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Report on

National and Local Capabilities for Early Warning

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REPORT ON NATIONAL AND LOCAL CAPABILITIES FOR EARLY WARNING

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FOREWORD

In 1989, the member states of the United Nations declared the period from 1990 to the year 2000 to be the International Decade for Natural Disaster Reduction (IDNDR). Its objective is to "reduce the loss of life, property damage, and social and economic disruption caused by natural disasters, through concerted international action, especially in developing countries".

The fundamental importance of early warning for realizing this objective of disaster reduction was recognized in 1991. The IDNDR's Scientific and Technical Committee declared the subject a program target, by which the success of the Decade would be judged by the year 2000. By drawing on global scientific knowledge and practical experience, the Decade's advisory committee encouraged all countries to ensure the ready access to global, regional, national and local warning systems as part of their national development plans. The IDNDR Secretariat has since coordinated an international multi-disciplinary framework to promote this issue. In doing so, it has been able to draw on the comprehensive views and abilities of the United Nations system, needs and concerns of individual countries, and related global expert knowledge.

The critical nature of early-warning for the protection of vital resources and for addressing national development objectives was highlighted by a technical committee session devoted to the subject at the United Nations' World Conference on Natural Disaster Reduction held in Yokohama, Japan in May 1994. Several of the expert presentations cited the importance of public policy commitment for successful early warning. The primary outcome of the Conference, The Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation further emphasized the importance of applied scientific knowledge and the public's awareness of hazard risks as essential components for more effective early warning practices.

The IDNDR Secretariat was requested by the United Nations General Assembly in 1995 to coordinate a review of the existing early warning programs and to suggest means by which global practices could become better coordinated and made more effective. Initial information was conveyed by the Secretary General's Report on Early Warning to the Fiftieth Session of the United Nations General Assembly in October 1995. (UN Document A/50/256, 9 October 1995). At that time, a further examination of new scientific and experimental concepts for accurate and timely short-term forecasting was requested of the IDNDR for the purpose of making recommendations on the applicability and development of more effective early warning in the context of international cooperation.

For the current work, six international expert working groups were convened to study different aspects of the early warning process: geological hazards, hydrometeorological hazards including drought, fire and other environmental hazards, technological hazards, the use and transfer of related modern technologies, and national and local capabilities pertinent to the effective use of early warning. Guiding Principles for Effective Early Warning were also compiled by the conveners.

This following report of the Working Group on Early Warning Capabilities for Geological Hazards summarizes global experience and reviews the current state of knowledge and practice on the subject. Recommendations are also made for improvements and areas that require additional international attention. The conclusions reflect the views of scientific and technical experts as well as those of the United Nations departments and agencies concerned. An effort was made to ensure that views of government authorities, non-governmental organizations and other elements of civil society were also represented, particularly as they relate to factors which determine the efficacy of early warnings.

This report is one of a series issued by the IDNDR Secretariat in October 1997 to review the current state of early warning systems. By the end of the Decade, these views will contribute to final recommendations for improved, and better coordinated, practices in fulfillment of the initial IDNDR

program target for the subject. They will first be considered by an International Conference on early warning systems for the reduction of natural disasters which has been held in Potsdam, Germany in September, 1998. This technical and scientific conference focusing on the application of successful warning practices was sponsored by the Government of Germany with the collaboration of United Nations' agencies and international scientific organizations. As a major topical event of the IDNDR closing process and the consolidation of global views, the conference has identified those accomplishments and local experiences which can best improve organizational relationships and practical effectiveness for early warning into the 21st century.

The following titles compose the series of information reports of the IDNDR Early Warning Programme:

Early Warning Capabilities for Geological Hazards
Early Warning for Hydrometeorological Hazards, Including Drought
Early Warning for Fire and Other Environmental Hazards
Early Warning for Technological Hazards
Earth Observation, Hazard Analysis and Communications Tech. for Early Warning
National and Local Capabilities for Early Warning
Guiding Principles for Effective Early Warning

The Secretary General's Report on Early-warning Capacities of the United Nations System with Regard to Natural Disasters presented to the Fiftieth Session of the United Nations General Assembly, October 1995. (UN doc. A/50/526).

The Secretary General's Report on Improved Effectiveness of Early-warning Systems With Regard to Natural and Similar Disasters presented to the Fifty-second Session of the United Nations General Assembly , October 1997. (UN doc. A/52/561).

These reports may be accessed on the IDNDR web site: http://www.idndr.org or on the EWC'98 web site at http://www.gfz-potsdam.de/ewc98/ They also may be obtained from the IDNDR Secretariat, Palais des Nations, CH-1211 Geneva 10 Switzerland. or by Fax: +41-22-917-9098, or E-mail: idndr@dha.unicc.org

EXECUTIVE SUMMARY

Early warning systems can make a substantial contribution to overall risk reduction objectives by enabling vulnerable groups to take timely action to mitigate loss and damage in advance of an impending hazard event. Existing early warning capabilities, however, are often limited to hazard monitoring, forecasting, and telecommunication aspects. If hazard warnings are to contribute to risk reduction, a range of national and local capabilities for warning systems must also be developed, normally in the framework of national disaster management agencies.

Hazard monitoring and forecasting capacities must be developed to deal with the hazard patterns most associated with disaster occurrence and loss, particularly at the local level. National and local capabilities for early warning must also include sub-systems for generating risk scenarios on the basis of hazard warnings, for developing disaster preparedness strategies appropriate to the needs of specific vulnerable groups, and for communicating information to people at risk in a way that allows them to take appropriate mitigation actions.

All these distinctive early warning sub-systems must be integrated into organizational structures which lead to effective decision-making based on the efficient flow of information and clearly delegated political authority. An effective warning structure requires the development of institutional capacity for risk analysis, warning, disaster preparedness and communication at the local level, as well as the horizontal and vertical flow of information. These typically are between the scientific organizations which forecast hazard events, national disaster management agencies, local level institutions and the media. At the same time, early warning systems need to be developed as an integral component of a broad programme of long term hazard mitigation and vulnerability reduction activities.

In order to develop national and local capabilities for early warning systems, it is recommended that countries should:

- carry out assessments of their existing warning system capabilities;
- strengthen the institutional capacity of national disaster management agencies, particularly at the local level; and
- develop national level risk information systems which enable both the identification of particularly high risk areas, and the incremental development of local level capabilities able to realized through training and other forms of institutional strengthening.

Regional and international organizations should support countries' own efforts to develop early warning systems by first, facilitating programs of comparative research and documentation of early warning programme implementation which can generate knowledge on key issues. Secondly, they should encourage networking, training and other mechanisms to share information on early warning methodologies among countries to build the case for early warning in risk reduction activities.

I. INTRODUCTION

Disaster risk is a measure of the capacity of vulnerable groups to absorb and recover from losses and damage caused by hazard events. The greater that capacity, the lesser the risk they face. At the national and local level, the implementation of early warning systems represents an opportunity to increase capacity and reduce risks. They were also defined as a programme priority in the Yokohama Strategy and Plan of Action for a Safer World. The underlying rationale of early warning systems is the timely and accurate communication of relevant information about impending risks to vulnerable people *before* a hazard event occurs, thereby enabling actions to be taken to mitigate potential loss and damage.

Increasing scientific knowledge of geological and hydrometeorological processes, coupled with advances in telecommunication and information technology, means that it is now technically possible to forecast many hazards. It also allows warnings to be communicated, often in real time, to the national authorities responsible for disaster management within a given country. In many contexts, however, improved scientific and technical capabilities for hazard warning have not been accompanied by a commensurate increase in the capability of disaster management agencies actually to apply warning information to reduce risks at national and local levels. The focus of both research and application has generally been on improving hazard monitoring, prediction and telecommunications, rather than on improving the organizational systems, information flows and decision-making processes needed to make effective use hazard forecasts for risk reduction purposes.

This report presents the views that unless national and local capabilities for early warning are improved, particularly in developing countries, improvements in hazard forecasting and telecommunications will not necessarily lead to more effective and relevant risk reduction. The first part of the report emphasizes that national disaster management authorities need to develop complementary and integrated early warning systems sub-systems in order to transform warning information into risk reduction. The second part of the report discusses the early warning systems decision making processes, information flows and organizational structures necessary to facilitate that transformation. The third part of the report proposes a framework for regional and international cooperation to improve early warning capabilities. It further highlights areas requiring particular attention by national authorities.

The available literature on early warning systems reflects the priorities of both research and application and is skewed towards the scientific and technical aspects of early warning, and predominantly, as those are applied in industrialized countries. Literature which examines early warning from social, political and organizational perspectives is restricted to a few definitive references (Mileti, 1990). The analysis of these aspects in the context of developing countries that have high levels of vulnerability is even rarer. The special edition of the journal Desastres y Sociedad (LA RED, 1996a), which systematically documented early warning systems applications in Latin America, is one of the few publications to focus on the social aspects of warning systems in developing countries.

Given the lack of bibliography, the research and writing of this report has relied heavily on unpublished case study material and other *gray* literature, including the personal contributions and insights of Working Group members from different parts of the world. Rather than reviewing well established principles and procedures for early warning systems implementation on the basis of a substantial body of existing research, the report analyses that warning experience which has been documented. It strives to identify common problems and then to suggest possible strategies for improving national and local capabilities. It is important to stress, therefore, that the present report is essentially exploratory in character; the problems, issues and strategies identified need to be validated by future research and through application projects. While the report attempts to be sufficiently general so as to be internationally valid, it is explicitly focused on highly vulnerable developing country contexts, reflecting the overall programme priorities of the IDNDR agenda.

The report was prepared with the collaboration of a Working Group of eleven experts drawn from the Americas, Asia, Europe and Africa. A „List of Issues and Questions on National and Local Capabilities for Early Warning Systems“ was circulated to members of the Working Group. Their contributions were then incorporated in a Draft Report that was presented to an IDNDR Working Group Conveners meeting in IDNDR, held in Geneva in June, 1997. The present report has benefitted from those discussions as well as from the views expressed by the other IDNDR Working Groups on scientific and technological aspects of early warning.

II. EARLY WARNING SYSTEMS AND SUB-SYSTEMS

What Are Early Warning Systems ?

Early warning systems can be interpreted narrowly as technological instruments for detecting and forecasting impending hazard events and for issuing alerts. This interpretation, however, does not clarify whether warning information is used at the national and local levels to reduce risks. In order to fulfill a risk reduction function, warnings of impending hazards need to be complemented by information on the risks actually posed by the hazards and likely strategies to mitigate the loss and damage which could arise. This added value of warning information needs to be communicated to vulnerable groups in a way that facilitates their own decisions and abilities to take timely actions.

In order to transform hazard warning information into effective risk reduction at the national and local level, early warning systems must be made up of a number of integrated sub-systems:

- **A warning sub-system**, in which hazards are monitored and forecasted, at the international, national and local levels. In these, scientific information about impending hazards is produced and communicated to national authorities responsible for disaster management.

- **A risk information sub-system**, which can enable disaster management authorities to generate risk scenarios. These should indicate the potential impact of an impending hazard event on specific vulnerable groups and sectors of the society.

- **A preparedness sub-system**, in which disaster preparedness strategies are developed that indicate actions required to reduce the loss and damage expected from an impending hazard event

- **A communication sub-system**, which allows the communication of timely information on impending hazard events, potential risk scenarios and preparedness strategies to vulnerable groups, so that they may take appropriate mitigation measures.

As such, an early warning system is much more than a scientific and technical instrument for forecasting hazards and issuing alerts. It should be understood as an information system designed to facilitate decision-making, in the context of national disaster management agencies, in a way that empowers vulnerable sectors and social groups to mitigate the potential losses and damages from impending hazard events. The usefulness of an early warning system should be judged, less on whether warnings are issued *per se*, but rather on the basis of whether the warnings facilitate appropriate and timely decision-making by those people who are most immediately at risk.

The Warning Sub-system

Hazard monitoring and forecasting

Hazard refers to the probability of a potentially dangerous phenomena occurring in a given location within a specific period of time. Hazards include geophysical events, hydrometeorological phenomena, and technological circumstances that relate to accidents or failures in industrial, military and energy generation activities. While some hazards can be considered to be exclusively natural in origin, the spatial and temporal patterns of hazard occurrence are increasingly correlated with patterns of human behaviour and relationship with their natural environment. Human practices such as the alteration of natural drainage, the creation of landfills, or increased groundwater extraction may radically alter patterns of seismic hazard. The destruction of natural coastal environments, such as mangrove swamps, can alter patterns of tsunami and tropical cyclone hazards. Consequences of human habitation, such as uncontrolled urban development, deforestation, or radically altered land use may have an even greater influence on the spatial and temporal hazard patterns created when geological and hydrometeorological processes are combined. Technological hazards are, by definition, closely associated with human activity.

The function of a warning sub-system is to generate accurate information on impending hazards including their likely spatial and temporal coordinates and attributes of the event. Hazard monitoring consists of measuring the probability of a hazardous event with specific attributes, occurring in a designated place, within a given period of time. Hazard forecasting involves, in addition, the prediction or warning, that an event with given parameters may actually occur. Existing capabilities for monitoring and forecasting different types of hazards is the subject of other IDNDR Early Warning Working Group reports. Depending on the hazards, monitoring and forecasting may be conducted more appropriately at different international, regional, national or local levels of responsibility.

Spatial and temporal hazard patterns

In many countries disaster occurrence and loss is associated not with a single hazard but with a large variety of different hazards. The 227 disasters that occurred in Ecuador between 1990 and 1995 were associated with 18 different types of hazards (LA RED, 1996b). At the same time, in many countries hazard patterns are rapidly changing due to processes of human habitation such as those involved in urbanization, economic change, population growth, migration and environmental degradation. Recent empirical evidence from Argentina, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Mexico and Peru shows that while disaster occurrence and losses related to earthquakes, tsunamis and volcanic eruptions have remained more or less constant in recent years, both the frequency and the severity of losses associated with all other hazards are increasing dramatically. In the countries mentioned, the number of people affected by other hazards in 1995 was 18 times greater than those affected by earthquakes, volcanic eruptions and tsunamis (LA RED, 1996b).

The spatial and temporal distribution of hazards is also changing, with an increasing predominance of physically dispersed, frequently occurring, and highly localized hazards. There is also the appearance of new hazard patterns in areas where no previous hazard monitoring and forecasting capacity exists. The spatial distribution, magnitude and frequency of hazard in a river basin, for example, can be altered radically in only a few years by human intervention. In the countries mentioned, the number of people killed by frequently occurring, small-to-medium scale disasters is now approximately twice as great as larger scale, infrequently occurring events. The spatial and temporal evolution of many hazards, such as localized floods, landslides, and wildfires as become as rapid as the attendant social and economic processes. While this data was collected in Latin America, the underlying social processes responsible for the transformation of hazard patterns are global in scope. Similar changes may well be underway in other developing regions of the world.

Development warning sub-systems

The existing capacity for hazard monitoring and forecasting in many countries may be limited, thereby reducing the overall relevance and effectiveness of early warning. Hazard monitoring also

may focus on a particular type of hazard in a country, ignoring others. While national and international capacities to monitor and forecast large scale hazards such as tropical cyclones and tsunamis may be well developed, often countries have no hazard monitoring and forecasting capacities operational at the local level, where most hydrometeorological hazards actually occur.

In order to be relevant to risk reduction objectives, the development of a warning sub-system in a country must take account of the full range of hazards, as well as their patterns and trends, as they evolve. If excessive emphasis is given only to monitoring and forecasting infrequent hazard, while ignoring the frequently occurring smaller scale hazards, then the development of a warning sub-system may be skewed away from dominant hazard types and patterns in a country. Unless this issue is seriously addressed, a country may invest significant resources in a „showpiece“ early warning system which makes only a minimal contribution to overall risk reduction objectives.

Warning sub-systems need to be developed as dynamic systems, capable of monitoring and forecasting newly emerging hazard patterns. In this respect, the development of appropriately economical methodologies for monitoring and forecasting highly localized hydrometeorological hazards at a high level of resolution should become a priority. So far, the development of locally based hazard monitoring and forecasting systems has received relatively little scientific attention in the context of early warning systems, but it will become increasingly important if current trends in hazard evolution continue. If warning sub-systems ignore the prevalence and impact of locally specific hazards in overall patterns of disaster occurrence and loss, then the relevance of early warning systems to risk reduction objectives will be limited.

Motivations for improving the monitoring and forecasting of a particular hazard may be due to the impact of a recent major disaster. This can be demonstrated by the global interest evoked by the El Niño Southern Oscillation in both 1982 and 1997, or in the national attention created by Monte del Ruiz volcanic eruption in 1985, the Bangladesh cyclone in 1991 or the Mt. Pinatubo volcanic eruption in the Philippines in 1991. Similarly, a prediction can generate political pressure in favour of monitoring and forecasting hazards, such as occurred following the famous prediction of a devastating earthquake in Peru made in 1981 by Dr. Brian Brady. Scientists studying some hazards and natural processes, may have a stronger political lobby than others, so it is important that investment decisions in warning sub-systems are informed by relevant information on overall hazard trends.

The Brady Prediction

In 1976 Dr. Brian Brady predicted an earthquake of Magnitude 9 for Lima, Peru, with defined magnitude 9 to occur during a very precise period in Lima, Peru, in 1981. It triggered concern in the Peruvian government, and also in the U.S. Fortunately for Peru, the forecast was wrong (Giesecke, 1983). The expected earthquake did not occur in the Nazca trench, but it did cause tremors at the scientific and political level (Olson, 1989). The Brady prediction illustrated how government institutions may not cooperate so readily nor help each other, such as in matters of competition for limited financial resources, or sharing data and information. However, on the positive side, the prediction promoted better seismic monitoring and improved preparedness planning in the country. Once the prediction was proven wrong, all government sectors carried out vulnerability assessments in Lima. Economic resources also were provided for a long term programme to develop the national capacity for earthquake monitoring.

The Risk Information Sub-system

Risk scenarios

An early warning system must have the capacity, not only to disseminate warnings of impending hazards, but also to generate risk scenarios of the potential losses and damages to be expected from their impact, including considerations of the vulnerable groups most likely to be affected. Necessary national and local capabilities for early warning must include the development of a risk information sub-system capable of monitoring hazard and vulnerability patterns and of generating risk scenarios for a given area at a specific time.

Risk is a complex variable related to: hazard types and patterns of vulnerability; the losses and damage produced by hazard events and the capacity of households, communities, businesses, utilities and others to absorb and recover from loss and damage. Vulnerability is much more than the possibility of suffering loss or damage. It refers to the capacity of a household, community, business or organization's capacity to absorb losses or damage and then to recover from them. When vulnerability is low it may be possible to absorb losses, without a crisis or disaster occurring. Conversely when vulnerability is high, even a small loss may provoke a disaster for the household or community concerned. Losses and damages occur at the intersection between hazard and vulnerability, but do not themselves signify a disaster. Households, communities and businesses implement different coping strategies, either explicitly or implicitly, to mitigate loss or damage. Such coping strategies may be able to deal with frequently occurring small losses over long periods of time, but they may fail in the case of unforeseen of infrequently occurring losses of a large magnitude.

An early warning risk information sub-system, therefore, should have the capability to analyse both hazard and vulnerability patterns in a given area. They enable the generation of risk scenarios on the basis of forecasts of both large scale events at the local level as well as smaller scale hazard events, too. In the case of a tropical cyclone affecting a large coastal area, an early warning risk information sub-system must be able to generate scenarios for the overall area to be affected, and for the hazards expected at the local level. These may include, areas prone to flash floods and landslides, as well as risks to infrastructure, property, production facilities, population etc. in hazard-prone locations. At the same time, risk information sub-system should strive to provide information on the vulnerability of the different sectors and social groups at risk.

Such information is crucially important to overall early warning system effectiveness, given that vulnerable groups are more likely to take appropriate mitigation if provided with information on potential losses and damages. There is far less chance of a warning being heeded or acted upon if vulnerable groups have no previous information on risk levels or only limited information about the likely impact of the hazard. Similarly, the information on vulnerability can enable specific groups of people to be targeted with appropriate disaster preparedness strategies, based on their capacity to absorb and recover from loss. At the same time, by monitoring risk, a risk information sub-system can provide vital information to prioritize the development of hazard monitoring and forecasting.

Spatial and temporal risk patterns

Risk patterns in many countries are evolving rapidly. The evolution of hazard patterns has already been addressed, but vulnerability patterns are even more dynamic in many countries due to rapid urbanization, economic change, migration and in some cases, complex variables such as civil conflict. With an increasing range of hazards interacting with an increasing range of vulnerabilities in the context of rapid territorial, economic and social change, risk is also becoming increasingly complex, dis-aggregated, and heterogeneous in space and time. The variety and irregularity of spatial risk patterns likely to be found in a given area tends to increase, while the velocity of change in these patterns tends to accelerate over time.

Existing capabilities for risk analysis

Existing national capabilities for risk analysis often have severe limitations. In many countries, risk analysis is limited to hazard mapping, showing areas where different levels of hazard can be

expected. Even where risk analysis takes into account vulnerability, this is normally restricted to the physical aspects. In most countries it is extremely rare to find risk analysis to take account of the social, economic, institutional and cultural aspects of vulnerability.

Despite the existence of technologies such as geographical information systems (GIS), risk analysis is still fundamentally static in character in many countries, often because base-line cartographic and census information is dated. In situations where data collection has been interrupted by civil conflict or by economic crisis, risk information is often so out of date as to bear little relationship to real risk levels. In areas experiencing rapid urbanization, economic growth or migration, no information may be available on extensive areas of new population, infrastructure and economic activities at risk.

Another dimension of the problem, is that available risk information is usually at too limited in spatial and temporal resolution to provide useful information on increasingly complex and dynamic risk patterns. Low resolution risk maps give the impression of uniform hazard and vulnerability patterns over wide areas. As risk becomes more complex, it increasingly becomes difficult to predict both the characteristics of hazard events and consequent loss with a reasonable degree of certainty. Limited assessment of risk in early warning systems may lead to widespread inaccuracies in the information produced. For example, a low resolution risk map may indicate a large coastal area at risk from tropical cyclones but will be unable to provide information on significant differences in risk at the local level, including the impact of small scale hazard events like landslides and flash floods from heavily localized rains and the unique impact of large scale events at the local level. Local topography, similarly, may have a major impact on wind acceleration in the case of tropical cyclone winds approaching mountainous terrain.

Risk Information sub-systems need to be able to deal with the increasing complexity of risk in order to be relevant to risk reduction objectives. This, in turn, implies improving risk analysis capabilities of national disaster management agencies in many countries.

Development of risk information sub-systems

A first priority in the development of risk information sub-systems must be to complement existing data on hazard patterns with data on physical aspects of vulnerability. This may include information about the location of infrastructure, urban centres and economic activities in hazard-prone areas as well as additional social, economic, institutional and cultural data on the capacity of vulnerable groups to cope with loss. Without this data, it is impossible for an early warning risk information sub-system to generate scenarios of potential losses and damages from a hazard event, or for it to target specific vulnerable groups with appropriate disaster preparedness strategies.

A second priority must be to build capacity to monitor dynamic changes in risk patterns. Early warning systems should be viewed not only as systems for warning of impending hazards, but equally important for monitoring, and then alerting, national authorities to a sudden increase in risk in a given area. Hence, data must be dynamic, and information frequently updated.

Given the growing complexity and dynamism of risk in many countries, risk information sub-systems must be able to analyse risk at a high level of spatial and temporal resolution, in order to be able to provide accurate information on the likely impact of a specific hazard event in a given area with any degree of certainty. Only risk analysis based on up-to-date situations, expressed at a high level of resolution, will be able to generate reliable scenarios. Low resolution risk analysis will prove inadequate for households, businesses and communities to take concrete actions.

Methodological problems in risk analysis

While there have been major advances in the development of risk analysis applications based on GIS in recent years, particularly in developed countries, there are still unresolved methodological problems in designing and implementing applications at a high resolution, especially in developing countries.

The higher the resolution, the greater the complexity of the models required to represent risk accurately. The large number of variables required to differentiate complex risk patterns in space and time, and the difficulties and uncertainties in modelling the interactions and relationships between the different variables make the development of high resolution risk models a difficult undertaking.

The development of risk information sub-systems is further hampered by a lack of adequate data, particularly in developing countries. Both cartographic and attribute data may have incomplete geographical coverage or be presented in unsuitable scales, be dated or of dubious quality, or difficult to obtain. Even when remotely sensed sources can provide current, high resolution data unavailable from conventional analogue sources, its cost is often prohibitively expensive for national disaster management agencies in developing countries.

The absence of conceptual and spatial models capable of representing the social, economic and cultural dimensions of vulnerability is another problem. Many aspects of vulnerability are difficult to quantify and to assign to clearly defined spatial and temporal entities, a precondition for their use in computer-based geographical information systems. The development of advanced models is still at the frontier of GIS research, with the result that there are still no tried and tested procedures available for building social vulnerability aspects into risk information systems.

Finally, but crucially, in many developing countries, national disaster management systems, particularly at the local level, generally lack the institutional and technical capacity or resources to create, sustain and maintain risk information systems based on GIS technology.

Strategies for developing risk information sub-systems

Faced with these problems, innovative strategies are required to develop appropriate risk information sub-systems at a suitably high resolution, particularly in developing country contexts (see Maskrey, 1997). Such strategies can include, the parallel development of national level sub-systems at a low level of resolution and specific local level risk information sub-systems in particularly high risk areas at a high level of resolution. This can enable the production of high resolution information at the local level, while reducing the complexity, cost and time scale of developing national level applications.

At the national level, different modelling techniques can be used to produce low resolution information on risk. Inductive modelling techniques combine selected indicators of hazard and vulnerability, which are then merged using algorithms to produce composite risk indices. For example, data on population density may be overlaid with data on flood prone areas, to *induce* an overview of likely areas prone to flood disasters in a country. Deductive modelling techniques consist in the building of geo-referenced databases of historical disaster occurrence, which enable risk patterns to be *deduced*. Both inductive and deductive techniques may be combined, as when, historical data on disaster occurrence may be used to verify the information provided by an inductive risk map. The experience of the Organization for American States (OAS) in developing national level risk analysis in Caribbean and Latin American countries shows that such applications can often be developed using available data and low cost equipment in short time frames. At the same time, specific software packages for risk analysis such as DesInventar (see LA RED, 1996b) are now available, which can enable countries to carry out national level analysis, without the need for extensive prior research and programming work. The introduction of risk considerations into existing information systems like population census is another important way of reinforcing national risk analysis capability.

At the local level, both inductive and deductive techniques may be used. The use of local *intelligence* on hazard and vulnerability patterns is usually necessary in order to highlight crucial variables, permitting a reduction in the complexity of models and a corresponding increase in the reliability of risk information. Local knowledge can permit the development of spatial-temporal risk models, specific to particular areas at particular times, and can allow the calibration and verification of models developed from secondary data sources. Such information may include local knowledge on hazard and vulnerability patterns, for example, accumulated historical knowledge on hazards in

an area or region (i.e., how a specific river behaves in a flood, local coping efforts of the past and how they worked or could work better). This local knowledge is particularly useful in areas where secondary data is unavailable or dated. There is growing experience in the use of both structured and unstructured methods for applying local intelligence to risk analysis. These methodologies such as Participatory Rural Appraisal (PRA, Chambers 1992) and Capacity and Vulnerability Appraisal (CVA, Anderson and Woodrow 1989) among others. The application of local intelligence to the development of local level risk information sub-systems is the best guarantee that the risk information is accurate and reliable.

There are clearly limits to the use of local knowledge in the development of risk information sub-systems. In areas where both hazard and vulnerability patterns are highly dynamic, even long established local communities may not possess intelligence on current risk levels. In areas, subject to colonization and migration, newcomers may have little understanding of the context in which they are locating. In the case of areas, affected by infrequent hazards, such as volcanic eruptions of tsunamis, there may be no local memory of the last disaster that occurred. In other words, while local knowledge and intelligence is vital, it is necessary equally to be aware of its constraints and limitations so as to combine it with scientific and historical information from secondary sources, where available.

The Need for stakeholder participation

To be useful for early warning purposes, risk information must be credible to those people at risk in a given area so it is recommended that the stakeholders at risk become involved in its production. Stakeholders should be involved in the verification of data and information and of the underlying assumptions in spatial risk models. This allows for the elimination of error or uncertainty, and the incorporation of local knowledge. Such involvement also serves to increase knowledge of risk patterns by vulnerable groups, consequently enhancing their own confidence in the risk information produced by an early warning system. There is a far higher probability of people at risk taking appropriate action on the basis of information which they have been involved in producing themselves. If risk information is developed without stakeholder participation, the credibility level of the information will be far lower and the possibility of warnings being ignored, far greater. In order to facilitate participation, the information systems used in early warning systems should not be proprietary and as transparent as possible for public verification. The abstract presentation of many risk maps does not allow users to verify the data sources and algorithms used to combine data and thus to identify sources of error in the information produced. The use of GIS to produce risk information may even inhibit public debate, unless this aspect is given due consideration.

The Disaster Preparedness Sub-system

Disaster preparedness strategies

The success or failure of an early warning system will ultimately be judged on whether the communication of warning information to people at risk leads to appropriate mitigation action enabling a reduction of loss and damage. If the communication of timely and accurate information on impending hazards and risk scenarios is not matched by effective mitigation, then early warning systems are not relevant to risk reduction objectives. The development of national and local capabilities for early warning must therefore include the design and implementation of disaster preparedness strategies, targeted at specific vulnerable groups, indicating the most appropriate action to be taken to mitigate loss and damage. Evidence suggests that warning about impending hazards, without providing information on what actions to take, may be counter-productive and create either panic or apathy.

The perception of risk and disaster preparedness

Vulnerable groups have different perceptions and various strategies to cope with risk. How each reacts to warning information will depend on a range of factors. These include the importance attached to the hazards embedded in the warning, the context of their vulnerability, and the context of other hazards faced and the effectiveness of previous coping strategies. These reflections on

previous experiences of reacting to warnings will almost certainly condition the decisions which are taken subsequently. If the cost of a previous course of action, such as evacuation, is perceived as having been greater than the expected benefits, or if the expected hazard event did not occur, then there may be resistance to act on future warning information, even if it is accurate and timely.

Disaster preparedness sub-systems should provide guidance on recommended strategies for mitigating loss and damage. Such strategies, however, must take into account the range of coping strategies of the people at risk. If a recommended disaster preparedness strategy contradicts the perceptions of risk and coping strategies of a vulnerable group, then it is likely that the strategy will be ignored or lead to unexpected results. If the recommended strategy is followed, but the costs are seen to be greater than the benefits, then the experience will be perceived as negative and may undermine the credibility of early warning systems as a whole. Hence, the design and implementation of disaster preparedness sub-systems need to consider a number of key issues.

Public information and education about risk

There is a much greater possibility of warning information being heeded and acted upon if warnings are associated with public information and education about risks. If vulnerable groups have a detailed awareness of risk levels in the areas where they live, it is likely that they already will have developed appropriate coping strategies. They will then be more receptive to warnings and will have more capability to understand and interpret information on impending hazards and risk scenarios. This implies that the design and implementation of public information and education programmes on risks, should be an integral part of any disaster preparedness sub-system. This may include the dissemination of risk information in the press and media as well as the incorporation of risk information into school curriculum. Such programs must be sustained in the long term if early warning capabilities are to remain relevant, particularly in countries or regions which suffer infrequent hazard events.

The development of disaster preparedness strategies

The development of disaster preparedness strategies must be accomplished locally, and be appropriate to the needs of different sectors of the society. They include distinctive strategies for communities, schools and hospitals, businesses, utilities and infrastructure etc. Effective preparedness strategies will be those which are negotiated and developed in consultation with people at risk, taking into account their different perceptions of risk, various needs and coping strategies. Experience suggests that a successful disaster preparedness sub-system depends on strengthening and empowering community level organizations, and on the development of contingency plans and disaster preparedness activities based on community needs, perceptions and priorities. Such disaster preparedness activities at the community level must be incorporated into disaster preparedness sub-systems if overall national and local capabilities are to be enhanced.

Disaster preparedness strategies should take into account factors such as the security of people's assets in the event of their evacuation, as well as legal issues concerning responsibility for asset loss, whether the expected hazard event occurs or not. The greater the effort made to ensure the involvement of stakeholders in the design of preparedness strategies, the greater the likelihood that warning information will lead to effective risk reduction. Once strategies have been designed and formally incorporated as part of an early warning sub-system, there is a need to ensure that they are periodically rehearsed in order to assure their continued effectiveness. The existence of strong community organizations with experience in disaster preparedness activities, such as training and evacuation simulations are vital to the effectiveness of disaster preparedness.

Disaster preparedness strategies should be monitored regularly, evaluated, and updated. The coping strategies of vulnerable groups are as dynamic as risk itself and should be adapted frequently in consultation with the vulnerable groups concerned in order to deal with changing patterns of hazard and vulnerability. Disaster preparedness strategies, therefore, should be regularly revised in consultation with vulnerable groups to ensure their relevance. In the event of a preparedness plan being activated by a warning, an evaluation of its effectiveness should be made, leading to either its validation or reformulation.

Examples of Disaster Preparedness Sub-systems

Community Preparedness, Vanuatu

The level of community response and preparedness had increased markedly following the introduction of education and awareness programs, and the establishment of more effective disaster information systems which included very strong linkages with the Meteorological Service. This resulted in no deaths and only minimal damage in six severe cyclones over three years. The level of aid provided by donors was minimized substantially owing to these measures and the self-sufficiency policy linked to disaster relief. (Ian Rector, DHA-South Pacific Programme Office)

Rabaul Volcano Eruption, Papua New Guinea

What really saved lives were not the warnings but the sustained public information exercise over the previous decade. The people didn't wait to be told to get out, they took the initiative themselves (Brian Ward, BAKORNAS PB, Indonesia)

Paez Earthquake, Colombia

Disaster preparedness activities in Belalcazar, Colombia enabled the majority of the population to survive the 6 June 1994 earthquake. On the day of the earthquake, most people evacuated, despite the fact that disaster preparedness planning had been focused on another, potential volcano eruption and debris flows at Huila.

Pinatubo Volcano Eruption, Philippines

Despite the magnitude and violence of the eruption, because of the timely evacuation, human losses were small - about 250 to 300 of the more than 20,000 residents in the affected area. This was achieved through an information dissemination effort initiated by the scientists and followed by political, media, NGOs and other concerned sectors. In this particular case luck was also present, since there was enough lead time for quick study, forecasts, education and warning. More than 350,000 people were spared personal physical harm from the largest explosive volcanic eruption of the 20th century. (R. Punongbayan in: WMO/UNESCO, 1994; UN, 1995)

Cyclone, Andhra Pradesh, India

Government officials were able to implement a previously planned programme to evacuate 600,000 people from the path of an approaching cyclone within 40 hours. This was possible because the results of meteorological forecasts and warnings were communicated through a combination of advanced and traditional channels to people conversant with the preparedness plan from earlier community exercises. Fatalities numbered less than one-tenth of the more than 10,000 people who perished in a similar cyclone 13 years before. At that time in the same location, neither warning, communications, nor local response capacities were as well established. (UN, 1995)

Lahar, Barangay Culatingan, Tarlac, Philippines

A lahar onslaught in 1991 partially submerged the houses in this community. A local peasant organization had been organized by the Non-governmental Organization, CONCERN as a preparation for the next year of anticipated lahar flows. A disaster response committee was formed as a part of the existing peasant organization. Preparedness involved various activities, including early warning and planning of an evacuation route. The 1992 lahar flows tested their preparedness. Even though another lahar struck the community, most of the houses were left standing and no one was killed in the episode.

The Communication Sub-system

Communication strategies

The effectiveness of early warning systems depends on the timely communication of warnings to communities, businesses and households at risk. If information on impending hazard events, risk scenarios and disaster preparedness strategies fails to reach the people at risk on time, then the early warning systems will have failed. The development of national and local capabilities for early warning systems must therefore include the design and implementation of communication strategies, taking into account both the content and the form of warning information, as well as the media used to communicate with the affected communities.

The content and form of warning information

The function of a communication sub-system should be to communicate to those people at risk relevant information on the existence of an impending hazard, its spatial and temporal coordinates and attributes, the pattern of expected loss and damage, and the mitigation actions which should be taken. The quality of this information, however, is not objective, but is relative to the perceptions of the people who receive it and are expected to act on it.

In many contexts, people at risk will have received information on impending hazards from both media and scientific sources, before receiving warning information formally through an official warning system. This information from other sources will influence their perception and interpretation of the official information. Throughout the foreseeable future the dissemination and reception of more, rather than less, information will be the rule. In the case of an impending tropical cyclone, for example, it is probable that people will receive information from numerous sources, ranging from satellite and cable television to local gossip and rumour, well before an official early warning system is activated. The effectiveness of an early warning system will be affected if a warning is either downplayed or exaggerated by the media or if conflicting scientific opinions are disseminated.

Given that it is neither possible nor desirable to restrict free access to information, the key to guaranteeing an effective communication sub-system is to establish among the stakeholders the credibility of both the national and local disaster management authorities responsible for warnings. The foundation of a credible warning is that the information it contains has to be perceived as being timely, accurate and truthful by those people at risk. It has to be accurate in the sense that it must be based on the best scientific data available, yet truthful without overstating risks and explicitly recognizing uncertainties. Unless authorities manage to establish credibility as providers of timely, accurate and truthful information, people at risk may pay greater attention to other information sources. If the warning authority lacks status in the area concerned, or has a history of conflicting relationships with local communities, warnings may not be well-received. Similarly, if too many warnings had been given previously, or no warning had been given at all when a disaster did occur, then the credibility of future warnings will be jeopardized.

A strategy for ensuring the credibility of warning information is for warning authorities to work together with scientists, media specialists and stakeholders to ensure that people have the most complete information possible. It is important to avoid creating the image that warning information is error free. When impending hazards which are forecasted do not occur, it is important that authorities provide information explaining the reason, especially if preparedness and contingency plans were implemented on the basis of the warning. Successful experience in the use of warning information, even when no disaster actually occurs, is without doubt, the best way of building confidence. It is vital that communication sub-systems do not attempt to limit the information provided on the pretext of avoiding panic, or on the assumption that people will be unable to interpret the information provided. Given the likelihood that people will receive information from other sources anyway, this is an untenable belief, that will also erode the credibility of warning information.

The quality of warning messages is also related to their specificity with respect to people at risk. The greater the local specificity of warning information, the greater its relevance and the better the possibility of its being used to improve local coping strategies. Even within an apparently homogeneous community perceptions will be different according to ethnicity, gender, class, age and other characteristics, so an individual generic warning will communicate different messages to various social groups. The level of detail and specificity provided, such as through the language and symbols used, or the geo-referencing that the warning contains, will all affect the quality of communication.

As in the development of early warning systems information sub-systems, the key to ensuring the communication content of warning information is to engage the active participation of stakeholders and to incorporate local knowledge.. Particularly in areas where there are different ethnic and language groups, or transient and migrant populations, it is important to develop protocols for warning information that is specific to the various communities and social groups. This may require the need for multiple translations of warning messages, by the disaster management organizations concerned. The use of well known local features and landmarks for geo-references in warning information has been shown to be particularly effective in obtaining local relevance.

Communication media

Communication sub-systems are likely to include a mixture of mass and selective communication strategies and various media appropriate to each country's own local context. Communication is not a one way process of only transmitting warning information to those at risk; to be effective it must be bi-directional and interactive. The national disaster management agencies need to monitor whether warnings are heeded, what mitigation actions are being taken, and the extent to which preparedness strategies are being implemented. Without this feedback, it would be difficult to and to determine remaining needs and to set priorities.

Communication strategies should take account of the relative effectiveness of different media for transmitting and receiving warning information, as well as the spatial and social coverage of each. Useful media can include radio, television, community alarm systems, the Internet, cable and satellite

communication systems. There are also local formal and informal communication systems. Conventional communication systems, such as television, may fail to reach particularly vulnerable groups, such as illiterate rural communities in remote areas. In some areas, alternative media, such as community level broadcast systems, may be more effective.

Different communication strategies can be identified. Mass communication consists of the transmission of a warning directly to vulnerable groups. Selective communication consists of the transmission of warning information to specific audiences, such as to local governments, hospitals, schools, public utilities, community organizations, etc. Each of these would then be responsible for the mass communication of the warning within their particular professional jurisdiction. Mass communication may be more direct and rapid, however selective communication may allow warning messages to be more appropriate for specific needs within local communities.

With improved telecommunications, warning information is increasingly easy to transmit from the national and international levels to the local communities. Nonetheless, many highly vulnerable rural areas and small towns in developing countries are not yet integrated into modern telecommunication networks. Therefore effective interactive communication for early warning through Internet is still not a viable option in some areas. While television and transistor radio are still the most commonly used media for communicating warning information, frequently there are no commonly accepted protocols or standard procedures to interrupt programs and to give priority to warning information. At the same time, broadcast television and radio are essentially tools for information dissemination and do not lend themselves to interactive communication between warning systems managers and communities at risk.

Walkie-talkies and two-way radios have often been used by both disaster management organizations and NGOs to relay warning information and have the advantage of permitting interactive communication. However, many areas are not covered on a continuous basis by this kind of communication infrastructure. In many highly vulnerable areas only alternative communication media are available: ranging from amateur radio through churches and mosques to the use of flags, beating of drums, or other local means.

Development of communication sub-systems

In developing communication sub-systems, strategies should be developed for each area consisting of a locally appropriate mix of mass and specific communication media, composed of both formal and informal mechanisms. Training in the use of communication strategies should be an integral part of developing warning capabilities, so that those at risk know how to respond to different kinds of communication media. Appropriate media management practices must be developed and followed to avoid contradictions. Protocols are necessary to allow the interruption of radio and television broadcasts in order to issue warnings. Communication sub-systems need to be tested frequently and related community exercises should be conducted regularly. Clear operating procedures should be developed by, with and for those authorities responsible for issuing warnings.

III. STRUCTURES FOR EARLY WARNING SYSTEMS

Organizational Structures

Responsibilities for hazard monitoring and forecasting

Hazard monitoring and forecasting is normally carried out by specialized scientific agencies at both the international and national levels. These include meteorological organizations and institutions involved in the monitoring and research of specific hazards. Depending on each country and region, these may be public sector and military institutions, universities, regional organizations, and others. Hazard warning information may be collected, processed and disseminated at the international,

regional, national or local levels. For example, while the monitoring of hazards associated with a global event, such as the El Niño Southern Oscillation (ENSO) requires coordinated international efforts, in the case of smaller, or more localized hazards, such landslides and flash floods, the only effective monitoring and forecasting possible, will be at the local level. In the case of tropical cyclones, floods or storms, the principal source of warning information may be regional or international meteorological organizations. In the case of volcanic eruptions, monitoring and forecasting may be carried out by national scientific organizations. Responsibility for issuing hazard warnings in most countries, therefore, falls on a number of different organizations according to the type of hazard.

Responsibilities for risk reduction

The responsibility for transforming hazard warnings into risk reduction, however, normally lies with organizations responsible for disaster management at the national level. In most countries, specialized government agencies, both civilian and military ones, have been created with specific responsibilities for disaster management. In other countries, organizations such as the national Red Crescent or Red Cross Societies or UN agencies also may play a significant role. These responsibilities may ordinarily include areas such as hazard and vulnerability mapping, the development of disaster preparedness strategies, and communicating warnings. Similarly, these agencies often have a political responsibility for ensuring that warnings are issued and acted upon. The structures and responsibilities of official agencies vary enormously from country to country, but they tend to share some common characteristics. In many countries, attempts have been made to develop national disaster management organizations, structured around a hierarchy of local level disaster management committees based on the municipal authorities, supported by sub-regional and national level entities. Similarly, government disaster management organizations often have formal responsibility for coordinating the actions of other sectors and agencies including scientific institutions, NGOs, international agencies and other government institutions. In most countries, therefore, responsibilities for developing national and local capabilities for early warning systems will lie, formally at least, with national disaster management agencies.

National and local structures

In order to develop relevant and effective early warning systems, disaster management agencies need to develop organizational structures, information flows and decision-making protocols, capable of integrating the four sub-systems effectively, at both local and national levels.

As all of the sub-systems depends on accessing local knowledge and on developing appropriate strategies that are responsive to local patterns of hazard, vulnerability and risk, early warning systems should be built up from the local level. Many warnings can only be generated effectively at the local level. The primary responsibility for generating risk scenarios, for developing preparedness strategies and for communicating warning information to vulnerable groups of people must rest at the local level. The transformation of hazard warnings into risk reduction, through an early warning systems, depends fundamentally on the existence of an institutional capacity at the local level, capable of developing and integrating the different sub-systems at a sufficiently high resolution. The overall effectiveness of early warning systems is closely related to the existence of capacities for risk reduction at the local level.

Many hazards, however, affect large areas of a country and may cross country boundaries. A warning sub-system may depend primarily on scientific information produced internationally or nationally. Local level warning systems, therefore, need to:

- be complemented by national level capacities to issue warnings of impending hazard events;
- monitor broad hazard and vulnerability patterns in order to prioritize areas for the development of local level early warning systems;

- facilitate the communication of warning information to the local level and between local level early warning systems; and

- support local level preparedness strategies, when it is likely that the impact of an impending hazard will overwhelm local capacity to mitigate loss and damage.

National disaster management systems

Given that the development of national and local capabilities for early warning is intimately linked to the organizational structures of national disaster management systems, it is necessary to review how these systems relate „vertically" between the national and local levels, and „horizontally" between government agencies and other organizations.

Effective early warning systems require the existence of institutional capacity for warning, risk analysis, disaster preparedness and communication at the local level. As mentioned above, given the needs for high resolution risk scenarios and the development of appropriate preparedness and communication strategies, targeted at specific vulnerable groups, the local dimension is fundamental to the overall goal of transforming hazard warnings into risk reduction. Unfortunately, in many countries national disaster management systems at the local level exist only on paper. While local governments often have legal responsibility for disaster management as part of national systems, their institutional capacity is often extremely weak outside of the major cities and, almost by definition, inversely proportional to vulnerability levels. A typical local government office in a highly vulnerable rural area of a developing country rarely has the technical capacity, resources, telecommunications infrastructure or know-how to undertake even a minimum level of warning systems development. Hence, in many countries, the institutional capacity to develop early warning systems at the local level in high risk areas simply does not exist.

Many national disaster management organizations and systems are focused almost exclusively on emergency response and often have little political motivation to become involved in risk reduction activities. As a result, while the response capacity of national organizations may be quite well developed, there is often little investment in areas such as information systems for risk analysis or in broad based hazard mitigation and vulnerability reduction activities. As outlined above, an effective early warning systems needs to be integrated as part of a broad programme of risk reduction activities. It also requires a long term commitment to the development of information systems and towards public education and information about risks. In many countries, unfortunately, the priorities of national disaster management organizations and systems are not conducive to coherent early warning development objectives.

At the same time many national disaster management organizations are dependent on structures of formal political representation, with barriers to the participation of community organizations, NGOs and other forms of organizations. There can be difficulties in cooperating with these organizations, even though they may enjoy greater legitimacy at the local level than government institutions, due to either political reasons or to legal and management structures. Even when national disaster management systems have been formally created, good coordination between different government and other organizations does not necessarily exist, leading to confusion, contradictions, overlapping functions, and gaps in responsibility. This can be the case particularly in countries where national organizations are established under military decision-making practices, and information flows tend to be hierarchical and not so conducive to the participation of stakeholders. There may also be poor coordination between military and civilian structures. In such cases, the opaque character of many national disaster management organizations can become an obstacle to the development of early warning systems.

The development of national and local capabilities for early warning systems, therefore, requires the strengthening of national disaster management agencies so as to provide a sound organizational structure. A first priority in this respect must be the development of institutional capacity for disaster

management at the local level, particularly in highly vulnerable regions. Secondly, the overall emphasis of national disaster management agencies needs to shift from one of emergency response towards an emphasis on risk reduction that includes hazard mitigation, vulnerability reduction and disaster preparedness. This change in emphasis clearly depends on the country concerned establishing risk reduction as a political priority at the national level and being willing to undertake both the institutional reforms as well as the necessary investment to make that happen. Thirdly, commitment is required to enhance the decision-making processes of risk-prone groups within the roles of national disaster management agencies in general, and early warning systems in particular. In order to achieve this objective, programmes need to be developed with their participation. These changes are essential to develop early warning systems that empower local level interests able to be supported by a national coordinating body. The more decentralized, participatory and risk oriented a national disaster management system is, the more it will be able to develop and manage effective early warning systems.

National level organizations should be responsible for producing low resolution information on risks in order to identify priority areas for the development of local early warning systems capabilities. These include facilitating the development of local level systems, improving the telecommunications capacity of local areas, and promoting the horizontal and vertical communication of warning information between local level systems and the national level. At the same time, national level organizations should be responsible for relating to scientific organizations that produce hazard warning information at the national and international levels.

Local level organizations should be responsible for the design and implementation of locally appropriate risk information, disaster preparedness, and communication sub-systems as well as local warning sub-systems which focus on the monitoring and forecasting of locally specific hazards.

In the case of small island states, it is unlikely that a full national and local structure for early warning systems is appropriate. In these and similar contexts, a regional coordinating body may be established to fulfill the functions mentioned for a national early warning systems, while each individual island could be considered as a local level early warning system.

Decision-Making Procedures and Information Flows

Frameworks for information flow and decision-making

Any early warning process requires a framework for information flow and decision-making that can enable international and national warning information to be transformed into risk reduction at the local level. The efficient flow of information through the organizational structure is key to well-informed decisions to activate warning systems at the right time.

Early warning systems are only as good as their weakest link. They can, and frequently do, fail for a number of reasons. There can be a failure of hazard forecasting itself, in that the expected hazard event never occurs, or it occurs, but with unexpected parameters. Risk scenarios that are generated, may also be inaccurate. The activation of disaster preparedness strategies may incur unacceptable costs for specific vulnerable groups. There may be a failure to communicate warning information accurately, in sufficient time, or in a way which can be usefully interpreted by people exposed to the hazard. All of these different issues, however, are compounded by a generalized problem if information does not reach decision-makers on time, or when appropriate decisions are not made. This may be either to the lack of information, opaque and overcomplicated decision-making procedures or perceived political risks.

Information flows and decision-making authority exist at different levels in warning systems. First, information is required about hazard monitoring and forecasting from national and international scientific organizations, and decisions about when to issue a hazard warning then needs to be provided to a national disaster management agency. Secondly, after generating risk scenarios of the impending hazard event, national disaster management authorities need to make a decision to activate

the early warning system and to transmit the hazard warning information to relevant local level systems in the areas expected to be affected. Again communication channels need to exist between the national and local levels of responsibility. Local level disaster management authorities need to take appropriate decisions to communicate information on the impending hazard, on the risk scenarios in each locality and on appropriate preparedness strategies. Information flows need to be two-way and interactive, allowing modifications to be made to forecasts, risk scenarios, and disaster preparedness strategies, according to how the warning situation evolves. Information flows also need to allow the two-way sharing of warning information and coordination of disaster preparedness and communication activities between different local elements of a warning system, for example as within a river basin affected by a major flood.

In each of these areas there can be breakdowns in communication and information flows, failures to interpret information, or competing political interests with respect to the decisions to be taken. While the issuing of a hazard warning by a scientific institution should not be politicized, the decision to activate an early warning system on the basis of a hazard warning is essentially political in character. This implies the importance of weighing the risks for different sectors of society if a decision is not taken, and consideration of the possible costs and benefits of activating the early warning system. Warnings may not be issued if they are perceived to pose unacceptable political risks for decision makers, for example in deterring foreign investment, or posing threats of litigation in the case of asset loss. Scientific institutions and the media may not be integrated into the national disaster management structure, providing a possibility for confusion and contradictions in the warning information produced. Information flows within national disaster management systems also may be indirect and hindered by bureaucratic obstacles. Hazard warning information may have to flow through several different national level organizations, before it is transmitted to the local officials responsible for activating early warning systems in risk-prone areas. At each stage, delays may occur before information is transmitted. Even when information is transmitted from the national to the local level it may not be accompanied by the necessary authority to act, leaving local officials powerless to take decisions. The horizontal flow of information between local disaster management authorities is often even more difficult given the normally hierarchical organizational structure of many national disaster management agencies. Information from one local authority to another often has to pass through a central national authority before being retransmitted.

This last problem is particularly critical in the case of hazards, such as floods and tropical cyclones, which may cross national boundaries, or on other occasions when there is little direct contact between local authorities on either side of a frontier. This impediment to effective warnings is exacerbated when neighbouring countries do not necessarily enjoy good political relationships.

Regional Cooperation in Early Warning

In Bangladesh, 90% of annual water flow originates from India and Nepal and frequently many people do not know anything about it until the water reaches them Experience shows that a centralized Flood Forecasting and Warning Centre is not suitable for issuing local flash flood warnings which are better done through local initiatives and community participation. Non-government organizations have a good working relationship at the grass-root level and can be much more flexible in their activities than government institutions.

Small rivers in the northern and eastern border regions of Bangladesh are „marginalized" so far as flood forecasting and warning systems are concerned. Local people have their own understanding about the incidence of calamities, but they cannot manage it adequately due to absence of information and forecast. Flood forecasts do not cover small rivers and constraints are imposed by administrative and political boundaries. However, the need to mitigate the suffering of people from flash floods is thoroughly recognized. It is realized that simple indicators could be developed for operationalizing them at the local level within a framework of regional cooperation.

Local level operations are required; receiving simply understandable warnings and information enabling villagers to get enough time to save themselves, to develop a system where information can be shared between areas and regions. Data exchange exists between Bangladesh and India at official governmental levels, but the exchange of information is not sufficient for the vulnerable communities. The Joint River Commission of India and Bangladesh operates for major rivers only and they do not plan to include smaller rivers. An alternative system needs to be developed for sharing information on smaller rivers. Forecasting at the local level is needed, involving local community groups, and community- based organizations to help each other between the two countries. (Wahra, 1995)

The design of information flows

The development of national and local capabilities for early warning systems must include the design of efficient information flows between the different sub-systems and organizational components, as well as the use of clear and unambiguous decision-making protocols. Information should flow as directly as possible through an early warning system, an objective which is consistent with minimizing the number of decision-making authorities between the origin and destination of the information.

Focal points for decision-making

In national disaster management agencies, there needs to be a designated focal point for decision-making, with political authority and responsibility for activating an early warning system. This would include the responsibility to transmit warning information to local authorities and to ensure that risk information, disaster preparedness, and communication sub-systems are put into effect at the local level. Similarly, there needs to be an early warning focal point designated also at the local level, with the political authority and responsibility to activate early warning mechanisms. In the case of locally specific hazards, where hazard warnings are produced locally, local authorities should have delegated political responsibilities for activating necessary sub-systems, without the need to seek authorization from the national level. On the contrary, delays in information flow and decision-making at the national level could lead to untimely transmission of warning information to people at risk in local communities.

It is also important to create horizontal communication channels between early warning systems at the local level, allowing the transmission of warning information, along river basins and from one area to another. National authorities should develop protocols to allow the direct exchange of early

warning information across boundaries. Local level systems, therefore, should be structured as mesh networks, allowing both the sharing of warning information as well as the coordination of preparedness strategies.

Authority in early warning decision-making

As emphasized throughout this report, the effectiveness of any early warning system ultimately depends on the decisions made by vulnerable groups of people, themselves. Whether or not households, communities and businesses should be made to comply with recommended warning strategies, under coercion if necessary, is a controversial issue.

In the case of key public institutions, such as schools, hospitals, utility operators, power generation facilities, transport providers etc., it is reasonably clear that local warning officials should have the political authority to ensure that disaster preparedness strategies are mandatory and fully implemented. Nonetheless, this requires the design of clear decision-making protocols between what are different kinds of public institution. For example, a health institution, such as a major hospital, may be responsible directly to a national health ministry rather than to a local authority. In such cases, negotiation is required between different parts of government to ensure that the necessary decision-making procedures are in place.

Arguments for making disaster preparedness strategies mandatory for vulnerable households, communities and businesses are less clear. According to the political culture in each country, this depends on the limits of state intervention in the public interest. It also raises issues of liability and legal responsibility, which need to be addressed. The spectre of litigation against warning authority due to the forced evacuation of an area on the basis of warning about a hazard that never materialized, is very real in some countries. Between the extremes of making disaster preparedness strategies mandatory, and leaving the decision to act as a matter of individual responsibility, there is a third option. If vulnerable households, businesses and communities have participated as stakeholders in the design of disaster preparedness strategies, they could be legally required to ratify those strategies once agreement with the local early warning systems authority has been reached. Once a disaster preparedness strategy has been legally ratified by stakeholders, then it could become mandatory to act on the strategy if a warning is given. This third option, would allow people at risk to feel ownership of warning and disaster preparedness strategies that then, in turn, could reduce likely problems of mandatory implementation.

Early Warning Systems and Risk Reduction Strategies

Risk accumulation

In both developing and industrialized areas, there is an accelerated accumulation of risk in many economic and social sectors. The effects of economic globalization makes the detection, management and reduction of risk an uncertain undertaking. Risk is becoming increasingly complex as local risk scenarios become enmeshed with broader economic and political decisions. The imperative of rapid economic development demonstrates that information on risk is not always factored into development processes. At the same time, however, the growing levels of disaster loss, as a consequence of not managing risk, are a major obstacle to achieving goals of social and economic development.

The role of early warning systems in risk reduction

Through the effective development of national and local capabilities, early warning systems can play an important role in risk reduction. However, it must be stressed that national risk reduction strategies should not rely solely on early warning systems. If risk considerations are not adequately factored into national development strategies, disaster occurrence and loss will continue to increase, with or without the improved warning capabilities. Early warning systems should thus be seen as a „last line of defence“ for dealing with unmanaged risks. They must therefore be developed as an important component of much wider national risk management and reduction strategies. If developed as a „stand alone“ system, they may create a false sense of security leading to apathy in both vulnerable groups as well as within national disaster management agencies.

If integrated in a broader framework, the development of national and local capabilities for early warning can make an important contribution to wider risk reduction objectives. Risk information sub-systems can also function to factor information about risks into land use and development planning on a permanent basis. Similarly, communications sub-systems can be designed to contribute to broad programmes of public information and education about risk. Disaster preparedness sub-systems can likewise be integrated as a component of medium term hazard mitigation and vulnerability reduction strategies.

Warning systems, therefore, should be designed as the leading edge of broad national and local strategies of hazard mitigation and vulnerability reduction. Without the existence of national and local capabilities for early warning, the credibility of these strategies will be threatened, given the absence of a mechanism for mitigating existing levels of accumulated risk. However, hazard mitigation and vulnerability reduction is essential in the long term, if rapidly accumulating risk is not to exceed the mitigation capacity of early warning systems.

IV. BUILDING NATIONAL AND LOCAL CAPABILITIES FOR EARLY WARNING SYSTEMS

The preceding sections have focused on the early warning sub-systems required at the national and local levels of responsibility, and on the organizational structures, information flows and decision- making procedures required to integrate them in an effective manner. The present section of the report defines programme priorities for strengthening national and local capabilities for early warning systems, with the objective that national governments and relevant international agencies should implement a comprehensive range of actions.

Reviewing Existing Capabilities

As a first step, countries should carry out a review of existing national and local capabilities for early warning systems, bench-marking existing early warning systems capabilities against the recommendations made elsewhere in other sections of this report. Such a review should focus on all early warning systems sub-systems and on the organizational structures, decision making procedures and information flows for early warning systems. The analysis of the information produced by the review should enable the prioritization of actions required to strengthen and reinforce particular organizational components and procedures.

Strengthening National Disaster Management Systems

As early warning systems are normally integrated at the national and local level with disaster management agencies, the institutional strengthening of those bodies is a precondition for the development of effective early warning systems. In particular, the building of sustainable institutional capacity for early warning systems at the local level must be established as a programme priority for national agencies, particularly in highly vulnerable areas, where existing institutional capacity is often weakest.

Improving Hazard Warning Capabilities

National authorities need to ensure that existing capabilities for hazard monitoring and forecasting are relevant to patterns of disaster occurrence and loss in a country. Investment in hazard monitoring and forecasting at the national level, should allow improved capabilities to reflect the spatial and

temporal evolution of disaster occurrence and loss. Particular consideration should be given to the development of local level hazard monitoring and forecasting capabilities in those countries where a large and growing percentage of disaster occurrence and loss is related to small-scale, highly localized, hazard events. In some countries, relevant international assistance may be required in the development and dissemination of relevant hazard warning technologies and methodologies.

Development of National Level Risk Information Capabilities

National disaster management agencies need to ensure that information systems are in place for monitoring hazard and vulnerability patterns at the national level and that they can generate low resolution risk scenarios on the basis of hazard forecasts. Many countries currently do not possess such systems and international efforts are required to disseminate appropriate technologies and methodologies for system development and to provide technical assistance to countries.

The existence of low resolution risk information systems in national disaster management agencies can enable the determination of priority areas for the development of local level early warning systems, usually in those areas where risk levels are high or rapidly increasing. National disaster management agencies need to invest in developing local level early warning capabilities in those areas.

Development of Local Level Capabilities

Necessary local level capabilities include the development of all warning sub-systems: the monitoring and forecasting of local level hazards; high resolution risk analysis on the basis of local knowledge and intelligence; disaster preparedness strategies appropriate to specific vulnerable groups; and communication strategies enabling timely warning information to reach targeted vulnerable groups.

Rapid, low-cost, methodologies for risk analysis at the local level have been developed and documented examples of their application exist in a number of countries. National disaster management agencies will need to access these methodologies and transfer them to the local level. A priority in the development of local level early warning systems should be to train local disaster management authorities in the use of appropriate methodologies and then follow with technical assistance for the development of local level risk information sub-systems.

Training programs should also be developed for local disaster management authorities in risk management and in the design and implementation of disaster preparedness and communication strategies. They need to build on documented experience of successful practice from different countries and contexts. Participatory training methodologies produced in Latin America, Asia and Africa already exist that can be adapted easily to early warning requirements.

The results of local level risk analysis and the design of appropriate communication and disaster preparedness strategies need to be integrated into local risk management plans, which include both early warning system components, as well as broad actions for hazard mitigation and vulnerability reduction. These plans should clearly define the institutional and decision-making responsibilities for early warning. They should be formulated and updated regularly with the participation of key local stakeholders and regularly updated. The plans should include options for simulating contingencies, in order to verify the effectiveness of proposed responses, as well as for broad based public information and education on risks and risk management strategies.

Strengthening Organizational Structures, Information Flows and Decision-Making

The development of early warning capabilities also needs to include the definition of key decision-making authorities at the national and local levels. This would need to be decided according to national political and government structures and the definition of the respective levels of responsibility attached to each specific function. Information flows need to be streamlined to ensure the efficient flow vertically and horizontally throughout early warning systems. Points of contact are necessary to facilitate the exchange of information between scientific organizations producing hazard warnings, national disaster management agencies, local community leaders, and the media. Numerous methodologies are available for analysing the requirements of organizations, and then to develop strategic or operational plans. In most countries, this analytical expertise already exists in universities and other specialized institutions.

National disaster management organizations, also need to ensure that local level early warning systems are effectively networked and relate horizontally and vertically through necessary telecommunication capacities. While the development of telecommunications infrastructure is often determined by market forces, effective early warning must depend on demonstrated telecommunication capacity at national and local level institutions. The strengthening of telecommunication capacity in high risk areas is of particular importance. The development of Internet capacity in national and local organizations, should equally be viewed as a short term priority, given the utility of rapid, interactive communication in early warning systems.

National governments also need to negotiate regional and cross-border agreements with neighbouring countries in order to ensure the integration of early warning systems at the local level, similarly as may be required, among small islands.

Implementation Strategies

In order to implement a comprehensive programme to strengthen national and local capabilities for early warning, countries should adopt a realistic strategy of incremental development. Rather than attempting to design all aspects of an early warning system before proceeding to implementation, it is recommended that countries plan to develop local systems first, particularly in the areas of highest risk. The experience so gained, can help to galvanize political support and resources for further expansion into other areas.

In a similar vein, it is recommended that simpler, economical, and readily available technology be used whenever possible. Such basic equipment can be maintained more reasonably with available national resources and expertise. The incremental development of early warning systems also enables new technology to be introduced gradually as system specifications evolve.

Many existing warning systems result from political pressure to improve disaster preparedness following a major disaster. As such, national authorities can use disasters at the local and national levels as opportunities for improving warning systems. There is likely to be a far greater receptivity towards participating in the development of warning systems at local levels following a disaster, whereas at the national and international levels, the offer of additional resources following a disaster can be utilized to finance improvements in early warning. This may only be possible though to the extent national disaster management authorities have a clear objective and explicit programme for developing their warning systems.

Monitoring and Evaluation

National and local capabilities for early warning systems should also include facilities for the monitoring and evaluation of early warning performance. In the event that warnings are issued, then the relative demonstrated results of disaster preparedness and communication strategies should be

evaluated so that they may be revised if necessary, or otherwise improved. The evaluations should be publicized, as should a ready acknowledgement of actions taken to improve warning systems after an emergency. The occurrence of an emergency also presents an opportunity to validate or revise previous risk information. The overall performance of warning systems at the national level also requires monitoring, for which performance standards should be established and agreed. Based on performance, the organizational structure, decision-making procedures, information flows or any specific dimension of warning sub-systems should be revised, as necessary. Again, both performance targets and performance monitoring should be publicized in order to build both disaster awareness and operational confidence.

International and Regional Cooperation

While international and regional cooperation is essential to the coordination of hazard monitoring and forecasting activities, it can also play a vital role in facilitating the development of national and local capabilities for early warning. A number of priority areas for regional and international cooperation should be emphasized:

i) Develop a body of knowledge on early warning systems development and implementation, particularly in developing countries.

While there is presently a tradition of research into early warning systems in countries such as the United States, and largely unpublished case studies on early warning systems from developing countries also exist, there is no widely accepted, documented, body of knowledge on the operation of early warning systems at national and local levels. It is difficult to foresee improvements in existing early warning systems capabilities, unless lessons from past experiences are taken into account. A priority for regional and international organizations should therefore be to facilitate research and documentation of the development of early warning systems in different countries and contexts, particularly with respect to useful methodologies and technologies used in the development of early warning systems. These would include key issues in the development of national and local capabilities for warning systems and the documentation of case studies of successful systems applications. Ideally research should be comparative in nature enabling cross-country comparisons, particularly between countries which share similar problems and institutional structures within the same region. Comparative research could also enable the development of regional standards for early warning systems, which then could be used as a basis for evaluating and bench-marking existing capabilities.

ii) Share early warning experiences among countries through information dissemination and networking.

Important multiplier effects in warning systems development can be achieved when countries learn from past experience and from each other. The dissemination of research findings on systems development and implementation, through publications, seminars, training courses and other means should be a priority for regional and international agencies. Building networks at the national and regional levels should also become a programme priority to enable countries to use existing regional resources for warning systems development. Regional expertise in areas such as training, information systems, hazard monitoring etc. can then be applied to warning systems in a way that maximizes the use of existing resources.

iii) Develop national and local capabilities for early warning systems through technical assistance and training.

Regional and international agencies with expertise in warning systems development should provide support through technical assistance and training in different aspects of early warning systems development as a priority for national and local authorities. This support may include, the evaluation of existing early warning capabilities at national and local levels, the dissemination of training methodologies, training trainers at the national level, provision of technical assistance to develop risk information systems, and the creation of early warning options in higher education programmes pertinent to disaster management functions.

iv) Provide information for national and international policy-makers on the role of early warning in risk reduction.

In many risk-prone countries, neither risk reduction in general nor early warning in particular, have become political priorities. It will be difficult to achieve strengthened national and local capabilities for early warning on a sustainable basis unless national governments give greater political priority to risk reduction. An important priority for regional and international agencies is to facilitate the transfer of information on the role of early warning systems in risk reduction to policy-makers and the establishment of dialogues among national governments, development finance agencies, and key stakeholders at risk.

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