammu Valley, resulting in devastating flash floods. Westerly waves moving across Kashmir and the northern parts of Pakistan can strengthen the monsoon depression. In July 2005, this type of a depression moved into Punjab and Kashmir and caused heavy rainfall in the upper catchment of the Chenab River (Shrestha 2008). Since the mountain catchments are very steep, the river flooded quickly.

Geo-environmental causes of flash floods

Geo-environmental factors can also precipitate flash flooding. The main geo-environmental factors to causes flash floods are the outburst of a landslide dam and the outburst of a glacial lake.

Outburst of landslide dams. The HKH region is prone to recurrent and often devastating landslides because the mountain slopes of the HKH are both steep and unstable. Excessive precipitation and earthquakes can cause the slopes to landslide. The landslides and debris flow can form temporary dams across river courses, impounding immense volumes of water. A landslide dam outburst flood (LDOF) can occur when these makeshift dams are overtopped or water breaks through.

As the reservoir level rises (due to river flow or otherwise) and overtops the dam crest the dam can suddenly erode and outburst. The dam can also be overtopped when a secondary landslide falls into the reservoir. Alternatively, since landslide dams are only makeshift, their own internal instabilities can trigger an outbreak even without overtopping. Landslide dam outburst floods scrape out riverbeds and banks causing heavy damage to the riparian areas and huge sedimentation in downstream areas.

In general, high landslide dams form in steep, narrow, valleys because this is where landslide debris gathers (Costa and Schuster 1988). Commonly, large landslide dams are caused by complex landslides that start as slumps or slides and become rock or debris avalanches. Volcanic eruptions can also cause the formation of dams, but there are no such examples in the HKH region. Other mechanisms that can contribute to the formation of landslide dams are stream under-cutting and entrenchment.

Outburst of glacial lakes. Glacial lakes form as glaciers recede, and their formation is directly related to climate variability. When glaciers recede they leave behind large voids that are filled with melt-water; these are moraine-dammed glacial lakes. Moraine dams are structurally weak and unstable; they undergo constant changes due to slope failures, slumping, and other such effects. When a moraine dam fails catastrophically the result is a glacial lake outburst flood (GLOF).

Glacial lake outbursts are a main cause of flash floods in the HKH. Glacial lakes can burst due to internal instabilities in the natural moraine dam triggered by hydrostatic pressure, erosion, overtopping, or other internal structural failure. Glacial lakes can also burst due to external triggers such as rock or ice avalanches, earthquakes, and the like. A GLOF can result in the discharge of water and debris whose flow is several orders of magnitude greater than seasonal high flow. Bhutan, China, Nepal, and Pakistan have suffered a number of GLOFs in the past (Ives et al. 2010).

Avalanches and earthquakes can also trigger GLOF events depending on the severity, magnitude, location, and other characteristics. Moraine dams can also collapse without the aid of an external trigger, such as when the dam slopes fail or when there is excessive seepage from the natural drainage network of the dam.

Outbreak of artificial structures. The failure of artificial structures can also cause tremendous flash floods. As more and more river basins in the HKH are being exploited by people, flash floods due to the failure of human-made hydraulic structures will likely increase. Flash floods can occur when there is the uncoordinated operation of a hydraulic structure. Moreover, when settlements are constructed on natural flood plains and water is re-channelled it can lead to conditions that can cause flash floods. Other causes of flash flooding are urban infrastructure development and deforestation (due to increasing urbanisation in mountain areas), and failure to maintain drainage systems.

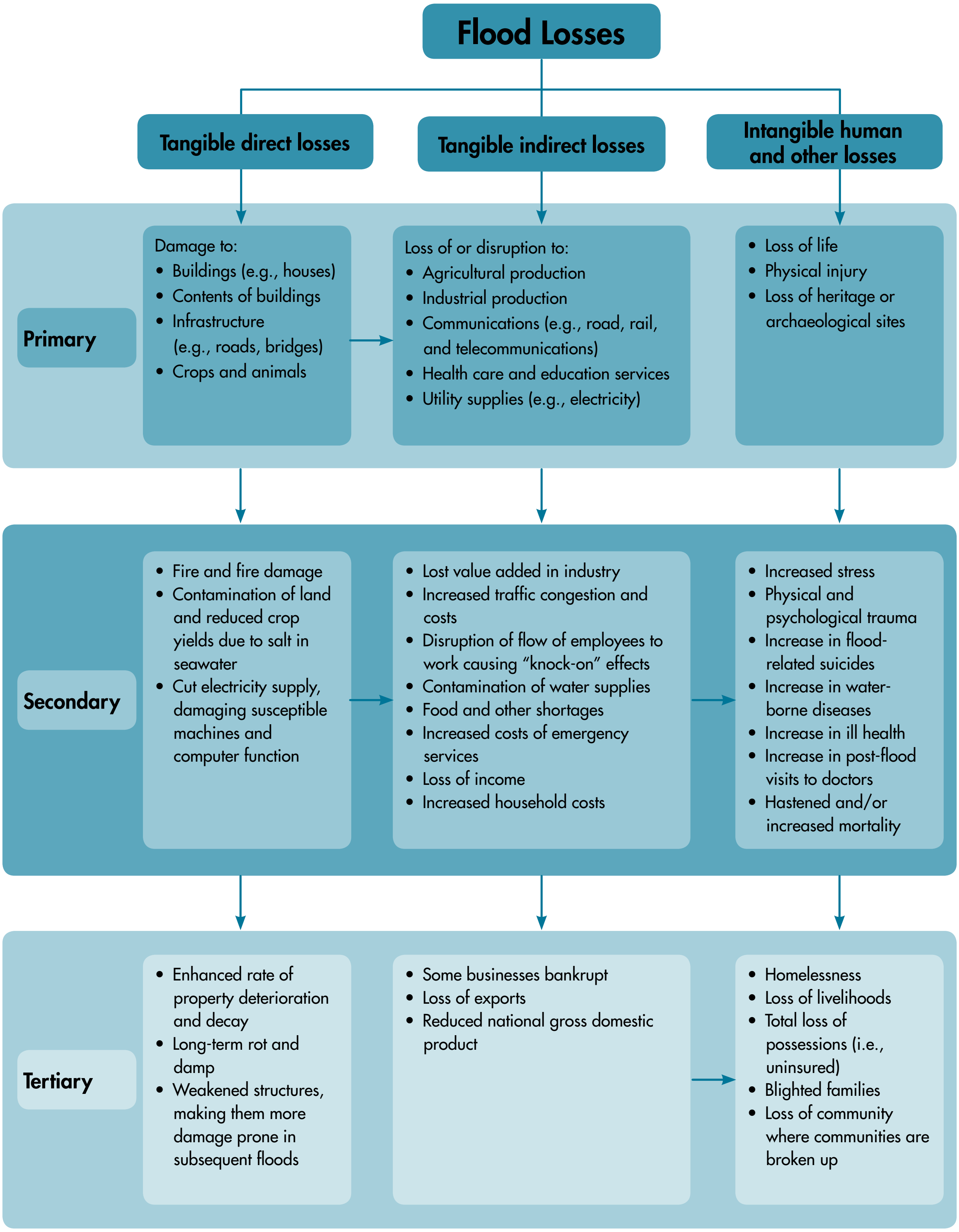
RM 3.2: Outcomes and impacts of flash floods

Flash flood waters flow at high speed and carry large amounts of debris. These debris laden waters can cause the loss of life and can sweep away critical infrastructure that is the lifeline of mountain communities. Some of the destruction which is caused by flash floods is immediately apparent while some subtly undermines existing structures and the true damage is not seen until some later time. Some of the destruction is short term while some has long term detrimental effects on the environment and the socio-economic life of communities. Typical flood losses are given in Figure 4.

Socioeconomic

Landslides and debris flows can have major socioeconomic impacts and can affect people, their homes, possessions, industrial establishments, and lifelines such as highways, railways, and communication systems. The indirect effects of flash floods are also many and can encompass aspects as diverse as reducing real estate values, causing the loss of industrial, agricultural, and forest productivity; and causing the loss of tourist revenues by damaging land or facilities or by interrupting transportation systems.

Figure 4: **Categorisation of flood losses**



Source: Parker (2000)

Environmental

Flash floods in the HKH take a great toll on the natural environment. Mudflows can cover terraced lands with boulders and debris and can damage standing crops laying waste to agricultural fields. In the foothills and plains of the river valleys, floods often deposit coarse sediment, which not only damages valuable crops but also renders the land infertile. Floods cause severe bank erosion and the loss of soil. Debris flows aggrade river beds, divert flows, and can cause riverine floods. When rivers change their course, the environmental setting is altered.

Session 4 Flash Flood Hazard Analysis and Assessment

Time: 90 minutes

Objectives

To understand flash flood hazards and to be able to understand:

- The concepts of risk and hazard
- The methods of hazard analysis and assessment

Activities

Activity 4.1: Flash flood risks and hazards

Time: 30 minutes

Step 1 Engage the participants in a short interactive question and answerer session; ask the class how the concepts of risk and hazard apply to flash floods.

Step 2 Clarify the concepts and introduce the source-pathway-receptor-consequence conceptual model of risk.

Step 3 Present the major steps involved in flash flood risk assessment and explain what information it is necessary to obtain from primary and secondary sources. Clarify that hydrological, meteorological, land use, and geographical information can be collected from secondary sources but that socio-economic and geo-morphological data need to be collected from the field. Emphasise that field verification is important for all data.

Note to the trainer

Before beginning the next activity take a moment to put things into perspective. Explain that risk assessment is the most essential part of the flash flood risk management process. Clarify that analysis and assessment of hazard and vulnerability are the prerequisites for risk assessment and that the following activity and the following session are leading up to this.
The analysis leading up to risk assessment is a multi-step process, where the steps are:

- The collection of essential information on the flood prone area as needed; and can include geographical, geological, hydrometeorological, land-use, and land-cover data as well as historical information on past flood events
- The actual hazard analysis and assessment
- The vulnerability assessment
- The risk assessment

Activity 4.2: Methods of hazard analysis and assessment

Time: 60 minutes

Step 1 Review the fact that analysis of hazard is based on information collected from different sources as discussed in Activity 4.1.

Step 2 Discuss the various methods of flash flood hazard analysis. Give a presentation that lists the methods and gives their major characteristics. Emphasise that a combination of social (community-based) and technical methods gives the best results.

Step 3 Clarify the concept of hazard intensity and hazard probability level and discuss how they are determined. Discuss how probability levels are assigned both to flash flood that are cause by intense rainfall and to flash floods that are caused by other means.

Step 4 Present the hazard-level scale and explain how it is determined.

Session 4 Resource Materials

RM 4.1: Flash flood risks and hazards

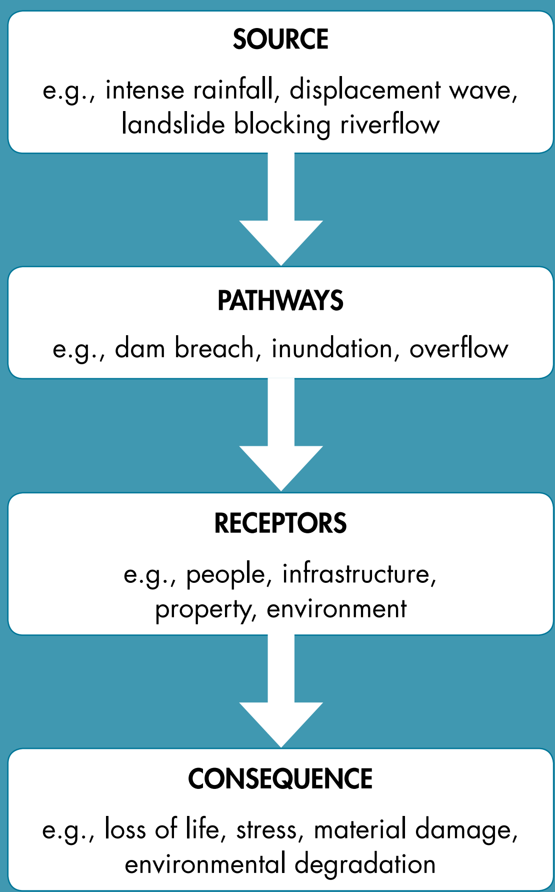
Flash flood risk refers to the chance for loss of life and property due to flash floods. Flood risk, in simple terms, is a function of flood hazard and vulnerability (Box 2). Flash flood hazards are those potentially damaging flood events that cause losses. Vulnerability is the capacity (or lack of capacity) of people to anticipate, resist, or cope with the event. Flash flood risk can be better understood using the 'source-pathway-receptor-consequence' (S-P-R-C) conceptual model proposed by Gouldby and Samuals (2005). For risk to arise there must be hazard, which is the source or initiator event (e.g., cloudburst); the pathway is the conduit between the source and receptors (e.g., flood routes, overland flow, or landslide); and the receptors are the people and property that are affected. The consequence depends on the degree to which the receptors are exposed to the hazard (Figure 5).

Box 2: Risk is a function of…

- The characteristics of a hazard event
- The vulnerability (exposure/sensitivity) of assets and livelihoods to potential hazards
- The options available for risk management, and the capacity to access them

The risk can be evaluated by considering of the following components: the nature and probability of the hazard; the degree to which the receptors (number of people and amount of property) are exposed to the hazard; the susceptibility of the receptors to the hazards; and the value of the receptors.

Figure 5: **Conceptual source-pathway-receptor-consequence (S-P-R-C) model**



Steps in flash flood risk assessment

The major steps taken to assess risk include the following:

- Collecting information about the flood prone area. The information needed includes: determining which localities or communities are at risk; evaluating the geographic characteristics such as the length of the river sections; peculiarities of the area, population and population distribution; geology and geomorphology; hydrology and hydraulics information; hydrometeorology; land-use; historical information on flooding in the area and existing counter measures.
- Assessing hazard or determining hazard level and intensity
- Assessing vulnerability
- Assessing risk

RM 4.2: Methods of hazard analysis and assessment

The different scenarios of flash flood hazard can be analysed using various methods and tools and the findings can be presented in the form of hazard maps. Modern technology has advanced hazard mapping and the prediction of possible events considerably through techniques such as geological mapping and satellite imagery, high resolution mapping, and computer modelling. Geographic information system (GIS) mapping techniques, in particular, are revolutionising the process of preparing hazard maps. Computer-based modelling techniques and community-based hazard mapping techniques are the cornerstones of hazard analysis. Even more reliable results can be achieved when the two methods are combined and the results are substantiated through field verification.

Hazard analysis is directed at understanding the intensity of the flood hazard, the strength of potential flash floods, and the scenarios for the catchment. The intensity of the hazard is determined by estimating the degree of the anticipated flooding. Generally, the degree of intensity is classified as high, moderate, moderately low, or low (Table 2).

After estimation of the degree of the intensity of the potential hazard, the hazard probability level is assigned. The probability of flash flooding is based on the return period of the flood. If the return period is short, the probability of hazard is high and vice versa. It is relatively straightforward to assign a return period or frequency when the flooding is caused by rainfall. However, it is often difficult to assign a probability level to flash flood events such as LDOFs and GLOFs, as they occur infrequently and are seldom repeat events. In such cases, it is customary to use probability levels based on the characteristics of the lake, dam, or surrounding environment. The characteristics of the surroundings are determined qualitatively.

As in the case of the degree of intensity, the four levels of hazard probability are high, moderate, moderately low, and low.

Assessing hazard consists of considering both the intensity of the potential hazard and its probability. Figure 6 shows an example of a hazard-level scale. Both the hazard probability and the degree of hazard intensity have four levels (high, moderate, moderately low, low). The resulting 16-cell hazard-level scale identifies four hazard levels: very high, high, moderate, and low.

Table 2: **A simple way of assigning hazard intensity**

Hazard intensity	Danger to population close to the stream	Danger to population in settlement (about 500 m from the stream)	Danger to population 1 km away from the stream	Danger to population more than 1 km away from the stream
High	yes	yes	yes	yes
Moderate	yes	yes	yes	no
Moderately Low	yes	yes	no	no
Low	yes	no	no	no

Figure 6: **Hazard-level scale**