Introduction to integrated flood management

Flood and Drought Management

Date of the project report

Strengthening Ethiopian universities in Integrated River Basin Management
1. **Introduction**

Integrated flood management (IFM) aims at minimizing loss of life from flooding while maximizing the net benefits derived from floodplains. As part of the approach, the management of flood risk is based on judicious combination of measures that address risk reduction, risk retention and risk transfer through a strategic mix of structural and non-structural measures for preparedness, response and recovery. The decision have to made on how to share the coast of taking risk placed on society among governments (central, regional and local governments), interested parties (such as private companies), communities and individuals.

Flood risks are essentially the cost of taking risk: the sum total of the cost of risk reduction, costs of managing the residual risks and the flood losses that finally materialize. There are three strategies for risk management: risk reduction, risk retention and as a last resort risk transfer. Risk reduction includes activities that contribute towards diminishing the probability of potential losses.

Risk reduction is the first step in risk management process. Within the IFM approach, flood risk can be reduced either through decrease of flood hazard; or the exposure of economic, environmental and social activities; through **structural** and **non-structural** measures. At the same time risk reduction can be achieved by reducing the vulnerability of those exposed to floods. Generally a judicious combination is the answer.

As protection against all floods is neither financially viable nor environmentally sustainable, residual risks are always present. Emergency preparedness plans, early warning and disaster response actions are undertaken to keep the residual risk to a minimum. Individuals also take responsibility by reducing their own vulnerability and implementing proofing measures through retro-fitting etc. transferring of flood risks physically by diversions of flood water to less vulnerable areas are also important options for flood risk management.
Recently, non-traditional financial mechanisms have been developed for the facilitation and support of recovery from flood events. Index based insurance, catastrophe bonds; micro-insurance are some of such financing instruments. Some of those mechanisms have almost exclusively been employed in developed countries and a developing country perspective needs to be brought into the financial risk sharing debate.

“Natural hazard” refers to all atmospheric, hydrologic, geologic (especially seismic and volcanic), and wildfire phenomena that, because of their location, severity, and frequency, have the potential to affect humans, their structures, or their activities adversely.

Flood risk is “the combination of the probabilities of a flood event (or hazard) and of the potential adverse consequences (or damage) to human health, the environment, cultural heritage and economic activity associated with a flood event” (EC, 2007)

\[ \text{Flood Risk} = \text{hazard} \times \text{vulnerability} \]

\[ \text{Flood Risk} = \text{probability} \times \text{damage} \]

Mathematically

\[ \text{Flood Risk} = \int_{0}^{1} p(E)D(E)dp \]

Where; \( p(E) \) : Expected damage due to event \( E \)

\( D(E) \): Probability of event \( E \) occurring
2. Types of flood
Many different types of floods occur around the world every year. In general, they can be classified into five categories:

1. Riverine floods; the majority of floods recorded globally are due to rivers overflowing as a result of long-lasting precipitation in the river basin. Melting snow and ice can also contribute to flooding

2. Flash flood; Flash floods generally occur due to local high-intensity precipitation in hilly or mountainous areas. The short warning times makes these difficult to predict. Discharge during flash floods are often much higher than normal flows in water courses.

3. Coastal floods; Areas along coast may be flooded due to tsunamis, hurricanes or/and unusual high tides. Also long-term phenomena like subsidence and sea-level rise can lead to the gradual encroachment of the sea.

4. Stagnant and Urban floods; Extreme rainfall in towns and cities combined with blocked drains can cause several flooding. This often occurs in urban areas, where a large percentage of the surface is impermeable.

5. Lake and canal floods; High levels of precipitation or long-lasting inflows from streams can cause a substantial rise in water levels of lakes and canals that lack sufficient drainage capacity. Also, long periods of drought can cause man made (peat) embankments to become unstable and fail, resulting in flooding.
3. **Concepts of Integrated Flood Managements**

Integrated Flood Management addresses issues of flood management from the perspective of human security and sustainable development, within the overall framework of Integrated Water Resources Management. There are no universal criteria to determine environmentally friendly flood management practices.

3.1 **Integrated Flood Management Objectives**

- Sustainable development: balancing development needs and flood risks
- Maximizing net benefits from flood plains: ensure livelihood security and poverty alleviation thereby reducing vulnerability
- Minimizing loss of life
- Environmental preservation

3.2 **Integrated Flood Management Principles**

Integrated Flood Management Principles includes; Risk management, Water cycle as a whole, Multi-hazard approach, River basin approach, and Public participation

3.3 **Traditional Flood Management Options**

Traditional Flood Management Options are Storing runoff: (Reservoirs; Detention basins), separating floods and the population, increasing the conveyance capacity of rivers, Source control to reduce runoff, Emergency response sand Recovery and Rehabilitation

3.4 **Traditional Structural Flood Alleviation Methods**

When a river is channelized the objective is to reduce the period of flooding on adjacent land and provide better freeboard to improve drainage. The structural methods outlined here may be thought of as ‘hard’ engineering methods.

1. **Resectioning**

This involves dredging and/or widening the main channel to increase the discharge capacity. In addition bed slope may be steepened to increase flow velocities and
increase flood capacity. In urban areas rectangular flume-like channels, or culverts, are often constructed due to limited space. In order to maintain a stable bank, vertical sheet piling, concrete or masonry is used to line the channel.

II. **Realignment**

Straightening the channel increases the gradient of the river and thereby, flow velocity and flood capacity. This is often carried out in association with resectioning. While this re-alignment will reduce flood hazard in the reach of interest, it should be noted that flood waves can be accelerated, which may make flood issues downstream worse.
**Adjacent flood banks**

The construction of flood banks is a very common engineering solution to flood control. Conventionally these are constructed close to the river and, as a consequence, they need to be higher than distant flood banks to achieve the same level of protection.

![Figure 3. Construction of embankment](image)

![Figure 4. Post construction problems on flood control channels](image)

### 3.5 Physical effects of channelization

Channelization involves changing one or more of the interdependent hydraulic variables of slope, width, depth, roughness or size of the sediment load. Channelization has a great impact on a river because it disrupts the existing physical equilibrium of the watercourse. To compensate for the alteration in one or more of the hydraulic variables, and to establish a new, stable equilibrium, other parameters will change.

**River restoration**

The loss of species, habitats and landscapes has been so great that it has become a political necessity to support remedial as well as protective conservation measures. Rivers and floodplains are prime candidates for restoration as their high ecological, sociological and economic value has been systematically degraded by previous generations.
Definition of Basic Terms

**Restoration** - The complete structural and functional return to a pre-disturbance state. However, the pre-disturbance condition can rarely, if ever, be achieved.

**Rehabilitation** - Partial return to a pre-disturbance state. Rehabilitation is the sensible alternative to full restoration and the needs of many user groups may be incorporated, for example, flood defence requirements, habitats and landscapes.

**Enhancement** - Any improvement in environmental quality. This is usually carried out on a smaller scale and works may be putting in place in-stream features, for example, gravel enhancement for degraded salmonids spawning grounds.

**Creation** - Development of an ecosystem that did not previously exist at that site. Many rivers have the ability to adjust and recover from their degraded state. In its attempts to attain a regained equilibrium a channelized river may erode and deposit sediment from its bed and banks thus creating a meandering or braided course.

### 3.6 Non Structural - Natural Recovery

Non structural methods can be summarized as: -

- **Catchment planning** - this leads to the integrated management of water quality, water quantity, and the physical environment in the catchment, often with an emphasis on retaining water in the upper catchment, thus reducing the magnitude of flood flows

- **Land use changes** - There are currently opportunities to secure sympathetic land use in river corridors.

- **Flood forecasting and warning** - This provides floodplain users advance information of potential flooding, allowing flood damage to be reduced by moving people and property out of harm's way.

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4. **Legal and Institutional Aspects of Integrated Flood Management**

**Positive aspects of flood plains**: preferred places for socio-economic activity due to development potentials

- Easy access to natural resources
- Fertile land for agriculture
- Services provided by ecosystems

**Negative aspects of flood plains**: areas recurrently affected by flooding. In the traditional flood management approach this has mostly lead to the adoption of flood control and protection works (e.g., dams, embankment, diversion works, etc.)

**What are Net-Benefits from Flood Plains?**

Benefits derived from using the flood plains, such as increased crop yields in agriculture, opportunities for subsistence/recession agriculture, available space for development, readily available transport links etc, minus **Losses** suffered from flood damages and economic losses due to floods. Human losses of life, biodiversity losses or losses of cultural heritage are not sufficiently quantifiable in economic terms but co-determine our policy options:

**Why Integrated Flood Management?**

- Need to address new challenges
- Need for a sustainable development and livelihoods perspective in flood management
- Need for policy options with a focus wider than only economic loss reduction
- Need for a multi-disciplinary and multi-sectoral approach in flood management
- Need for a river basin approach in flood management

**Roles of Law in Flood Management**
Figure 5 roles of law in flood management

Fig 6 Role of Flood Managers

Role of Flood Managers
The role of flood managers is to implement flood management policies within the given legislative framework and to inform policy-making and legal reform processes about the realities of flood management.

Central Legal Themes in IFM
- Ensuring coordination and integration across institutional boundaries
- Information generation and sharing
- Enabling stakeholder participation
- Rights, powers and obligations

Legal and institutional framework
The key legal mechanisms that can ensure public participation in the process are as follows:
- Right to information to ensure regular, precise, comprehensive and timely information;
• Right to participate, which is a legal provision ensuring participation of all relevant stakeholders;

• Accountability in the process by flood management and mitigation agencies, the community and other key stakeholders;

• Transparency to ensure that all processes and decisions are transparent.

Information sharing and networking are among the most crucial factors ensuring the efficiency and stability of the approach, anticipating and managing conflicts, and furthering collaboration across jurisdictions and sectors. This requires an enabling institutional framework, which facilitates effective coordination, cooperation and collaboration across jurisdictional boundaries, departments, institutions, disciplines, users and uses.

Conflict management
Stakeholders, each with their own perspective on issues of concern, understanding of flood risks, development priorities, interests and approach, sometimes create conflicting viewpoints. Upstream and downstream communities with unequal access to resources and flood protection measures can develop resentment against each other. In such case, unbiased third-party involvement can provide a common ground for stakeholders in reaching a settlement. For international river basins, the prospects for success grow when riparian countries, facing conflicts between the countries and issues that are beyond their control owing to limited capacity and resources, approach a third party. In managing conflicts arising from water resources management and flood mitigation issues, two mechanisms are particularly effective: incentives and trade-offs
5. Social Aspects and Stakeholder Involvement in Integrated Flood Management

Flood management measures in the past have contributed to mitigate the adverse impacts of floods, but have at times created inequalities and conflicts (where inadequate attention has been paid to social issues). To ensure equity in development there is need to deal with social concerns and involve stakeholders in the decision making process. Integrated Flood Management is the need for paradigm shift from flood control to flood management.

Integrated Flood Management

- Combination of structural and non-structural measures
- Address both the negative and positive characteristics of floods
- Cover on the physical, social, environmental and economic aspects of floods

Beneficial aspects of floods

The beneficial aspects of floods includes; Recharging water sources (recharge groundwater, restock man-made reservoirs), Agriculture (provide nutrients and sediments), Fishery (provide an ecological trigger for spawning and migration), and Rejuvenation of the river ecosystem (provide seasonal variability and variable sediment, wash down pollutants and contaminants, flush out organic substances)

Negative socio-economic impacts

The negative socio-economic impacts are Loss of lives and property, Loss of livelihoods, Decreased purchasing and production power, Mass migration, Psychosocial effects, Hindering economic growth and development, Political implications

Why Stakeholder involvement

- Ensure implementation of basin flood management plans with full public support
- Ensure sustainability of plans and associated decisions
• Build consensus and public support on the flood management options
• Build stakeholders commitment
• Build resilience of flood-prone communities
• Provide all stakeholders, including the public, with full opportunities to share their views and influence the outcome

Historically, flood plains have been the preferred places for socio-economic activity as is evident from the very high densities of human settlement found there due to positive impacts of floods.

On the other hands, flood plains and the economic activities therein adversely are recurrently affected by flooding. Some of the adverse impacts are debilitating the achievements of development. Therefore, strategies that largely rely on structural solutions, for example, dams, embankments, diversion works, etc, have been adopted in the past.

These interventions have been successful in accelerating the development process in flood plain. However, strategies that largely rely on structural solutions alter the natural environment of the flood plains by fixing the shape of the rivers, separating river channels from their flood plains and altering natural morphological and ecological processes. This has resulted in loss of habitat, biological diversity, ecosystem productivity, and services provided by such ecosystems.

The need and concerns for sustainable development has highlighted the importance of addressing the negative consequences of such flood control and protection measures on the environment and has led to a paradigm shift from flood control to flood management. Environmental degradation will threaten human security, for example, life, livelihoods, food and health etc. Ecosystems, such as forests, wetlands and lakes provide enormous services to mankind.

It is useful to have an insight into the ecosystem services being provided by natures. Ecosystem services are “the benefits that people obtain from ecosystems”. These include supporting services such as provisioning (Food, Freshwater, Wood and fibre,
Fuel, etc.), regulating (Climate regulation, Flood regulation, Disease regulation, Water purification, etc.), and cultural services needed to maintain other services

Human ingenuity is presented with a dilemma between development imperatives and environmental degradation. However, it is important to understand various causes of such degradation.

- **Poverty and consumerism**: Inequality in modern societies may foster unsustainable behaviour because the poor rely on natural resources, and have no real prospects of gaining access to other types of resources while the rich through higher per capita consumption impact the sustainability of natural resources.
- **Agricultural development**: Direct impacts of agricultural development on the environment arise from farming activities, which contribute to soil erosion, loss of fertility, increase of land salinity, etc.
- **Industrialization**: Large quantities of industrial and hazardous wastes, created by the chemical industry, have compounded the waste management problem with serious environmental health implications.
- **Urbanization**: Rapid and unplanned expansion of cities in developing countries has resulted in degradation of the urban environment.
- **Population growth**: Increasing population densities in floodplain areas necessitates huge infrastructure investment to protect people, their livelihoods and property from flooding.

Flood managers should understand what are the basic concepts of the morphology and ecology of rivers and their flood plains? and how morphological and ecological processes are driven by the flow regime? It requires understanding of the environmental impacts of flood management measures. This will help their in exploring environmentally sensitive designs. Many of the flood management measures have the potential to cause consequential hydrological, morphological and
environmental impacts, with further significant impacts on socio-economic development.

**Biological diversity**

Biological diversity requires three basic elements: the adequate quality of water, appropriate variability of focus and the diversity of habitat. The later is determined by the spatial heterogeneity and temporal variability. Both of them are grounded by the flow regime and the sediment regime. All the three forms of connectivity help in keeping these regimes in place. Shifting habitat created by disturbances, are essential components of riverine ecosystems.

Environmental assessment at various levels of decision-making is important. Strategic Environmental Assessment (SEA) is a proactive approach at the strategic level. It can help pre-identify key issues that should be addressed in the subsequent Environmental Impact Assessment (EIA), which are implemented at the project design and implementation level. SEA supports EIA in screening, scoping and thereby integrating environmental considerations into decision-making processes.

**Importance of habitat diversity to riverine ecosystems**

Rivers and floodplains are dynamic systems. They are continuously adjusting to changes in discharge and sediment load. Such changes affect the channels, altering courses, creating new ones, and cutting off old channels as they migrate laterally. The continual changes in river form are critical to wildlife. Natural watercourses have
an intricate pattern of strong and weak currents and there is an array of different habitats available, as follows:

- In channel riffles are spawning areas for fish species. Gravel bars may support a wide range of invertebrates.
- Eroding bank side cliffs provide nesting locations for a range of birds.
- Channel margins, backwaters and lowland wet grassland with high water tables are particularly valuable habitats for wetland plants.
- Backwaters are important refuge areas for fish, birds, mammals, invertebrates and amphibians as well as plants.
- Wet grassland and wet woodland within floodplain provide a range of feeding and breeding areas for a number of birds. Plants found in backwaters and on wet grassland provide both seeds and habitat for invertebrates, which are food for a variety of waterfowl.
- Flood plain grassland provides a continuous habitat range from drier to wetter areas, which is used by breeding waders.
- Amphibians thrive in floodplain pools that occasionally dry out during the summer.

**River degradation - Environmental problems in rivers**

A wide range of human activities may lead to environmental degradation of rivers. The major activities are listed below:

- Supra-catchment effects: (acid deposition and Inter-basin transfer)
- Catchment land use change: (Afforestation and deforestation; Urbanization; Agricultural development; Land drainage/flood protection)
- Corridor engineering: (Removal of riparian vegetation; Flow regulation/dams; Channelization; Dredging and mining)
- Instream impacts: (Organic and inorganic pollution; Thermal pollution; Abstraction; Navigation; Exploitation of native species; Introduction of alien species)
River regulation
River regulation is a general term describing the physical changes that man imposes on watercourses. Various human activities that physically influence/regulate rivers are listed below:

Table 1: Human activities physically influencing river systems

<table>
<thead>
<tr>
<th>• Land drainage</th>
<th>• Channelization</th>
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</thead>
<tbody>
<tr>
<td>• Flood protection</td>
<td>• Interbasin water transfer</td>
</tr>
<tr>
<td>• Reservoirs</td>
<td>• Navigation</td>
</tr>
<tr>
<td>• Dams</td>
<td>• Dredging</td>
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River channelization
Channelization is the term used to embrace all processes of river channel engineering for the purposes of flood defence, land drainage, navigation, erosion control and river relocation for transport purposes. Of the specific reasons for channelization the requirement to defend land and property from the risk of flooding is the most important. This has long been the policy of the successive governments.
7. Economic Aspects of Integrated Flood Management

Economics is the application of reason to choice to understand issue and to determine the best means of managing floods and the risk of flooding. Choices are difficult because they arise from conflict, and are always about the future and so are set in uncertainty. It may be said that economic efficiency is not the only objective of society. At the same time, economic efficiency issues can never be ignored if society is to progress. Economic issues are always given prominence in planning and management. Economics, therefore, is concerned with the problems of choice related to the use of resources. As the application of reason to choice, economics involves the development of a rigorous analytic framework with which to compare the alternative courses of action open.

**Economics analysis**

The contribution of economic analysis to decision-making lies in providing a set of fairly reliable tools for an objective evaluation of the benefits and costs of specific flood management projects in monetary terms so as to enable their comparison and judge the economic viability of the proposed projects. Economic analysis helps to select not only the optimum level of adjustment to floods on the basis of risk-safety trade-off decisions but also an optimum combination of measures for the purpose.

I. Appraisal method
   
i. Cost-benefit analysis

Cost-benefit analysis examines whether the total benefits of a project, evaluated in terms of money, exceed the costs of utilizing resources. Being a monetary-based analysis, CBA does not take into account any moral issues, such as distributional equity. The increasing importance of social and environmental concerns in development projects urged to expand the range of economic analysis and put monetary values to social and environmental concerns.

   ii. Multi-criteria analysis

MCA involves judging the expected performance of each development option against a number of criteria or objectives. This is particularly highlighted when the problem
presents conflicting objectives and when these objectives cannot be easily expressed in monetary terms. Multi-criteria analysis can be useful in ranking options, short listing a limited number of options for subsequent detailed appraisal (say through CBA).

II. **Public participation**
Since evaluation involves social values, it would be quite appropriate to carry out CBA/MCA in conjunction and close consultation with and participation of the public affected by the project. Public participation in decision-making and CBA/MCA is likely to raise the level of their consciousness and to make them more societal responsive. The defining characteristic of stakeholder involvement is clearly the interaction between the stakeholders; hence a primary requirement of the project appraisal technique is that it supports and enables such an interaction. The requirement is to support stakeholders in the process of making a choice, to provide a rigorous analytical framework in and through which they can argue, debate and negotiate the choice.
8. Integrated Management of Urban Floods

The ultimate aim of integrated urban flood risk management is to minimize human loss and economic damages, while making use of the natural resources for the benefit and well being of the people.

However it is realized that absolute flood security is in most cases utopian. Flood risk cannot be entirely avoided, thus they have to be managed. Consequently, flood management does not strive to eliminate flood risks but mitigate them. This may be achieved either by reducing flood risks to an acceptable level or by retaining, sharing or transferring flood risks through respective measures. These measures should form part of an integrated risk management process. The basic steps of an integrated management process are:

- Risk assessment
- Planning and implementation of measures,
- Evaluation and risk reassessment

![Figure 7 Steps of risk management process](image)

### Risk management measures

The composition of risk can help to address not only the efforts towards floods risk management but also in improving the well being of people, particularly if the analysis points toward need to build resilience in the effected population. Flood risk management has to follow the stages of risk cycle through

- Preparedness;
- Response; and
- Recovery
Preparedness measures attempt to prevent potential risks turning into disasters, both at societal level as well as at individual level. This involves mitigation of flood risks to an acceptable and affordable level and at the same time the preparation of activities to cope with the residual risks.

Response measures are implemented during or directly after a flooding incidence. They need advance planning and preparedness to respond to the emergency. The respective measures deal with the mitigation of emergency situations and the provisional reconditioning of basic services and infrastructure.

Measures to mitigate hazards
Floods are a consequence of natural hydro-meteorological phenomenon, combined with their interaction with the catchment characteristics. The reduction of surface runoff in absolute terms can be achieved by a variety of measures that increase infiltration, evaporation and/or transpiration from the catchment areas that contribute to local flooding. The easiest way to do so is to preserve unsealed and greened spaces in the city.

Since the potential for in-town infiltration and evapotranspiration is limited, especially in cities where convective precipitation and non-absorptive soils prevail, measures of stormwater retention are vital for the mitigation of urban floods as well as for the
prevention of downstream floods. A complementary multipurpose retention strategy is stormwater storage as a source of water supply, so-called “rainwater harvesting”. A major concern in many cities, particularly in developing countries with sub-optimal solid waste disposal systems, is the **clogging of drainage facilities** with rubbish that reduces the carrying capacity of the drainage systems. An appropriate waste disposal system this becomes an essential part of flood risk management strategy. Cleaning and maintenance of drainage facilities is essential to the operational reliability of such drainage systems.

**Mitigating Hazards of Local Floods**
- Reducing local floods by inducing infiltration through:
- Retaining/ transferring local floods:
- Preventing stormwater contamination:

**Riverine Floods**
With reference to riverine floods in cities the respective upstream conditions have to be taken into account which requires considering urban floods not as isolated phenomena but as closely interlinked with overall basin characteristics. If upstream discharge is to be reduced, **upstream land use** issues have to be addressed. Since the potential for upstream runoff reduction through respective land-use planning is limited, complementary structural measures are in most cases indispensable. Following structural measures may be implemented in order to mitigate urban riverine floods by detaining or diverting run-off.

**Mitigating Hazards of Riverine Floods**
- Reducing riverine floods through infiltration and evapotranspiration:
- upstream landuse planning:
- Retaining/ transferring riverine floods:

**Preventing exposure**
Based on the definition of exposure as the fact that people and infrastructure are likely to get in contact with flood waters because of their location, exposure mitigation refers to **measures of urban planning** which are supposed to prevent the location
of settlements and infrastructure in areas exposed to flood hazards. To this end the ability of plans to reconcile the spatial demands of watercourses and development is crucial. Ideally, flood sensitive urban planning should avoid the intensification of flood risks as a result to development activities.

Prerequisite for the consideration of flood risks as an integral part of long-term urban planning is the knowledge and awareness of present and future flood risks among planners. Such knowledge can be generated by combining flood models with scenarios of urbanization in terms of demographic and economic development, technical progress, altering life styles etc.

Integration of flood risks in urban planning

I. Delineation of risk zones
II. Definition of land-use for different risk zones
III. Implementation of land-use regulations through:
   o restrictive regulation (prohibitions, penalties, resettlement)
   o economic incentives (preferential taxation for desired land-uses, extra taxation for undesired land-use)
   o knowledge enhancement (communicating necessity for regulations, awareness campaigns)
   o public investment (purchase of property)

Reducing vulnerability: building resilience
Vulnerabilities are generally not just the given circumstances, but rather unsafe conditions which have developed by human actions or inactions. It is essential to be aware of the root causes of these vulnerabilities in order to mitigate whenever possible the underlying causes and not merely the consequences. The goal of reducing vulnerability is to reduce the susceptibility of people, livelihoods and infrastructure to floods.

The physical vulnerability of people in case of flood events is largely determined by their initial physical constitution, which in turn, depends on adequate nutrition and medical care. Thus facilitating proper access to food supply and to medical facilities
should not only be considered as emergency relief actions in the case of disasters but also as preventive measures to reduce vulnerability in those neighborhoods where access to such basic needs is not guaranteed.

**Reducing vulnerability**
- Reducing physical vulnerability of people and infrastructure:
- Reducing constitutional/economic vulnerability:
- Reducing informational/motivational vulnerability
9. **Groundwater flooding**

A groundwater flood event results from a rise in groundwater level sufficient for the water table to intersect the ground surface and inundate low lying areas. Groundwater flooding (also commonly referred to as “clear water flooding”) has been defined as the type of flooding that can be identified as being caused by water originating from beneath the ground surface from permeable strata through a natural process (rather than through anthropogenic activities such as leakage from pipes and seepage into ground excavations).

Groundwater flooding can also be differentiated from surface water flooding by its persistence, with a typical duration that is measured in weeks rather than hours and days and has a tendency to occur throughout the winter, often extending into spring and sometimes into the early summer.

**Frequency of Occurrence**

Applying standard statistical techniques used in fluvial flood estimation, to estimate the return period of groundwater level peaks is difficult. The techniques require independent peaks. Groundwater peaks are closely related to the summer minima which, in turn, are related to the previous peak. This dependence or memory can extend back many years in some aquifers. Selecting independent peaks reduces the total number of peaks considerably and therefore the level of confidence that can be placed on the results. It is therefore only possible to state the number of occurrences of high groundwater levels or groundwater flooding in this study rather than formal frequency analyses.

**Causes of Groundwater Flooding**

Considerable knowledge on the behaviour of groundwater levels has been built up with the development of groundwater simulation models. However, these are usually calibrated and validated on low flows and they generally do not perform well at above-average flows. This is largely because at high groundwater levels, the permeability and storage characteristics of the Chalk in the normally unsaturated zone are very different and the properties of the Chalk in this zone are poorly understood or documented.
Although a general understanding of the causes of groundwater flooding is becoming apparent, the location, timing and extent is difficult to predict principally because of the heterogeneous nature of the Chalk.

Groundwater flooding is caused by the association of a number of factors which are:

- Geological conditions;
- Presence of dry valley, winterbournes, spring lines, fault lines;
- Presence of properties located adjacent to dry valleys;
- “16 weeks of heavy rainfall” – defined as a total of 400 mm in Wiltshire.

**Impact of Groundwater Flooding**
There are a number of physical, economic and social impacts that result from groundwater flooding events some of which are common to fluvial flooding and others unique to groundwater flooding.

**Long Duration of Flooding**
During groundwater flooding events, property, land, roads and services are “under water” for long periods of time with significant physical, economic and social consequences that are described below. Compared to fluvial events where floodwater dissipates in a few hours or at the most a day or two, groundwater flooding can be present for periods of up to many months.

**Physical Impacts**
The damage to property is of a different type to that normally associated with fluvial flooding. In groundwater flooding events the water usually emerges relatively slowly so that the force and the velocity of the floodwater can be much less than occurs at times of fluvial flooding. However the majority of the flow is not contained in a restricted channel or floodplain as it generally occurs where there is no established drainage path and only shallow gradients.

Nevertheless, the persistence of the floodwater flow can have a deleterious impact upon the fabric of a property. In many cases, the properties are old structures that are situated in a dry valley or relatively close to a source of water such as a shallow well, which had a water table close to the ground surface. They do not benefit from modern construction methods in that they would originally have had thin unreinforced floor slabs that were waterproofed with tarred paper or similar short-lived
materials. Generally, these older properties had floors at ground level with low ceilings. Modernisation has sometimes involved the lowering of floors to obtain extra headroom exacerbating the flood risk.

**Agricultural Land**
In agricultural areas the occurrence of groundwater flooding does not usually have a significant impact upon the farming community but in the 2000-01 event water levels were very high over a long period causing a more pronounced impact than usual. In the Yorkshire Wolds there were incidents of large-scale market gardening enterprises being affected that employed several hundred staff and suffered extensive damage and loss of income. It should be noted that this is believed to have arisen from poorly designed boreholes becoming artesian and flooding the local area.

**Social Impacts**
With the long duration of groundwater flooding houses can become uninhabitable for long periods of time without such ground-floor facilities as kitchen, toilets, power and heating. Roads can be closed for several weeks, which prevent people from leaving their properties. Workplaces, shops, and schools may become inaccessible thereby affecting the normal way of life and means of employment.
Between March 2009 and June 2012 (post)graduate level training in Integrated River Basin Management (IRBM) in Ethiopia will be strengthened. This aims to address the considerable demand for professionals and practitioners in the water sector. The project is a co-operation between eight universities in Ethiopia and a consortium of knowledge providers.

In some universities selected modules related to water resource management and development will be improved, in other universities a full-fledged MSc program in Integrated River Basin Management will be developed. The project is based on the premise that the different universities will also work together in exchanging staff and students.

In addition the links between the institutes of higher education and the water sector organizations will be strengthened. This will take shape in a Universities Water Sector Partnership that will discuss the relevance and orientation of the education offered and opportunities for cooperation in guest lectures, internships and research. A number of short courses for mid-career professionals will be developed too.

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