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INTERNATIONAL EXPERIENCE REVIEW

Climate change impacts and adaptation responses for the water resource engineering sector

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1 INTRODUCTION

1.1 Water Induced Disasters

The main water induced disasters that the Department of Water Induced Disaster Prevention (DWIDP) is coping with are landslides, debris flow, river bed variations (degradation, aggragation, lateral shifting), and flooding.

Although these are all natural processes, they have been aggravated over time by increase in population and human activities, such as encroachment of flood plains, deforestation, cultivation of marginal lands, construction of road in hilly and mountainous areas, etc. As a result of climate change the frequency and severity of landslides, floods, and other calamities is expected to increase.

In the following Chapters the impacts of climate change on water induced disasters are discussed in some more detail and examples are given of adaptation measures in some other countries.

1.2 Design criteria

Gradual shifts in climate and flood risk have important implications for engineering design. An essential element in hydraulic design is the prediction of maximum flood peaks that occur at a certain return period. Such estimates are usually made on a frequency analysis of flood peaks observed in the past.

However, as the climate changes, historical observations will not be indicative of future events since future flood statistics will be different from past statistics.

Obviously, historical data remains very useful, for example for the calibration of hydrological models and to observe how the frequency of flood volumes and flood peaks are changing.

Based on the present knowledge the hydrologist should make the best estimate of these changes to ensure that the design of structures indeed fulfills the adopted design criteria for the life period of hydraulic structures.

2 WATER INDUCED DISASTERS

2.1 Landslides, debris flows, and river bed variations

Both landslides and floods are amongst the most devastating events in Nepal causing severe loss of lives and property. Landslides usually occur in areas of weak geological formations or active tectonic activities and steep topography. Landslides are usually triggered by high rainfall, when the upper soil strata are saturated. Landslides can also result from road construction or erosion of riverbanks.

Riverbed variations result from both erosion and sedimentation. Deposition of sediment is often observed at locations where there is a sudden drop in the longitudinal river gradient, for example when the river enters the alluvial plain.

In the braided rivers in Nepal the river channels change frequently. Due to the sediment deposition the riverbed gradually rises reducing its discharge capacity . Once the riverbank is breached during a large flood the river may laterally shift to take a new course with large consequences for intakes of irrigation schemes and public water supply.

2.2 Floods

The different types of floods can be classified as follows:

- Flash floods
- River (or fluvial) floods
- Ponding (or pluvial) floods

In Nepal the flash floods and fluvial floods are the most common flood types.

Flash floods

Flash floods usually occur in mountainous or hilly areas. They are characterised by high flow velocities and a very steep rise and fall of the discharge. They usually are of short duration and cover relatively small areas along the river. Flashfloods may transport large amounts of debris, including large boulders in mountainous areas and may be very devastating with regard to loss of life and property.

There are a number events that could cause flash floods:

- High intensity rainfall
- Sudden massive melting of snow
- Landslides blocking rivers
- Melting glaciers

High intensity rainfall floods

Flash floods resulting from high intensity rainfall are quite common in Nepal. In July 1993 a rainfall of more than 500 mm was recorded in 24 hours in central Nepal, causing a destructive flash flood with much damage to infrastructure and lives.

Sudden massive melting of snow

Due to rapid temperature increase in spring sudden snowmelt can occur causing flash floods.

Landslide Dam Outburst Flood (LDOF)

In addition to their direct impact, landslides and debris flows can create conditions for flash floods or trigger flash floods.

This happens when large amounts of material from landslides or debris flows temporarily block the river flow down in the valley. The water behind the dam builds up and creates a lake. Once the water level in the lake overtops the dam, sudden erosion of the dam can cause a flood outburst. Overtopping can also be triggered by a flood wave when a secondary landslide falls into the temporary lake. A sudden collapse of the dam could also be caused by internal instability.

Resulting floods, called Landslide Dam Outburst Floods (LDOFs), usually scrape out beds and banks causing heavy damage to the riparian areas and huge sedimentation in downstream areas. ICIMOD (2008) distinguishes the following types of landslide dams (see Table 1).

Table 1 Types of landslide dams

Type	Cause	Effect
I	Falls, slumps	Dams are small with respect to the width of valley fl oor and do not reach from one side to the other
II	Avalanches, slumps/slides	Dams are larger and span the entire valley fl oor
III	Flows, avalanches	Dams fi ll the valley from side to side and considerable distances upstream and downstream
1V	Falls, slumps/slides. Avalanches	Dams formed by contemporaneous failure of materials from both sides of a Valley
V	Falls, avalanches, slumps/slides	Dams formed when the same landslide has multiple lobes of debris that extend across a valley fl oor at two or more locations
VI	Slumps/slides	Dams created by one or more surface failures that extend under the stream or river valley and emerge on the opposite valley

Glacial Lake Outburst Flood

Glacial lakes often result from retreating glaciers. The space between the retreating glacier and the moraines will be filled by meltwater of the glacier, thus forming a glacial lake.

The moraine dams, consisting of boulders, gravel, sand and silt are usually structural weak and unstable. Once these dams collapse due to overtopping or piping a very destructive Glacial Lake Ouburst Flood may result. Overtopping could also be caused by upstream rockslide into the lake, or a snow/ice avalanche or an earthquake (ICIMOD, 2008).

Fluvial floods

Fluvial floods are quite different from flash floods. They usually occur in the flatter alluvial areas and are of longer duration. Flow velocities are relatively low and rise and fall of the floods is very gradual.

Fluvial floods are generally caused by high rainfall over a large upper catchment area and over a longer period. Once the river banks or the embankments along the river are over- topped or a breach in the embankment occurs, large areas may be inundated, often resulting in large loss of life and property. Sedimentation in the river bed as a result of upstream debris flows will increase the risk of such flooding because of the reduced carrying capacity of the river.

3 IMPACTS OF CLIMATE CHANGE

3.1 General

Major factors related to climate change that increase the risks of water induced disasters in Nepal are the changes in rainfall characteristics and the increase in temperature.

The climate change impacts are manifold. Not only are these impacts affecting all of the above water induced disasters directly, but one event, such as a land slide, may also trigger or aggravate another event such as a debris flow or a flash flood.

3.2 Rainfall intensities and floods

It is generally expected that the occurrence and severity of floods will increase in view of the world-wide observed tendency, attributed to climate change, of higher rainfall-intensities. This tendency has a more amplified effect on the river flows. It is generally excepted that the shape of the flow duration curves will change, with a higher probability of both high and low flows whereas the probability of medium flows is expected to decrease.

A worldwide review of global rainfall data, carried out by the University of Adelaide, found that the intensity of the most extreme rainfall events is increasing as temperatures rise (source: www.globalccsinstitute.com). The study was based on data collected at more than 8000 weather stations around the world. It was concluded that a seven per cent increase in extreme rainfall intensity occurred for every degree increase in global atmospheric temperature over the past century.

Assuming an increase in global average temperature by the end of the 21st century of 3-5 ^{o}C (depending on the CO_2 scenario), the increases in rainfall intensities would be very substantial. The research found the strongest increases in rainfall intensity in tropical countries.

This increase in rainfall intensity will result in a comparable percentage increase in peak flood discharges from the cloud burst, as can be shown by simulation with some well known flood estimation methods, such as the unit hydrograph method.

3.3 Temperature and glacial lakes

As is true with other glaciers worldwide, the glaciers of Asia are experiencing a rapid decline in mass. A litterature review (see Wikipedia) showed that the fast majority of glaciers in the Himalayas and other mountain chains of central Asia are retreating at a rate of 10 to 30 m/year.

In the Khumbu region of Nepal 15 glaciers examined from 1976–2007 all retreated significantly and the average retreat was 28 m per year ICIMOD (2010). The most famous of these, the Khumbu Glacier, retreated at a rate of 18 m per year from 1976–2007.

In examining 612 glaciers in China between 1950 and 1970, 53% of the glaciers studied were retreating. After 1990, 95% of these glaciers were measured to be retreating, indicating that retreat of these glaciers was becoming more widespread.

In Pakistan the glacial area covers around 15,000 km^2 which is rapidly retreating. The Meteorological Department (PMD) expressed concern about more than 50 potentially hazardous glacial lakes in the northern areas, where a rise in temperatures of 0.8 to 1.5 ^{o}C was observed between 1990 and 2010.

Because of these rising temperatures, the GLOFs were becoming a regular feature in the summers. In the last 2 years five GLOFs occurred..

In 2012 four automatic weather stations on Passu and the Baltoro glaciers in Gilgit-Baltistan were installed to better understand the melting rates of glaciers in the area. More recently, another 14 new automatic weather stations were installed to expand the glacier monitoring network in the higher Himalayas and the Karakorum ranges. These new stations (installed above 4,000 metres) would help gather data on temperature, humidity, precipitation, pressure, solar radiation and wind speed and direction.

Satellite observations are providing a clearer picture of changes in the glaciers. Running 2,000 kilometres from east to west, the Hindu Kush-Karakoram-Himalaya (HKKH) region contains an estimated 60,000 square kilometres of glacier and surface ice.

ICIMOD (2011) published inventories calculating the entire glaciated and snow-covered area of the HKKH, based on satellite remote sensing imagery. This was followed in 2012 by two studies calculating glacial mass changes for the entire mountain chain.

A US team (Jacob, et al. 2012) measured the Earth's gravitational pull to detect changes in mass on the Earth's surface. A France–Norway team (Kääb, A, et al.,2012) analysed laser signals sent by the Ice, Cloud and Land Elevation Satellite (ICESat) to the Earth's surface between 2003 and 2008. This analysis found an overall annual loss of 12.8 gigatonnes of glacier ice from the HKKH, three times more than the estimates gained from measuring the Earth's gravitational pull, but less than the mass changes calculated by conventional mathematical methods using scarce field data.

The study also reported pronounced regional variations, with Jammu and Kashmir thinning at the fastest rate of 0.6 metres per year, and the Karakoram, further west, thinning by only a few centimetres per year, or almost not at all. This is not necessarily surprising, given that the Himalayas vary greatly in topography, rainfall and snow accumulation, with the eastern glaciers accumulating the most during summer from the Indian monsoon, and the western glaciers accumulating the most during winter through westerly winds.

In September, a US National Research Council report (National Academy of Sciences, 2012) concluded that glaciers in the eastern and central Himalayas appear to be retreating at accelerating rates, while those in the western Himalayas are more stable and could be growing.

Sing and Kumar (1997) estimated the effect of temperature increase on snowmelt runoff and glacier melt runoff of the Spiti river, a high altitude Himalayan river located in the western Himalayan region. They estimated a 33 to 38% increase in glacier melt runoff based on a temperature increase of 2 ^{o}C due to climate change.

With the retreat of glaciers in the Himalayas, a number of glacial lakes have been created. A growing concern is the increased risk of GLOFs. Researchers estimate that 20 glacial lakes in Nepal and 24 in Bhutan pose hazards to human populations.

As a result of projected increase in temperature the glaciers will more rapidly decline and the risk of GLOFs will increase.

3.4 Erosion and sedimentation

Changes in climate can also affect flood magnitude in an indirect way. For example, increases in rainfall intensity will lead to increases in erosion and the occurrence of landslides and debris flow. When this material is delivered to the river system it may be transported downstream where it is deposited in the river bed, raising the bed level and reducing the conveyance capacity of the river channel. As a results more flooding of adjacent areas will occur. In the upper more steep reaches the opposite may occur when increase in floods also result in greater flow velocities and increase in the forces to transport sediment. Thus the system of degradation and aggradation is expected to vary in time and space.

3.5 Increase in Water Induced disasters

Because of the above described impacts of climate change on landslides, debris flows, and floods it seems that future water induced disasters will increase in frequency and severity if no further adaptation measures are taken. Increase in population and further encroachment into areas subject to flooding and deforestation will aggravate the problems.

As a rough estimate it is thought that the frequency of water induced disasters will increase by some 25 to 50%

3.6 Vulnerability of water related infrastructure

Water related infrastructure such as dikes/embankments, reservoirs, head works for irrigation, bridges, road drains, sewerage systems, etc. are all based on expected flood peaks or related water levels for specific return periods which usually are related to the expected lifetime of that structure.

For existing infrastructure these estimated flood peaks are all based on historic data. Since temperature as well as rainfall intensities increased over time it may be concluded that in principle all existing water related infrastructure is subject to floods that are more severe than anticipated in the design. Therefore, all these structures are becoming increasingly vulnerable for damage, since adaptation measures most likely are not viable.

In certain cases, such as a storage reservoir, this situation may endanger human life when the spillway capacity cannot be increased. In those cases it seems that extra safety should be sought through a change in the reservoir operation. In case of seasonal reservoirs part of the reservoir storage could be allocated to flood storage prior to the monsoon season.

4 INTERNATIONAL EXPERIENCE

4.1 Adaptation to climate change in The Netherlands

In the Netherlands the rivers relinquished much of their space over the centuries, and they are now squeezed between dikes which in recent decades have become ever higher. At the same time the land behind the dikes has sunk in many places. Due to demographic trends and economic growth flooding in these area would have huge consequences and both the emotional and economic damage would be devastating. Climate change is expected to compound the problem. The imminent threat of flooding in 1993 and 1995 clearly showed the severity of the problem.

The statutory design levels of the flood protection dikes in The Netherlands vary. The coastal dikes are based on storm surges that occur at average return periods of 4,000 to 10,000 years. The dikes along the Rhine branches are designed to carry peak floods with a return period of 1250 years. The 1993 and 1995 floods pushed the design levels up, from 15,000 m^3/s to 16,000 m^3/s at Lobith where the Rhine enters The Netherlands. (see Figure 1)

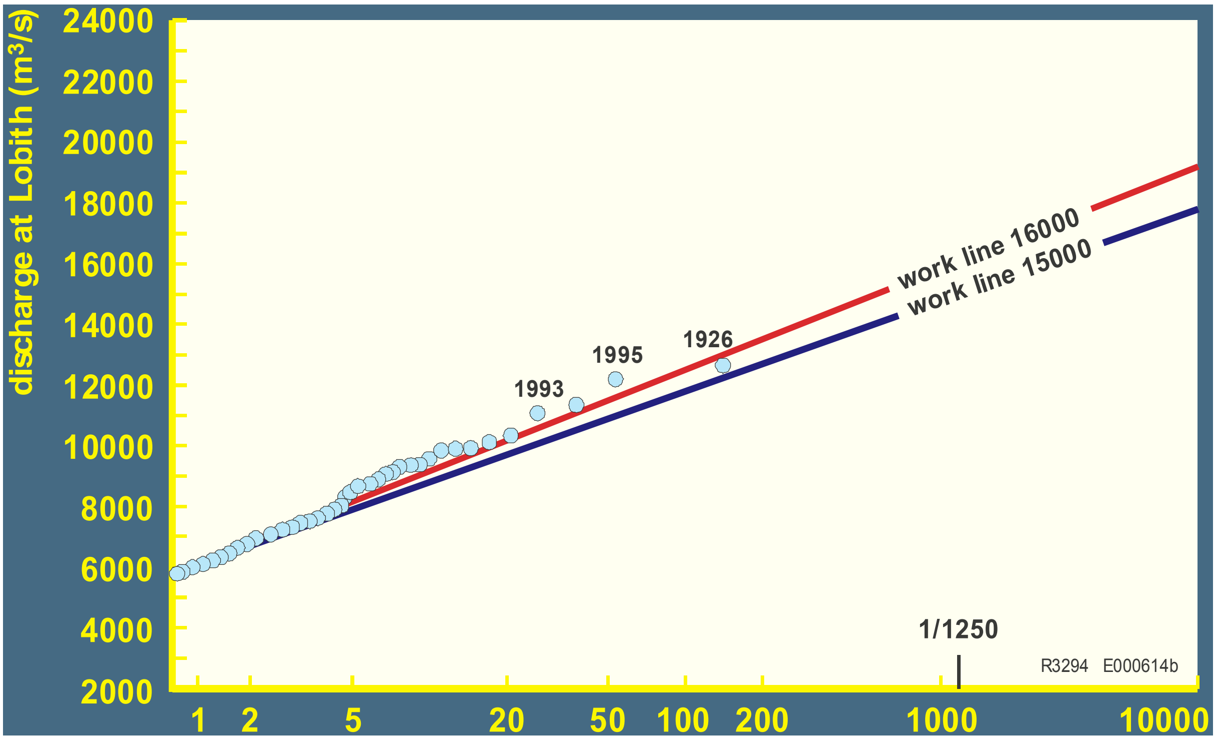

Figure 1 Increase in design discharge of the River Rhine after the floods in 1993 and 1995

Given that design river discharges are expected to further increase in future due to climate change, the government wishes to achieve the required safety levels by applying measures that prevent a further increase in design high water levels. This is a shift from dike reinforcement to river relief, and will involve measures on both sides of the dikes. Dikes will only be improved where other measures are either inappropriate or unaffordable. Some restructuring of the riverine area appears however unavoidable.

In 2007 the Dutch Government approved the “Room for the River” project which sets out a coherent set of measures needed to ensure compliance with statutory levels of protection by 2015 and which has three main objectives (Rijkswaterstaat, 2006):

1. By 2015 the Rhine system will be able to to safely discharge 16,000 m^3/s without flooding; .

2. The measures implemented to increase safety will also improve the overall environmental quality of the river region;
3. The extra room the rivers will need in the coming decades to cope with higher discharges due to the projected climate changes, will remain permanently available.

The Dutch riverine area is of international economic, ecological and scenic importance, and an important feature of the main national and international spatial planning structure. In places where measures are taken to enhance safety, an effort will be made to also improve spatial quality.

Funds have been earmarked and the necessary land reserved. Climate change in particular means that investment will be needed to ensure the safety of the riverine area in the future too.

Given its viewpoint on flood protection and improved spatial quality, and its decision to shift towards river relief, the government has made the following strategic policy choices:

- The package of measures proposed by the government for 2015 must be of use in the longer term and not thwart measures which might be needed later. These measures must be seen as a first step towards a more extensive, more robust river system, enabling additional steps to be taken if the design discharge increases further due to climate change
- The government is taking account of the fact that climate change could cause the design discharge of the river Rhine at Lobith to rise to about 18,000 m^3/s and that of the river Maas at Borgharen to about 4,600 m^3/s by the end of the century. A rise in sea level of about 60 cm is also expected. In view of the uncertainties about future climate trends and the responses of other upstream countries to them, accurate predictions cannot be made about the measures that will be needed after 2015.
- Detention reservoirs will not be among the measures adopted for the short term. In the long term, however, detention will be necessary, should the design discharge rise to about 18,000 m^3/s. This measure is now regarded as a last resort. The government assumes that 1400 m^3/s of the additional 3000 m^3/s expected in the long term (the difference between

Photo: Flood risks in The Netherlands

the design discharge of 15,000 m^3/s and the 18,000 m^3/s expected by the end of this century) can be discharged between the river dikes.

- At some locations, the government intends to take measures in the short term to provide more protection against flooding than strictly necessary by current standards. In doing so, it will be preparing for developments expected in the future and staying one step ahead of developments in spatial planning – plans for housing for example – which could form a serious obstacle to implementation of these measures at a later date. The government also wishes to avoid having to take successive sets of measures in the same area. In some cases, the measures in question will make a significant contribution to enhancing spatial quality. However, budgetary constraints may prevent the Government from implementing these plans.

4.2 Manual to Estimate floods in New Zealand

The Ministry for the Environment in New Zealand published a Manual entitled “Tools for Estimating the Effects of Climate Change on Flood Flow”. In this manual the percentage increase in extreme rainfall intensities for different durations and return periods are given per 1 °C increase in temperature (see Table 2).

Table 2 Percentage increase in extreme rainfall intensities per 1 °C increase in temperature

Duration		Return period (years)						
		2	5	10	20	30	50	100
<10	minutes	8.0	8.0	8.0	8.0	8.0	8.0	8.0
10	minutes	8.0	8.0	8.0	8.0	8.0	8.0	8.0
30	minutes	7.2	7.4	7.6	7.8	8.0	8.0	8.0
1	hour	6.7	7.1	7.4	7.7	8.0	8.0	8.0
2	hours	6.2	6.7	7.2	7.6	8.0	8.0	8.0
3	hours	5.9	6.5	7.0	7.5	8.0	8.0	8.0
6	hours	5.3	6.1	6.8	7.4	8.0	8.0	8.0
12	hours	4.8	5.8	6.5	7.3	8.0	8.0	8.0
24	hours	4.3	5.4	6.3	7.2	8.0	8.0	8.0
48	hours	3.8	5.0	6.1	7.1	7.8	8.0	8.0
72	hours	3.5	4.8	5.9	7.0	7.7	8.0	8.0

The entries in this table for a duration of 24 hours are based on results from a regional climate model using the medium-high emissions scenario. The entries for 10-minute duration are based on the theoretical increase in the amount of water held in the atmosphere for a 1 degree increase in temperature (8 per cent). Entries for other durations are based on logarithmic interpolation between the 10-minute and 24-hour rates.

4.3 Effect of climate change on landslide activity in New Zealand

In a publication on landslides in New Zealand Cozier (2006) discusses the climatic factors that influence slope stability, in particular the amount of water within the slope, which is indirectly a function of precipitation, drainage conditions and other less direct inputs. These in turn are governed by such factors as evapotranspiration, infiltration rates, hydraulic conductivities of the slope materials, and the nature and type of instability.

With respect to the frequency of landslides a relationship was shown between the average interval between landslide events and average annual rainfall (see Figure 2)

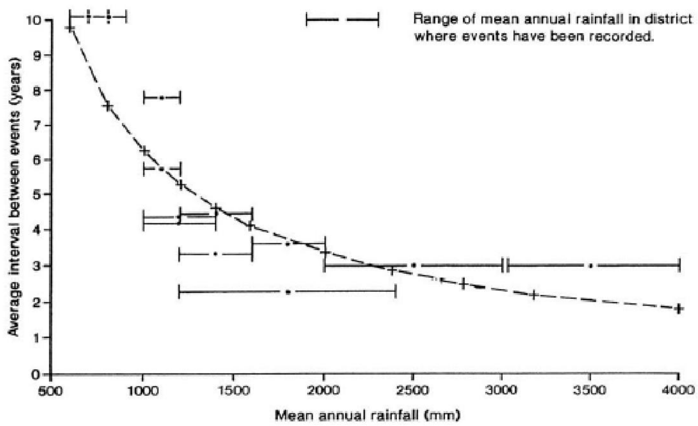

Figure 2 Relationship between the frequency of landslide events and mean annual rainfall for localities throughout New Zealand (source: Hicks, 1995).

The magnitude of landslides in terms of percentage of hill area affected by the landslide was related to the 24-hr storm rainfall (see Figure 3).

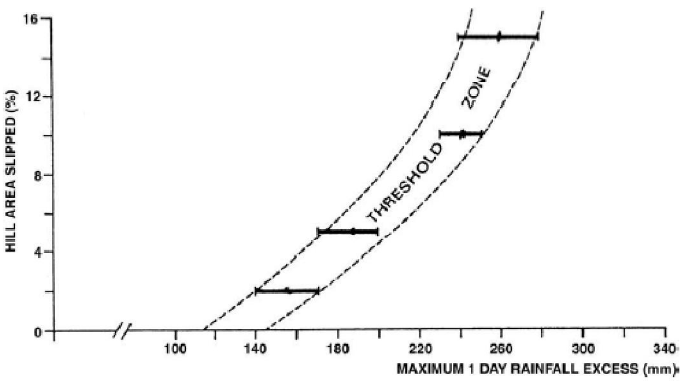

Figure 3 Relationship between magnitude of landsliding and storm rainfall, Wairoa, New Zealand (source: Eyles and Eyles, 1982).

Although there are still uncertainties about future changes in rainfall, there are sufficient indications of how areas that are already prone to landslides would response to climate change to invoke the precautionary principle in management decisions.

As GCM predictions continue to improve in terms of resolution and ability to translate global changes into accurate local outcomes such as precipitation intensity, a clearer picture of potential landslide response will emerge. However, also the role of human activities should be considered.

4.4 Effect of climate change on rainfall intensity in Europe

In a study on the future extreme one-hour precipitation (Larsen et al., 2008) the potential increase of extreme precipitation in a future warmer European climate was examined.

Output from the regional climate model HIRHAM4, covering Europe was analysed for two periods, a control period 1961–1990 and a scenario period 2071–2100, the latter following the IPCC scenario A2. The model has a resolution of about 12 km, which makes the results unique in relation to extreme precipitation events critical to urban drainage systems.

Extreme events with one- and 24-hour duration were extracted using the Partial Duration Series approach. A Generalized Pareto Distribution was fitted to the data and T-year events for return periods ranging from 2 to 100 years were calculated for the control and scenario period in all model cells across Europe.

The analysis shows that there will be a general increase in the intensity of extreme events in Europe. Scandinavia will experience the highest increase and southern Europe the lowest. A present 20 year 1-hour precipitation event will e.g. become a 4 year event in Sweden and a 10 year event in Spain. Intensities for small durations and high return periods will increase the most, which implies that European urban drainage systems will be challenged in the future.

4.5 Impact of climate change on seasonal floods in Quebec, Canada

The impact of climate change on summer and fall flooding in the Chateauguay River Basin (2500 km^2), located in the southern part of Quebec province (Canada), was investigated using results from the Canadian GCM (CGCM1) and a coupled hydrology–hydraulics model of the basin (Roy et al. 2001).

Three 20-year periods, corresponding to 1975–1995, 2020–2040 and 2080–2100, were used for the analysis. For each period, 24-h precipitation depths corresponding to the 20 and 100-year return periods were determined from a frequency analysis of the summer–fall maximum 24-h precipitations using a general extreme value frequency distribution.

The 24-h rainfall hyetographs were generated using region-specific cumulative distributions provided by the Canadian Atmospheric Environment Service. These hyetographs were then used as inputs to the hydrology–hydraulics model to simulate hydrographs, maximum discharge and maximum water levels at two sections of the river.

Results indicate potentially very serious increases in the volume of runoff, maximum discharge and water level with future climate change scenarios. The changes get more drastic as longer return periods are considered. Increases of up to 250% of the maximum water discharge are encountered and water levels are significantly higher than the current flood levels. If realistic, these scenarios indicate that important decisions will have to be taken to alleviate future increases in flooding damages in what is already a flood prone river.

Simulation results for the 20-year return period flood are shown in Figure 4.

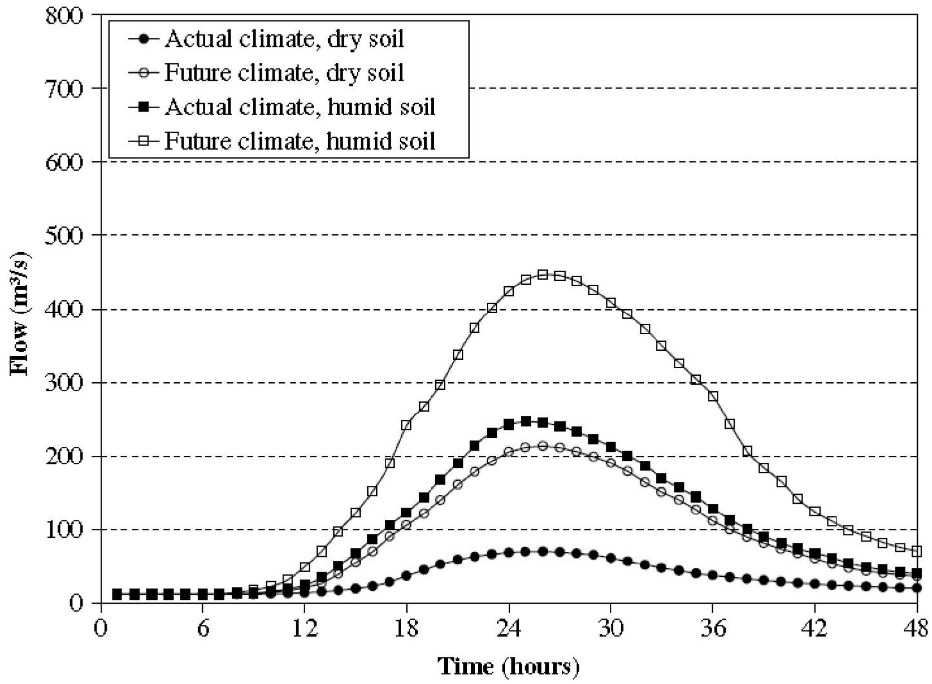

Figure 4 Hydrographs for 20-year return period rainfall (source: Roy et al., 2001)

4.6 Impact of climate change on urban drainage infrastructure planning and design

According to Arisz and Burrell (2006) climate change is a reality that planners and designers of drainage infrastructures must consider. The cumulative effects of gradual changes in hydrology due to climatic change are expected to alter the magnitude and frequency of peak flows over the service life of drainage infrastructure.

Potential future changes in rainfall intensity are expected to alter the level of service of drainage infrastructure, with increased rainfall intensity likely resulting in more frequent flooding of storm sewers and surcharging of culverts. The expected effects of climate change necessitate a change in the approach used to plan for and design drainage infrastructure.

New development should ideally be served by both a minor storm drainage system, such as a traditional storm sewer system, and a major overland storm drainage system designed to convey the excess runoff when the capacity of the minor system is exceeded.

The planning and design of new drainage infrastructure should incorporate development features and sustainable urban drainage systems that provide multiple benefits (such as a reduction of localized urban flooding and harmful environmental impacts). Modifications to existing drainage infrastructure in existing development is complicated by the integration of the minor drainage system with other infrastructure and a lack of space for the construction of major drainage system components.

The expected changes in extreme event frequency curves is shown in Figure 5.

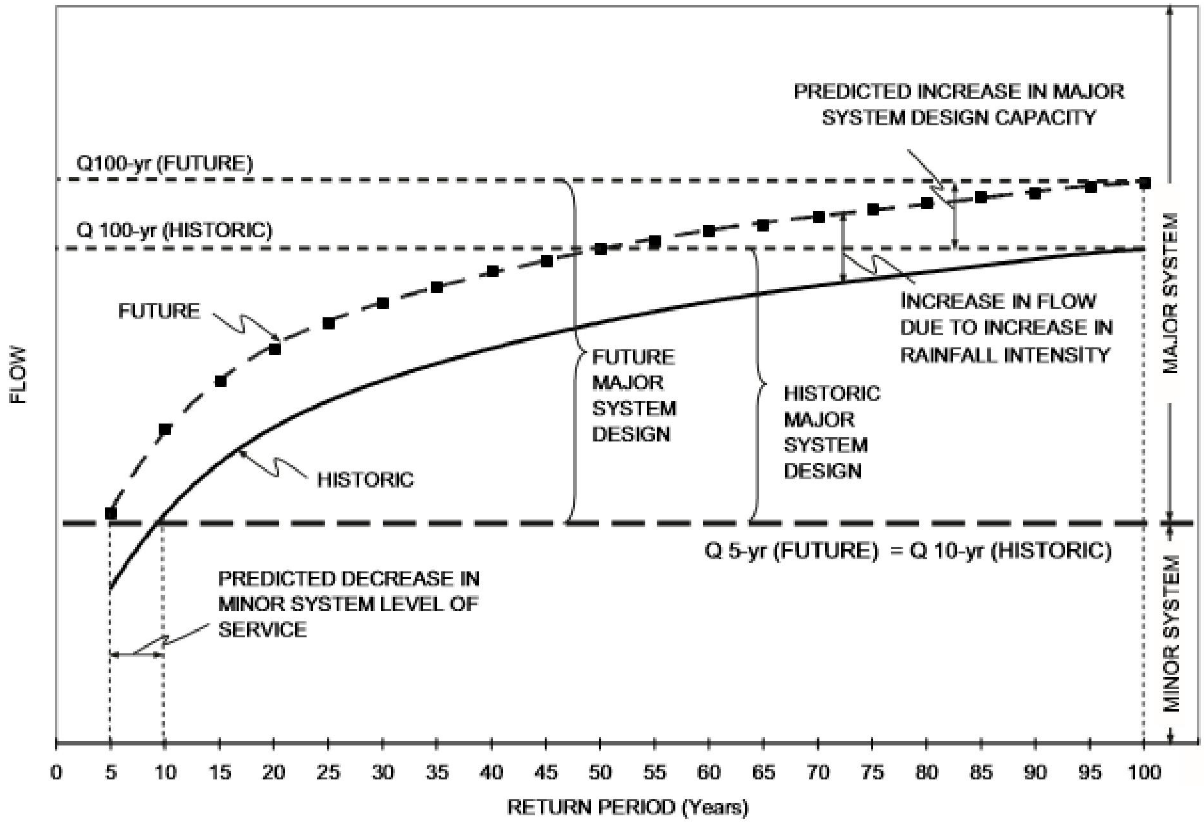

Figure 5:Expected changes in extreme event frequency curves

5 CONCLUSIONS FOR THE CONDITIONS IN NEPAL

Impacts of climate change are very evident in Nepal through increased melting and retreat of glaciers. As discussed in Chapter 3 one of the projected impacts of climate change in Nepal is that both the frequency and severity of WIDs are expected to increase significantly. At the same time the population is increasing at a rate of about 1.8% per year (World Factbook CIA) and, if no measures are taken, further encroachment of population into potentially sensitive and hazardous areas is expected to increase, adding even more to the severity of future disasters.

DWIDP being the main Government department to cope with WIDs, seems presently not well prepared to deal with these future conditions. Up till now there has been no mainstreaming of climate change risk management in the department's policies, programs and activities.

A number of WIDs that occurred in the past were characterised by large losses of life and property. Given the expected increase in frequency and severity of future WIDs it seems that no time should be lost in the preparation of structural and non-structural measures to protect vital infrastructure and more importantly to protect the most vulnerable people (the poor, women, children, and people with disabilities).

The best adaptation measures seems a combination of structural and non-structural measures. For structural measures a quantitative estimate should be made of the magnitude of floods that are expected to occur in future at specific frequencies.

The estimation methods used so far in Nepal seem not adequate to predict increases in the magnitude of floods due to climate change. It is therefore recommended to adapt better estimation methods. One of such methods is the HEC-HMS method which was also proposed by ICIMOD (2008). A relevant aspect to be studied in relation to climate change when using this method is the change in rainfall Intensity Duration Frequency (IDF) relationship. Based on information already available from research in other countries (see above Chapters) this should not be too difficult.

Non-structural adaptation measures could be very effective and sustainable as well and, compared with structural measures, usually less expensive. A number of major non-structural measures are grouped under Watershed Management and Floodplain Management.

A primary aim of watershed management is to reduce the runoff through a number of good agricultural practices (e.g. contouring, terracing, no agriculture on higher slopes, adaptation of cropping patterns, etc.) and reforestation. Floodplain management is more related to different types of land use restricted to different zones in the floodplain, depending on the flooding risks.

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