World Meteorological Organization

GUIDELINES ON INTEGRATING SEVERE WEATHER WARNINGS INTO DISASTER RISK MANAGEMENT

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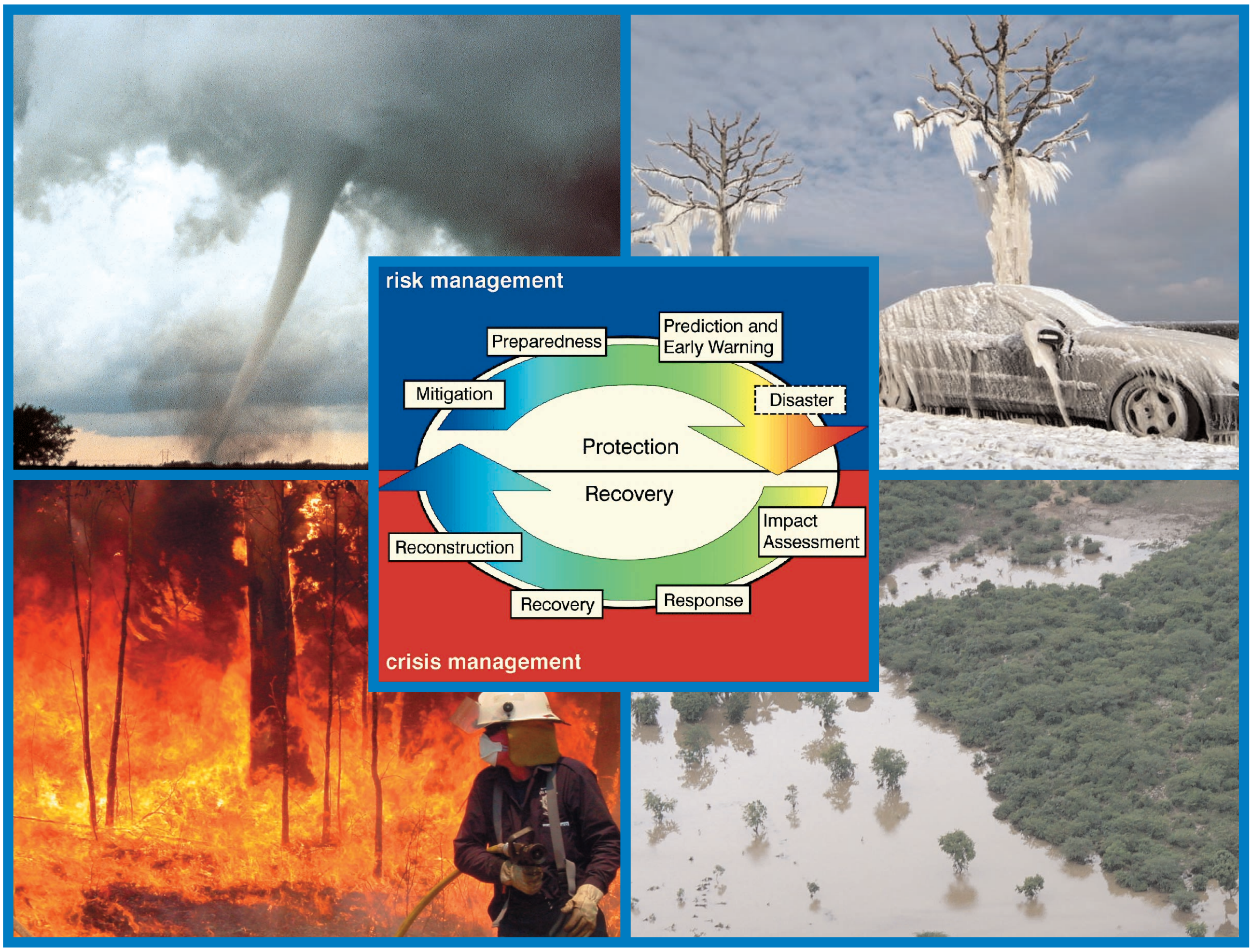

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Figure of Risk Management vs Crisis Management
Courtesy of: Donald Wilhite (2000)

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NOTE

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Chapter 1
INTRODUCTION

During the ten-year period of 1992-2001, weather-related disasters worldwide killed over 622,000 and affected over 2 billion people (WMO, 2004). In 2004, Japan saw a record year for typhoons, with ten tropical cyclones making landfall, two within ten days. Tokage was the most powerful typhoon to hit Japan in 16 years. The year's number of tropical cyclones in Japan surpassed the previous record of six set in 1990 and left the largest number of people dead (some 220) and injured since 1983 (MeteoWorld, 2004). A related disaster was the corresponding lack of rainfall in the same season in China resulting in widespread drought resulting in the migration of birds carrying the avian flu virus to populated areas.

In the same year, United States was severely affected by four hurricanes making landfall in Florida, with five other hurricanes of different intensities making landfall elsewhere along the US coastline (National Hurricane Centre/Tropical Prediction Centre, 2004). The last time with such frequent tropical cyclone activity was in 1916 when eight hurricanes impacted the US coastline. Total damage in 2004 as a result of tropical cyclone landfalls could approach 50 billion US dollars (Colorado State University News, 2004). Charley brought death and destruction to the Caribbean and Florida. Damage to property in Cuba was in excess of 1 billion US dollars. Preliminary estimates of Charley's damage in Florida ranged from 13 to 15 billion US dollars, making it the second costliest hurricane in the US history. Then came Ivan, the most powerful hurricane to hit the Caribbean in ten years. Following a trail of havoc across Grenada, Jamaica and Alabama, Ivan left in its wake more than 100 deaths and property damage estimated at 12 million US dollars. Jeanne, weaker but no less deadly, swept along the north coast of Haiti on 16 September, killing more than 2,000 people and destroying the country's economy.

The South Pacific islands also had their share of weather-related disasters. In the austral summer of 2002-2003, a powerful tropical cyclone Zoe impacted a number of remote island communities in the Solomon Islands and caused significant economic loss. This was followed in 2003-2004 by another intense tropical cyclone Heta that left a trail of utter devastation through the small island nation of Niue. The economic loss at Niue was so great that the continuing viability of the country came into question, with survival possible only through international aid. In early 2005, the Cook Islands in the Southwest Pacific were affected by four intense tropical cyclones (Meena, Nancy, Olaf and Percy) causing significant damage being reported.

On the morning of Sunday, 26 December 2004 a magnitude 9.3 earthquake, the world's most severe in 40 years, ripped apart the seafloor off the coast of northwest Sumatra. It unleashed a devastating tsunami that swept thousands of kilometres across the Indian Ocean, taking the lives of some 300,000 people in countries as far apart as Indonesia, Thailand, the Maldives, Sri Lanka and Somalia, making it the deadliest in recorded history. Those hardest hit were the people living in low-lying coastal areas. Beyond the loss of human lives, the tsunami also destroyed livelihoods, traumatized whole populations and severely damaged habitats. The scale of the disaster shocked the international community and the United Nations (UN) made a "Flash Appeal" immediately after the event to raise funds to support relief and recovery operations. While attention was understandably drawn towards this tsunami and its aftermath in south Asia, the impact caused by the perennial threat of global severe weather should not be under-estimated.

The latest event at the time of writing these guidelines was category 5 hurricane Katrina, which struck the Gulf coast of the United States in August 2005 causing many deaths and estimated economic losses in excess of US$100 billion, the largest loss on record resulting from a single weather-related event. Between 1998 and 2002, 45 weather-related disasters in the United States caused damage with a total cost of approximately US$200 billion.

The dramatic impact of natural disasters and the subsequent response activities often attract much international interest. Attention is being increasingly focused upon natural disasters inflicting tremendous economic losses (in addition to human suffering and casualties) and the efforts expended on the mitigation and reduction of such disasters. Disaster mitigation is now a recognized international priority. WMO cooperates within many other organizations and international programmes, particularly the International Strategy for Disaster Reduction (ISDR), in its efforts to improve natural disaster prevention and mitigation. The UN Secretary General, Mr Kofi Annan, recommended in his report to the General Assembly on 21 March 2005 the establishment of a global early warning system for all natural hazards. Increasingly it is recognized that disasters are linked. The impacts of many types of natural disasters do not happen in isolation, but are sequential (Rogers 2005). For example, a drought in one region followed by famine can be exacerbated by dust storms transporting locusts spawned by heavy rains in another location. Similarly, the diversion of moisture from one region to another causes flooding in one region and drought in another. The recognition of such cause and effect on a global and regional scale is leading to the creation of early warning systems that can accommodate multiple hazards and cross-boundary impacts. At the same time, governments are becoming aware that a paradigm shift from crisis management to risk management is necessary if the finite resources available are spent in the most efficient way to assist the populations at risk to prevent or mitigate disasters.

The Public Weather Services Programme was given the mandate by the WMO Commission for Basic Systems to produce disaster risk management guidelines for National Meteorological Services and National Meteorological and Hydrological Services (hereafter NMSs). These guidelines on "the application of risk management principles in the provision of severe weather warnings, and the use of this approach in efforts to secure extra funding from innovative sources" are prepared with the central purpose of recommending a risk management action plan suitable for adoption by NMSs. They are not meant to be an exhaustive treatise on disaster risk management. There is already a wealth of literature on this subject and relevant documents are referenced here. The intention is to promote the role of NMSs in disaster risk management, to encourage their more proactive involvement, and where appropriate lead in developing and implementing a risk management action plan. Effective risk management is often the difference between a natural hazard and an impact disaster.

Risks can be characterized as being a complex combination of unavoidable, acceptable and treatable circumstances. Having identified and evaluated risks, a decision must be made as to what level of risk is acceptable, and at what level a risk is to be treated. Increasingly, this is being discussed in terms of consequences of the event and cost effectiveness of the treatment. These guidelines relate to the various risks that are considered treatable or manageable in the context of the provision of severe weather warnings. They are prepared with due reference to the outcomes of various Disaster reduction conferences, workshops and seminars held around the world in recent years, including:

(i) 1st World Conference on Natural Disaster Reduction held in Yokohama, Japan in 1994;
(ii) 1st International Conference on Early Warning – Potsdam, Germany – 1998;
(iii) Risk Management and Assessments of Natural Hazards Forum – Washington, USA – 2001;
(iv) 2nd International Conference on Early Warning – Bonn, Germany – 2003;
(v) Workshop on Early Warning Systems – Shanghai, China – 2003;
(vi) 2nd World Conference on Natural Disaster Reduction, Kobe, Japan 2005.

It is noted that the 3rd International Early Warning Conference will be held in Bonn, Germany in March 2006.

Chapter 2
EXPLANATION OF KEY CONCEPTS

Issuing weather forecasts and warnings is a core business for NMSs. Most of the time, NMSs focus on the application of science. In fact, one of the great achievements of meteorological science and technology during the 20th century has been our increased ability, through improved warning and forecasting systems, to provide much more reliable weather information for effective protection of life and property from natural hazards. However, in an information age with higher public expectation, more intense media coverage as well as much closer connection with the global community, NMSs can no longer afford to play a passive role in disaster reduction and mitigation effort. It is just as critical for NMSs to be actively involved in disaster management programmes to ensure that the users get the full benefit of reliable forecasts and warnings.

It is important therefore not just how we forecast a natural hazard but how we plan for and minimize the impact of the hazard. In the context of the current guidelines, a natural hazard is a weather or flood-related situation with potential to inflict loss or damage to the community or environment. A **natural disaster** is a catastrophic event caused by a natural hazard that severely disrupts the fabric of a community and usually requires the intervention of government to return the community to normality. While hazards may induce a crisis, they do not necessarily lead to disasters. Though most natural hazards may be inevitable, natural disasters are not totally unavoidable. A disaster will depend on the characteristics, probability and intensity of the hazard, as well as the susceptibility of the exposed community based on physical, social, economic and environmental conditions.

In some instances, natural disasters cannot be prevented from occurring. However, their overall impact can be significantly reduced through **disaster mitigation**. Disaster mitigation is the process of managing the "risks" associated with potential natural disasters so that loss may be minimized or even eliminated. This includes the **disaster response** which are actions taken in anticipation of, during and immediately after, a natural disaster to ensure that its effects are minimized, and that people affected are given immediate relief and support. A systematic approach should be taken to manage the risk of natural disasters. This process of **disaster risk management** should consider the likely effects of natural hazards and the measures by which they can be minimized. A disaster risk management system should incorporate response actions that are appropriate to the social and economic conditions of the community under threat. Because of this, disaster reduction has become increasingly associated with practices that define efforts to achieve sustainable developments.

The concept of **disaster risk** is used to describe the likelihood of harmful consequences arising from the interaction of natural hazards and the community. Two elements are essential in the formulation of disaster risk: the probability of occurrence of a hazard, and the vulnerability of the community to that hazard.

Risk = Hazard Probability x Vulnerability

A closer look at (a) the nature of hazards and (b) the notions of vulnerability allows for a better and more comprehensive understanding of the challenges posed by disaster mitigation:

(i) Nature of hazard - By seeking to understand hazards of the past, monitoring of the present, and prediction of the future, a community or public authority is poised to minimize the risk of a disaster. The NMSs play a key role in this aspect of risk management of weather-related natural disasters.

(ii) Notions of Vulnerability - The prevailing conditions within any group of people in a society can determine the extent of their susceptibility or resilience to loss or damage from a natural hazard. The community vulnerability is the susceptibility and resilience of the community and environment to natural hazards. Different population segments can be exposed to greater relative risks because of their socio-economic conditions of vulnerability. Reducing disaster vulnerability requires increasing knowledge about the likelihood, consequences, imminence and presence of natural hazards, and empowering individuals, communities and public authorities with that knowledge to lower the risk before severe weather events, and to respond effectively immediately afterwards. Increasing this knowledge depends on focusing science and technology investment to improve disaster mitigation and resilience by identifying and meeting needs and closing knowledge gaps wherever possible.

As the decade progresses, a broader global awareness of the social and economic consequences of natural disasters has developed highlighting the increasing importance of engaging a much broader community in hazards awareness and risk management practices. The importance given to socio-economic vulnerability as a rapidly increasing factor of risk in most of today's societies underlined the need to encourage the participation of wide spectrum of **stakeholders** in hazard and risk reduction activities. Stakeholders are those people or organizations who may affect, be affected by, or perceive themselves to be affected by, a decision or activity. Stakeholders can include governments, delivery agencies, private sector and the public. In developing a disaster risk management system, no single agency can provide a fully comprehensive solution. It is essential that agencies work together and with stakeholders to narrow knowledge gaps and to develop disaster risk management plans using a coordinated approach.

Chapter 3
RISK MANAGEMENT PHILOSOPHY

The devastating effects of natural disasters can quite commonly be associated with inadequacies in a community's development strategy. Poorly planned development turns recurring natural hazards into disasters. Housing a dense population on a flood plain or permitting poor building codes in cyclone-prone and earthquake-prone areas aggravate not only the vulnerability of the exposed communities but also increase the losses due to natural hazards. Wilhite (2005) has taken the commonly accepted cycle of disaster management and redefined it in terms of crisis management and risk management. Crisis management emphasizes post disaster impact assessment, response, recovery and reconstruction; whereas risk management emphasizes protection through mitigation, preparedness, prediction and early warning. Traditionally, the focus of disaster management has almost been exclusively on actions taken *immediately* before, during and shortly after a disaster. While many governments nowadays still employ reactive crisis management, rather than proactive risk management, approaches to disasters, the tide appears to be turning.

There is no doubt that the role of relief assistance during a crisis will remain important and need to be enhanced at all levels. However, the question must be asked: "Can we afford to value lives and properties only after they have been lost in a disaster?" Much greater attention will need to be given to preventive strategies that can contribute to saving lives and protecting assets before they are lost. In fact, a paradigm shift is occurring with a move away from reactive response and recovery to a much more proactive and holistic concern with preparedness and prevention. There is now an increased emphasis placed on risk management rather than crisis management, and an acceptance that natural disasters, development problems and environmental issues are inextricably linked. Instead of diverting resources away from ongoing projects through budget re-allocation in order to finance recovery and re-construction efforts, proactive mechanisms are sought to reduce the economic costs and impacts of hazards, improve the countries' response capacity, decrease vulnerability and enhance communities' resilience to disasters.

Responses to warnings on natural disasters/hazards generally involve making decisions based on calculated risks and uncertainty. Although safety assurance of life and property is a common ideal underlying all warnings, we have to accept that risks can never be totally eliminated. Thus risk management generally involves the challenging task of minimizing threats to life, property and the general environment, yet at the same time without creating unnecessary disruption and chaos to the communities likely to be affected by natural disasters/hazards.

With this new philosophy of risk management, countries will need to develop policies that focus on the importance of taking appropriate preparedness and prevention measures. Through such measures, the overall impact of natural hazards can be significantly reduced:

(i) improved scientific understanding of the range of natural hazards that can occur and their potential to occur at specific locations (hazard/risk mapping on a firm scientific basis);
(ii) improved understanding of the cost implications of the above hazards;
(iii) better design and construction of buildings, bridges and other structures (including flood plain management) to reduce the risk of damage during a severe weather or flood event;
(iv) increased community awareness through public education of the impacts of natural hazards and the measures individuals can take to reduce damage and protect life;
(v) improved technology and modelling effort to extend the lead time for warnings of potential natural hazards; and
(vi) integrated risk management approach, treated as a total package instead of separate components.

Among the measures mentioned, NMSs would be involved to a greater or lesser extent. But in all aspects of risk management, effective communication with stakeholders, especially the public, is vital. A community at risk to a natural hazard will not be prepared to meet it if the general public is not well informed. Communication of mitigation and preparedness measures can transform a community's readiness to face an extreme event. Effective communication is especially critical immediately before, during, and after a hazard event to ensure the public has adequate warnings and complete information to maximize public safety. Ultimately, the messages must also be understood and acted upon by those communities at the greatest risk, including the disadvantaged people.

As such, severe weather warning systems must be viewed as an integral element of long-term strategies in the sustainable development for a safer and more adaptable community. Such systems thus constitute an essential and highly cost-effective component of national strategies and must be properly embedded and integrated in national risk management programmes. Building on this foundation, there is inevitably a need to ensure that severe weather warnings of natural hazards becomes an integral part of government policy in every disaster-prone country, and it also follows that NMSs need to be recognized as a major component of the corresponding infrastructure in support of risk management and disaster mitigation.

With continuing scientific and technological developments, there is a growing expectation that forecasters will be able to warn at longer lead-times, and with more emphasis or greater accuracy regarding the 'where', 'when' and magnitude of an impending natural hazard. While the advances and successful applications of weather warning systems are most encouraging, the common pitfall is to over-emphasize on the technical details and under-state the practical implications for the communities exposed to the hazard. In the communication process, not only should the communities be adequately informed, but also they should be sufficiently impressed that preparedness actions are taken before and during the anticipated hazardous event. Warning messages must convey to an often-sceptical public that they are vulnerable, that the danger is real, and that specific measures can be taken to protect themselves and their property. Messages must also consider the target audience, making provisions to reach high-risk areas and to overcome language barriers in diverse populations.

In the spirit of an integrated risk management approach, the multi-discipline and multi-sector nature of the warning process must not be overlooked. Although based on scientific and technology, warnings must be tailored to serve users' needs, with due consideration given to their situations and available resources. While severe weather warning capabilities must continue to be strengthened at the global level, it is just as important that enough emphasis should be given to developing capacities that are relevant, and responsive to, the needs of local communities. Fundamental to the process is the existence of a Risk Management Action Plan, which is the subject of discussion in the next chapter.

Chapter 4
NMSs' RESPONSIBILITIES WITHIN A RISK MANAGEMENT FRAMEWORK

Disaster risk management consists of three broad activities: mitigation, preparedness, and early warning. Mitigation includes risk reduction; preparation includes risk assessment, risk analysis, hazard identification, research and development, public education and outreach; whereas early warning consists of hazard forecasts, communication and dissemination. NMSs contribute to risk management in three ways: The first is to provide early warning of weather, water and climate hazards for operational decisions; the second is to support risk and impact assessments to determine who and what is at risk and why; and the third is to improve forecasts and analyses to help reduce or remove risks (Rogers 2005).

The following sections provide a framework for NMSs to consider in developing and implementing a Risk Management Action Plan in partnership with other agencies and organizations involved in risk management. This framework focuses on the role of the NMS in developing and executing the Risk Management Action Plan with regard to severe weather warnings, but acknowledges the ultimate Risk Management framework should also address non-weather hazards and draw expertise from many other partners. Some NMSs may have implemented some or most of these elements in a Risk Management Action Plan; where that is true, the framework may prompt these countries to increase or enhance their efforts.

4.1 CORPORATE CULTURE

For meteorological hazards, the NMS is the sole warning authority for its citizens. NMSs are the experts on the meteorological aspects of severe weather hazards, and are therefore a critical player in the development of the country's risk management plans.

The NMS must be a credible authority for information on severe weather warnings and has a reputation for accuracy, reliability, and timeliness. It is also increasingly recognized that NMSs need to develop a corporate culture of being caring and people-centred, in addition to the more traditional culture of being professional and science-centred. Developing working relationships with partners such as emergency managers and the media (see section 4.3) and involving stakeholders in the development and review of the warning system (see section 5.1) is essential.

Many NMSs are now emphasizing a user-centred approach to improving their products and services, in addition to the traditional science-oriented approach. Some examples of a user-centred approach are:

(i) plain-language descriptions that are clearly understood by the public in weather bulletins and outreach material about the hazards and warnings;
(ii) making observations, forecasts, and warnings available in real-time on the Internet;
(iii) frequent updates of the latest information, even if nothing is new; and
(iv) distributing purposely designed educational and outreach material to educate stakeholders about severe weather events, the associated risks, and actions to take in advance of, during, and after the event.

4.2 CAPACITY BUILDING

In support of an effective severe weather warning system, it is vital that NMSs secure the necessary financial and personnel resources for:

(i) ongoing maintenance and improvement of the national meteorological observation infrastructure;
(ii) pure and applied research – both meteorological and in other disciplines associated with risk management (most likely through partnerships and collaboration);
(iii) ongoing training for NMS staff, partners, and stakeholders;
(iv) public education and awareness; and
(v) development of technical, operational, and dissemination capabilities.

NMSs should ensure that:

(i) the capacity building of their severe weather warning specialists is high on the agenda;
(ii) the operational procedures are sound; and
(iii) the communication mechanisms and systems are robust.

Training should not be limited to NMS staff, but must also include partner agencies as well as communities at risk. For example, in the United States, the National Weather Service (NWS) works with the Federal Emergency Management Agency (FEMA) to develop and teach emergency managers how to use NWS product and services, using resident and distance-learning components:

(i) Hazard Weather and Flood Preparedness;
(ii) Warning Coordination;
(iii) Partnerships for Creating and Maintaining Spotter Groups; and
(iv) Hurricane Planning.

NMSs also need to allocate sufficient resources to develop a knowledge base for the effective provision of severe weather warnings. Examples of such initiatives are:

(i) sponsor or conduct applied research regarding the severe weather hazards of their country;
(ii) maintain a historical database of past severe weather events;
(iii) support the production of hazard risk assessments; and
(iv) play an active role in the development of a risk management plan for their country for regional and local applications.

NMSs and other agencies involved in risk management planning should establish collaborations and methods for effective exchange of information among relevant hazard databases to facilitate monitoring, assessment, and prediction.

4.3 DEVELOPING PARTNERSHIPS

The design and operation of severe weather warning systems, and on a larger scale, the risk management plan, must be based on a commitment to cooperation and information exchange and the concept of partnership in the overall public interest. The benefits of such partnerships include:

(i) drawing expertise from a wide range of disciplines, such as social science, community planning, engineering, etc.;
(ii) accomplishing tasks that cannot be managed by a single agency or organization;
(iii) demonstrating to government budget planners a commitment to work together towards a common goal and making better use of scarce financial resources;
(iv) leveraging resources for research, awareness, preparedness, etc.;
(v) sharing costs, knowledge, and lessons learned;
(vi) ensuring a consistent message (the warning bulletins and other outreach material) from multiple credible sources; and
(vii) yielding wider distribution of the message through multiple outlets and receiving feedbacks from a whole range of users.

To identify and evaluate the weather information needs of the users, NMSs need to build relationships and work in partnership with users in both the public and private sectors. NMS partners include:

(i) other government agencies with missions involving the protection of life and property, such as the NHS where that is a separate agency from the NMS, national, regional or local emergency management agencies, first responders, infrastructure managers (dams, highway departments, bridges);
(ii) the media;
(iii) non-government organizations;
(iv) emergency relief organizations, such as the Red Cross and Red Crescent Society;
(v) academic institutions and schools;
(vi) trained volunteers associated with the NMS, such as cooperative observers, storm spotters, and amateur radio operators;
(vii) meteorological societies and other professional associations in risk management disciplines;
(viii) private sector weather companies, and
(ix) utility services, telecommunication operators and other operation-critical or weather-sensitive businesses.

A typical partnership would involve disaster, warning, and risk management experts from government, business, academia, non-government organizations such as the Red Cross and Red Crescent Society, as well as emergency management officials to agree on warning standards, procedures, and systems. An example of this is the Partnership for Public Warning in the United States. More discussion and examples of partnerships can be found in Section 5.1, Stakeholder Involvement, of this document, as well as the WMO document PWS-8, Guide on Improving Public Understanding of and Response to Warnings.

4.4 PUBLIC EDUCATION & AWARENESS

Public education and awareness programmes need to focus on the NMS's severe weather warning systems, the hazards, the vulnerability and appropriate responses. The goal of effective public information materials and programmes should be to ensure all those who are potentially at risk fully understand the nature of the threat and the appropriate action to take at various stages as the threat develops and disaster strikes (Zillman, 2004).

Working with partners can enhance the effectiveness of education and outreach efforts and spread the cost of development and printing among several groups. In addition to printed material, the same information should also be made available electronically via the Internet, and in alternative languages for different ethnic groups or in formats that are accessible to people with disabilities.

Educational and outreach material should highlight scientific capability, hazard awareness, risk, and preparedness. The effectiveness of brochures and educational material can be increased if they follow a similar format, featuring sections such as:

(i) a description of what causes the weather hazard;
(ii) a map highlighting areas of the country vulnerable to the hazard;
(iii) historical information about major events of this type of weather hazard in the country;
(iv) definitions of terminology associated with the hazard;
(v) how to anticipate and monitor the hazard in one's own situation;
(vi) measures that individuals and communities can take in preparation for the occurrence of hazard;
(vii) recommended actions to take before, during, and after the event;
(viii) how to stay informed during the event;
(ix) contacts for more information; and
(x) contingency measures in the event of a disaster (for the family, the community, the business, etc.).

Even the selection of graphics and photographs is significant. Rather than images of destroyed structures, social scientists recommend including pictures of people taking the proper actions in preparation for and during the event, such as people boarding up windows, heading to a storm shelter, shopping for items in their emergency supplies kit, etc.

NMSs should support hazard awareness education in schools by contributing to the development of educational material for teachers and students. In educating the students, the messages are also brought home to their families and neighbourhood as well.

The WMO document PWS-8, *Guide on Improving Public Understanding of and Response to Warnings*, includes more discussion and examples of public education and awareness initiatives.

4.5 ESTABLISHING A KNOWLEDGE BASE

One must have relevant knowledge and information in order to properly understand the hazard and vulnerability. At the same time, the value of local knowledge, community "memory", and relevant experience during past events should not be overlooked. Furthermore, knowledge and information is central to almost every aspect and every stage of natural disaster risk management. It is essential for assessing risk and potential vulnerability in the earliest stages of community planning for construction of new facilities (such as dams, bridges and population centres) or for individuals planning to move to new locations (such as beaches, flood plains and mountain sides). NMSs therefore need to allocate or secure sufficient resources for the development of an adequate knowledge base for the effective provision of severe weather warnings. The knowledge base shall consist of (i) risk databases, (ii) risk assessments, (iii) cost-benefit analyses, and (iv) research activities. These will be discussed in turn in the following sections.

4.5.1 Risk Databases

Information that is most vital in the early stages of sound risk management consists of the full suite of climatological data and products, including model studies of extreme events, that will enable the potential natural hazard to be accurately characterized (e.g. through hazard maps) and the necessary decisions on siting, construction, protection and precaution to be taken on a fully informed basis.

Information is essential when natural hazards threaten and when communities prepare to withstand the potential onset of disaster; and it is often even more essential in the critical post-disaster recovery phase when affected communities are shattered and confused, when fear of the unexpected is greatly heightened, and when relief authorities need to know everything that is going on to enable them to manage the complex mix of issues involved in restoring essential facilities and in meeting the physical or social needs of devastated communities.

Effective risk management of and preparedness for natural hazards require free and unlimited access to relevant databases to facilitate monitoring, assessment, and prediction. It is recommended that all agencies responsible for these databases develop good collaborating links for the exchange of information included in the databases.

Communities and civic authorities need to know the nature, severity and likely return periods of all kinds of potential hazards. One of most important sources of information is still the careful analysis of records of what has happened in the past. In this regard, meteorological databases (including warnings and climate databases) contain information relating to natural hazards of a meteorological origin. On the other hand, disaster databases in general contain information largely driven by economic and financial considerations such as insured or un-insured losses, but often with very little emphasis on information relating to the weather and climate conditions at the time of the disaster event. There is a growing recognition that in order to effectively assess the vulnerability and risks involved, analysis has to be done based on information drawn from both types of databases. At present, there is no easy means of integrating or cross-referencing such data and information for completing an adequate risk analysis. More research on the effective application of these data and information is therefore required.

4.5.2 Risk Assessments

Risk assessment requires a "by the people, for the people" mindset. Risk is the outcome of the interaction between a hazard phenomenon and the elements at risk within the community (e.g. the people, buildings and infrastructure) that are vulnerable to such an impact.

Each hazard likely to impact upon a community can be systematically analyzed in this fashion. The vast majority of information, relationships and processes involved in understanding risk are spatial in nature. Graphical Information Systems (GIS) are especially useful for this purpose.

In risk assessment, one has to consider the probabilities of hazardous events affecting the community and the consequent harm to the community. Probability is a concept and skill that most people have problems with understanding, as many cannot handle statistical concepts or effectively factor probabilities into their decision-making. More research is needed to help describe how low probability/high consequence events (such as an impact by a very intense cyclone) affect the community's mitigation desires and actions.

4.5.3 Cost-Benefit Analyses

General Principles

We will never be in a position to reduce hazard-induced losses to zero. The measurement of how much reduction is achieved is usually referred to as the Loss Avoided (**La**). Against this, there will be an attributable cost in providing warnings and taking preventive actions, called Cost of Prevention (**Cp**). The ratio, Σ**La**/Σ**Cp**, gives a simple but effective Benefit Cost Ratio (**BCR**). Clearly we need to aim for as high a value as possible. The **BCR** can be used to:

(i) support investment proposals to improve disaster prevention and mitigation, and
(ii) prioritise work programmes and financial investment.

Understanding of the Benefit Cost Ratio (**La**/**Cp**) allows us to make effective use of probability forecasts.

Calculation of BCR

In practice it is difficult, even impossible, to get an accurate measure of **La**. However, this should not deter attempts to do so with varying levels of sophistication. In a rudimentary approach, a subjective value can be derived by making estimates of:

(i) number of people or organisations receiving a warning;
(ii) percentage of recipients taking action;

(iii) effectiveness (average cost saving) of these individual actions;
(iv) frequency of the phenomena and accuracy of forecasting.

In addition, in cost-benefit analyses, a nominal monetary value to human life saved and a surrogate value for public or political goodwill are sometimes assigned. This valuation is merely a matter of convenience and does not mean a judgement on the intrinsic value of lives. Any other common measure of value would, in principle, do equally well.

Cost of prevention, **Cp**, is usually easier to measure or more accurate to estimate. A decision has to be made as to whether to use full or marginal costs. Marginal costs are those attributable to taking mitigating actions such as extra manpower and resources (for example from emergency authorities) to reduce losses and save lives.

It follows that there needs to be detailed discussions with other stakeholders in order to derive **Cp** and **La**. The strive for higher **BCR** is more likely to attract extra funding for capacity building leading to improved effectiveness of severe weather warnings. Often it will be found that efforts to improve response to warnings, rather than a higher accuracy of forecasts, offer the most economical way of improving the **BCR**. This again highlights the need to work closely with professional partners in designing a risk management plan and in bidding for funds.

Probabilities and Consequences

In trying to forecast a severe weather event, we are dealing with extreme events and thus working within the tail-end regime of a statistical distribution. The main issue is the societal impact caused by the weather, i.e. amount of damage, disruption, economic loss or number of deaths. These factors usually increase exponentially with an increase in the severity of the phenomena.

From a risk management viewpoint, it will be more valuable to deal with the probability of various thresholds being exceeded. Unfortunately our professional partners (and the public) are generally not well versed in the use of probability forecasts as a decision making tool.

Correct and accurate use of probability forecasts means that, given a large sample, on average an event will occur at the same frequency as the forecast probability. For example, events assigned with a 50% probability will occur on half of the number of occasions they are predicted. Similarly, those assigned with a 10% probability should occur 1 in 10 times, and those with 90% probability on 9 out of 10 occasions. As such, the full BCR is only realised over a period of time. Therefore our partners must appreciate that they need management strategies that are different from those dealing with deterministic forecasts. In particular, the response must be commensurate with the risk involved.

As part of the partnership approach it is necessary to have a common understanding and use of thresholds. An example illustrating the use of probabilities of a severe weather event affecting the community in calculating BCR and the determination of threshold for decision making is described in Appendix A.

4.5.4 Research Activities

Every NMS, according to the available resources in qualified workforce and technical facilities, will currently perform some research activities in the fields of meteorology, climatology, hydrology, oceanography, or even seismology. An important part of these efforts is the understanding and prediction of hazards. Storing and updating the results of such research activities is a fundamental requirement for any scientific approach for risk management planning of hazards.

An aspect, which probably deserves more attention, is the benefits that may be derived from international collaboration of research activities, through networking of institutions or individual scientists. A primary motivating factor is that the understanding of physical processes in the atmosphere often requires full scale field experiments to gather data and information; and such efforts are usually out of the reach of individual scientists, a single NMS or even national consortia of research institutions in many countries. A good example is the progress made in the understanding of Atlantic storms after FASTEX (Fronts and Atlantic Storm-Track Experiment) (Browning et al, 1999). This has lead to the development of the decade long WMO research project THORPEX (The Observing System Research and Predictability Experiment), which is addressing the use of ensemble forecasts and targeted observations to improve early warning of hazard weather (Shapiro and Thorpe 2004).

International cooperation among meteorologists and other scientists in different fields is also an effective way of securing funding and support from international institutions. For example, the five-year cycle of the R&D programmes of the European Union, which various European meteorological services contribute to and get funding for, contains components that directly address the hazard risk management issues (e.g. GMES (Global Monitoring for Environment and Security)).

Another related structure, different but related to the European Union and is more of a networking mechanism, is the European Cooperation in the field of Scientific and Technical Research (COST) organisation. It is well known that the origin of the European Centre for Medium-range Weather Forecasting (ECMWF) is to be found in a COST action decided 30 years ago. More recently, actions in the domains of nowcasting, urban pollution, radar techniques and waves modelling also provide the international community with valuable results and deliverables (exchange formats, data bases, tested algorithms, etc.) (further details can be found in http://www.cordis.lu/cost/home.html). The fact that the COST approach is "bottom up" (i.e. actions initially proposed by individual scientists) and multi-disciplinary is a great advantage; at the same time, there are also effective coordination and controls ("top down") by national representatives that look after users' interests and ensure productive outcome of the actions. Eventually, application programmes would be derived from such actions, currently funded by the European Commission of the European Union. In this sense, participation in COST can be an efficient leverage for obtaining much-needed funds for meteorological institutes to increase their knowledge base.

As already mentioned, a mere "natural sciences" approach is not sufficient. Risk management requires a combined multi-disciplinary approach because of the socio-economic, political and in some respects, psychological, dimensions involved in the formulation of policies and strategies. A workshop on early warnings held in Shanghai in 2003 noted (Glantz, 2003): "With regard to geological or hydro-meteorological hazards, the physical processes are either well understood or are under close scrutiny by scientific researchers. With regard to socio-economic and political processes, there is a heightened need to understand their roles in the conversion of a potential hazard into an actual disaster."

NMSs will increase their capacity to fulfil their role in a risk management plan when the results of such research activities in other specialized fields are integrated, to a greater or lesser extent, into their own knowledge base. Participation in multi-disciplinary seminars or colloquia dealing with natural hazards is necessary, but not sufficient. In building a real knowledge base, the mere exchange of results among meteorologists, hydrologists, sociologists, psychologists, media specialists is a good start but will probably still fall some way short of providing an overall approach and understanding of hazards in the context of attendant societal or economical problems. A recent prominent report on Risk Management in the USA notes: "In developing the nation's all-hazards approach to disaster vulnerability reduction, no single federal agency can provide a fully comprehensive solution. Agencies must work together to narrow programme gaps through a coordinated science and applications research agenda to pursue common solutions to common problems" (Executive Office of the President of the USA, 2003).

A conspicuous illustration of this may be derived from the lessons learnt from the deadly heat wave that hit Western Europe, especially France, during the first fortnight of August 2003. A comprehensive evaluation, from the risk management point of view, is to be found in Section 6.1.2. It has been publicly acknowledged that in such an occurrence, the collaboration and synergy between key stakeholders in the fields of meteorology, public health, and civil security have been very insufficient. As far as the research implications are concerned, it is clear that at the time there were available neither a comprehensive understanding of all the factors that resulted in such a catastrophe, nor in the aftermath adequate and detailed indicators that could have been of precious use for the authorities and the public (the cited Shanghai workshop noted: "The selection of indicators is very important, because monitoring will centre on them. The wrong indicators can lead to wasted time, effort and resources").

The predictions for the onset, duration and end of the heat wave by the relevant meteorological services were mostly correct and timely (as allowed by the state of the art) (Grazzini et al., 2003), but still quite general and insufficiently echoed by the media and relevant institutions. Taking the case of Météo France, its warning action (press releases mentioning the people at risk) was actually more efficient and reflected the user-oriented approach of Météo France. Yet only a few years ago, a bio-meteorological conference (Conseil Supérieur de la Météorologie, 2002) had correctly pointed out the deadly potential of such heat waves and roughly described its consequences. Nevertheless, it is now understood that the setting up of combined indicators for such events requires definitions and testing that can be achieved only through multi-disciplinary research into biological, demographical and sociological behaviours affecting the most vulnerable populations, as well as much needed precise documentation and understanding of the meteorological circumstances, not only minimum and maximum temperatures but also wind, humidity and air quality.

In France, these conclusions have led to formalized agreements between Météo France and two institutions in charge of public health. By the end of 2003 (see also Chapter 6), a first agreement was quickly set out to provide some new indicators, albeit on a provisional basis, with the operationally oriented "Institut de Veille Sanitaire" (Institute for Sanitary Watch). Another collaboration which is much more far-reaching was established in July 2004 with the medical research institute INSERM. According to the press release, it is due to enlarge and enhance the combined research on heat (and cold) waves and their impact on public health, with an aim to document and study in details the bio-meteorological mechanisms at much finer scales and over a longer period of 30 years.

In building up a comprehensive research basis for risk management planning, NMSs are advised to actively enter (according to their resources and/or those that could be provided by interested sponsors) into joint research agreements with other scientific institutions. This would normally imply the constitution of mixed research teams or the exchange of scientific missions; or to host post-doctorate researchers coming from different scientific horizons. In the medium to long term, the results of such research will prove to be of great use for the prevention and mitigation of complex hazards. The same cited American report (Executive Office of the President of the USA , 2003) lists as follows the research and development areas to be considered:

"- fundamental and applied research on geological, meteorological, epidemiological and fire hazards developments;
- application of remote sensing technologies, software models, infrastructure models, organizational and social behaviour models, emergency medical techniques; and
- many other science disciplines applicable to all facets of disasters and disaster management".

4.6 DISASTER RISK MANAGEMENT EXPERTISE

NMSs should give due consideration to gaining access (full-time or occasional) to risk management expertise to complement its core operations. As an example, the Australian Bureau of Meteorology has over the past few years established a cross-cutting disaster mitigation programme with the recruitment of a disaster management specialist. This programme supports the Bureau's severe weather warning services and works in partnership with various stakeholders throughout the community to ensure the application of risk management principles in the communication of severe weather warning information and related risk messages.

4.7 FORMULATING A RISK MANAGEMENT ACTION PLAN

Risk management provides structured systems for identifying and analyzing potential risks, as well as devising and implementing responses appropriate to their impact. According to the Secretariat of the ISDR (International Strategy for Disaster Reduction, 2004), disaster risk management focuses on three key areas:

(i) assessment of the risk factors present;
(ii) tools and practices to reduce the risks; and
(iii) institutional mechanisms to support both risk assessment and risk management.

It thus spans a wide range of methods and activities – assessment and analysis, public information, community participation, warning systems, policy and regulation, project impact assessment, education programmes, conservation practices and political processes. When advantage is taken of the mutual benefits achieved through adoption of a systematic integrated approach to the various activities, it is appropriately referred to as "integrated disaster risk management".

Risk management consists of a systematic process of assessing and dealing with risks. This process involves consideration of the context, followed by identification, analysis, evaluation, and treatment of risks. It is a repetitive cyclic process that also requires monitoring and review, and should include communication and consultation with stakeholders all along. The process of disaster risk management is shown schematically in Fig. 1. This process can be used in formulating the Risk Management Action Plan. The steps to follow are:

(i) <u>Communicate</u> and <u>consult</u> with stakeholders throughout the process;
(ii) Establish the <u>Context</u>;
(iii) <u>Identify</u> and <u>Quantify</u> the risks;
(iv) <u>Analyse</u> and <u>Evaluate</u> the risks;
(v) <u>Treat</u> the avoidable and manageable risks; and
(vi) <u>Monitor and Review</u> the Risk Management Plan.

Each of these steps will be discussed in detail in the following sections.

4.7.1 Step 1: Communicate & Consult with Stakeholders

Communication and consultation are important considerations at all stages of the process to ensure that stakeholders are involved. This is the first step in the disaster risk management process. Consultation is a two-way process that enables disaster risk managers to be aware of perceptions and to accept input to the process from stakeholders. Stakeholders will have perceptions of risks that can be useful in the risk assessment stages. In developing risk responses, it is also desirable to consider communication strategies for both internal and external stakeholders. Consultation ultimately aims at developing partnerships. Communication must be effective to ensure that those agencies and/or individuals responsible for implementing risk treatment measures are given sufficient information about the measures and the reasons for the adopted strategies.

4.7.2 Step 2: Establish the Context

The problem must first be defined by determining the nature and scope of the risk management project. This includes defining the community involved and the types of natural hazards to be addressed. A project management structure must also be established. A simple SWOT (strengths and weaknesses, opportunities and threats) analysis can be an excellent means in the initial consideration of the context of risk assessment.

4.7.3 Step 3: Identify & Quantify the Risks

In the world of natural hazards, there are many different ways of defining and quantifying risks depending on the intended purposes (e.g. for deciding what protective measures to put in place or what insurance premiums to charge). However, most definitions would include some combinations of:

(i) the nature of the hazard, including its severity;
(ii) the probability of its occurrence;
(iii) the exposure and vulnerability of human and natural systems; and
(iv) the numbers of people and the costs of the facilities at risk.

Risk identification is achieved by:

(i) identifying and describing the natural hazards – the sources of risk;
(ii) identifying and describing the community and its environment – the elements at risk;
(iii) determining the vulnerability – the balance between susceptibility (the level to which a particular natural hazard will effect a community) and resilience (the ability of a community to recover from the impact of a natural hazard); and
(iv) describing the risk.

The process of quantifying and mapping risks thus involves an integrated approach to the use of physical/geographical/environmental information in conjunction with both social and economic data, usually through integrated assessment models of various kinds.

4.7.4 Step 4: Analyse and Evaluate the Risks

Risk is analysed by determining the likelihood of a natural hazard occurring and the consequences of that hazard event. This is done in both qualitative and quantitative terms. The analysis considers community vulnerability and existing risk management measures with all assumptions clearly stated. The relationship between likelihood and consequences then enables the level of risk to be determined. The level is not an absolute level, but reflects a multi-faceted set of criteria that enables societal judgments on the risk to be made.

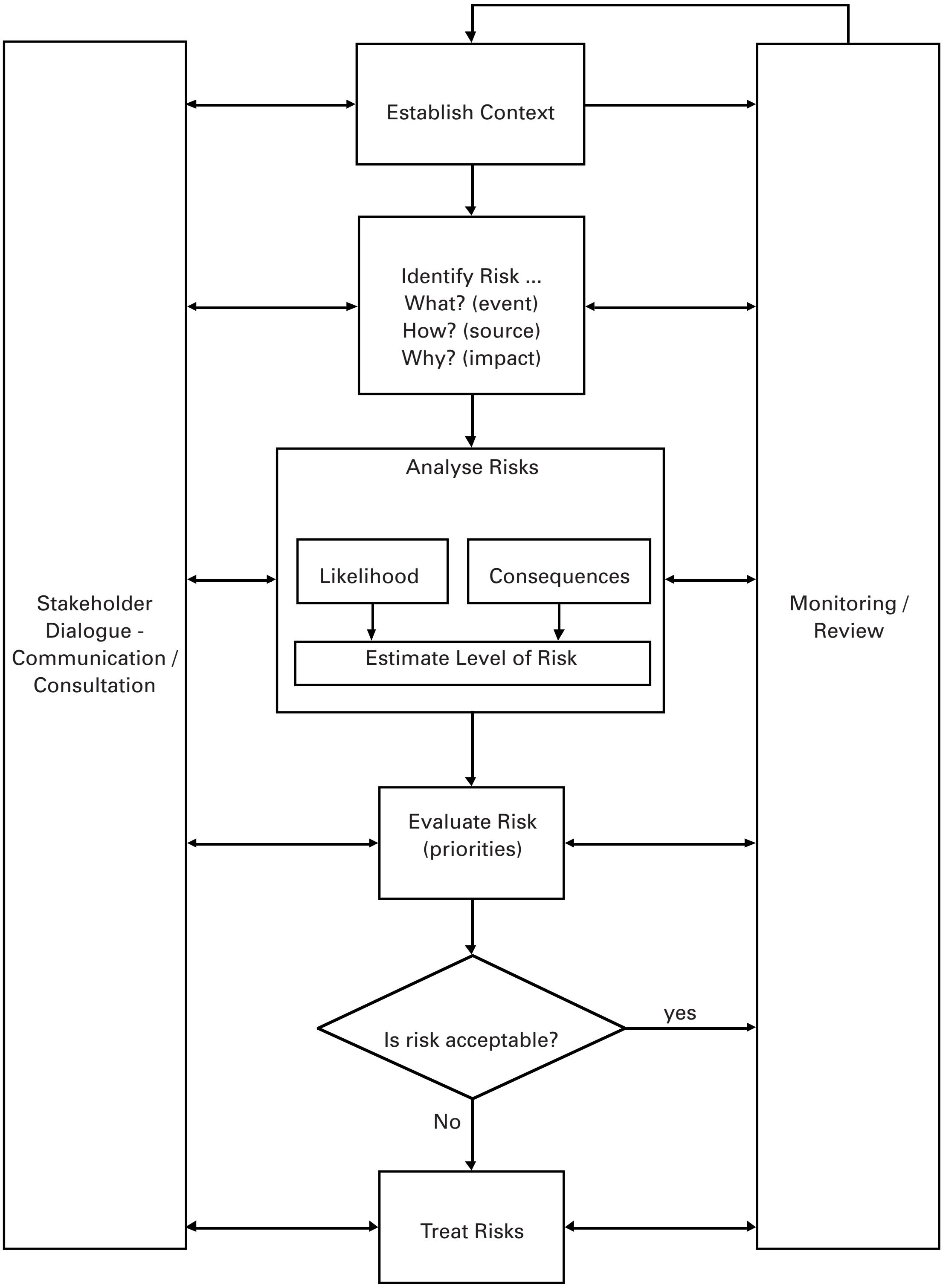

Fig. 1. The Disaster Risk Management Process

Risk is evaluated by comparing the risk evaluation criteria with the level of risk. This establishes the priority for the treatment of each risk and/or the acceptability of the residual risk. Acceptable risk is sufficiently low risk at a level that the society is comfortable with. A particular risk may be accepted when the cost of treatment is considered excessive compared to the benefit of the treatment. The process is achieved by consultation with all stakeholders and is subject to review and modification if required.

4.7.5 Step 5: Treat the Avoidable and Manageable Risks

Risk treatments are designed to reduce any or all of the vulnerability of elements at risk, the likelihood of risk occurring and the consequences of the event. The process involves identifying and evaluating options, selecting the most appropriate treatment(s), and planning and implementing the treatment programme(s).

The treatment of identified risks will almost certainly lie in technical innovation, personnel skills development and the ability to do both pure and applied research. There is a range of actions that can be taken to reduce the risk associated with natural hazards. These measures fall into four main categories:

(i) adoption of adaptive strategies such as temporary or permanent migration away from the areas of high risks;
(ii) education and awareness programmes for key stakeholders;
(iii) implementation of a works programme aimed at fortifying the infrastructure; and
(iv) adoption of diversified responses, such as a combination of the above measures along with land use planning, refined warning systems, and insurance incentives.

Formal reporting is an important phase of the risk management process. A Risk Management Action Plan is a helpful formal way to report on designated or major undertakings. It should summarize the results of the risk management process, action strategies and implementation framework. In particular, it should describe the risk response measures to be implemented to reduce and control risks. For major risks, risk action schedules should be prepared to assign individual responsibilities and time frames and to identify those who are responsible for follow-up. The Plan should also include provisions for implementation and ongoing reporting.

The most important task in risk management is implementing the Risk Management Action Plan and allocating management resources. This should be followed by monitoring the effectiveness of these measures over time (Step 6). Planning for implementation requires particular attention to be given to resources needed, management responsibilities and timing of tasks.

4.7.6 Step 6: Monitor and Review the Risk Management Action Plan

Risk is not static. It is therefore necessary to continually monitor the status of the risk being managed and the interaction of risk, community and the environment; and to review the risk management processes in place. Continual monitoring enables the process to dynamically adapt to changes in risk as well as changes in stakeholders' needs. The frequency of monitoring and the responsibility for conducting the review should be specified in the Risk Management Action Plan.

4.8 SECURING FUNDING

In planning and implementing the risk management programme, resources for ongoing training activities, public education as well as the development of both technical and operational capabilities are essential. Severe weather warnings are effective only to the extent that policy makers at national levels of authority have the will to make a sustained commitment of resources that establish and operate the required risk management mechanisms.

To obtain and maintain such resources, a collaborative approach to funding requests is more likely to be successful. If the NMS is able to join forces with partners, it not only adds influence and weight to the scope and substance of the proposed project, it also enables the politicians to consider the merit of the project in the context of the complete risk management picture, and not simply confining it to the narrow and more technical role of the NMS.

Presenting a well considered risk management plan is also a very significant step in soliciting funding from both national and international sources, such as the World Bank or the European Union. Weather and climate hazards have never been bounded by national boundaries; and in an increasingly globalized community with active information exchange and population movement, the impact of any severe weather events would be even more keenly felt. As such, NMSs need not be too inward looking in the search of possible funding options; sponsors with international interest may just as likely be prepared to contribute. A joint funding bid with key stakeholders or other NMSs in the region would inevitably broaden the horizon and hence enhance the likelihood of success. Sometimes, it may even lead to a larger funding allocation than a NMS working alone would otherwise have achieved.

Apart from international sponsorships and traditional sources such as the NMS budget, other appropriate funding alternatives can also be explored in connection with different components in the overall risk management plans. Collaboration with universities or research organizations is one such option through the utilization of research grants. Often, the academia can also offer the necessary expertise across a multitude of disciplines and provide a dedicated environment for research studies. This kind of collaboration is particularly rewarding for NMSs that do not have in-house capacity to undertake basic research and technology development. NMSs can also consider the possibility of securing funding through joint venture with other community or infrastructure projects, particularly those that are weather-sensitive and may require meteorological support for planning and operation; e.g. the setting-up of observation networks along highways or bridges, consultancy role in urbanization or conservation projects, forecasting and warnings services for recreational or major sporting events, etc.

As an illustration of what can be achieved, success stories of funding acquired from some innovative sources are presented in more details in Section 6.2.

Chapter 5
EFFECTIVE EARLY WARNINGS

Natural disasters can lead to extensive property damage, disruptions on social activities and loss of life. As noted in the Introduction, during the period 1992-2001, natural disasters worldwide have killed over 622,000 and affected over 2 billion people. While the figures have been high, it should be pointed out that they would have been even higher without pre-disaster efforts, particularly early warning systems, which contribute significantly to an effective risk management strategy.

The primary objective of a warning system is to empower individuals and communities to respond appropriately to a threat in order to reduce the risk of death, injury, property loss and damage. Warnings need to get the message across and stimulate those at risk to take action.

Effective inclusion of the severe weather warning system in a risk management plan relies on NMSs to appreciate the needs of a multi-cultural, economically stratified and often mobile community, and the community understanding the hazard, its vulnerability and the most suited protective action to take.

Greater focus towards disaster mitigation also means (Gunasekera, 2004):

(i) further increasing the emphasis on extending the lead time of warnings;
(ii) improving the accuracy of warnings at varying lead times;
(iii) satisfying greater demand for probabilistic forecasts;
(iv) better communication and dissemination of warnings;
(v) using new technologies to alert the public;
(vi) better targeting of the warning services to relevant and specific users (right information to right people at right time at the right place); and
(vii) ensuring that warning messages are understood and the appropriate action taken in response.

5.1 STAKEHOLDER INVOLVEMENT

Stakeholders need to be consulted as partners in the design and refinement of severe weather warning systems, and on the larger scale, the risk management plan. Stakeholders include the public, other national government agencies, emergency management agencies, local authorities, non-government organizations, the media, social scientists, national and regional infrastructure authorities, academia, etc.

Involving stakeholders in developing and enhancing the end-to-end severe weather warning system has many benefits, such as:

(i) improved presentation, structure, and wording of the warnings themselves;
(ii) more effective communication of the risks and actions to take in response to severe weather;
(iii) better understanding of how, and how often, stakeholders want to receive warnings; and
(iv) increased sense of ownership, and therefore, credibility in the warning system.

5.2 WARNING PRESENTATION

Effective warnings are short, concise, understandable, and actionable, answering the questions of "what?", "where?", "when?", "why?", and "how to respond?". The use of plain language in simple, short sentences or phrases enhances the user's understanding of the warning. In addition, the most important information in the warning should be presented first, followed by supporting information. Effective warnings should also include detailed information about the threat with recognizable or localized geographical references.

Warnings should be presented in several different formats – text, graphics, colour-coded categories, audio – and should include specific actions for people to take to respond to the event. The various formats also make it easier for people with disabilities to receive and act on the warnings. All formats, however, must present the information accurately and consistently.

The suggestions above are based on social scientist recommendations to structure the message to encourage the public to feel personally affected. For a more thorough discussion of warning presentation, see WMO document *PWS-8, Guide on Improving Public Understanding of and Response to Warnings.*

5.3 WARNING COMMUNICATION

Dissemination is delivery of the warning messages; but communication is accomplished only after the information is received and understood. So the foundation of warning communication builds on the format and wording of the warnings, dissemination methods, education and preparedness of stakeholders, and their understanding of the risks they face. Communication is also significantly enhanced when consistent warning information is received from multiple credible sources.

NMSs should ensure their severe weather warnings are communicated using a variety of formats (text, graphics, voice) and disseminated via as wide a range of media as is available (press, radio and television, e-mail, cell phone, Internet, etc.). Media broadcasts from the weather office and/or radio and television interviews with one or more authoritative figures can be effective in triggering response from people. These authoritative figures may be from the NMS (such as the NWS director or the manager of a local weather office) or a community leader (such as the governor or emergency manager).

The NMS should identify and designate the appropriate source of warnings and information from within the NMS structure for different types of risks occurring at different locations. For local hazards, the community is more likely to trust information from someone with a local knowledge of the area, rather than someone from a distant office who may not be as sensitive to the local needs.

Effective communication about risks and warnings requires knowledge about the recipients. In most countries, the public is very diverse, with different backgrounds, experiences, perceptions, circumstances and priorities. Any attempts to communicate with the public must reflect this diversity.

5.4 WARNING RESPONSE

Public education and awareness (section 4.4), stakeholder involvement (section 5.1), warning presentation (section 5.2), and warning communication (section 5.3) all contribute to an appropriate response to the warning.

The warning message by itself does not stimulate an immediate response from individuals. Individuals receiving the warning will first assess their own personal sense of risk. The additional information required before they take action depends on the content and clarity of the initial warning and the credibility of the issuing organization. The potential for individuals to respond appropriately is dramatically increased if they are provided with information to assist them in defining their personal risk and highlighting what life- or property-saving actions to take.

Two excellent references on warning systems and public response are Mileti and Sorenson (1990) and Mileti (1999). Their work is summarized below.

Successful warning programmes strive to ensure that every person or organization at risk:

(i) receives the warning;
(ii) understands the information presented;
(iii) believes the information;
(iv) personalizes the risk;
(v) makes correct decisions; and
(vi) responds in a timely manner.

An individual's perception of risk is enhanced if:

(i) warning messages before and during a particular event are issued and updated frequently;
(ii) warnings are delivered by multiple credible sources;
(iii) warning messages are consistent;
(iv) the basis for the warning is clear; and
(v) suggested response actions are included.

Preparedness prior to a hazardous event is critical to an effective response to the warning. Individuals, families, schools, businesses, communities and public facilities should have an advance plan in place, so they know what to do and where to go when a warning is received. The NMS and its risk management partners have a key role to play in educating their constituents in how to prepare a plan of action.

For a more thorough discussion of warning response, see WMO document PWS-8, *Guide on Improving Public Understanding of and Response to Warnings*.

5.5 MONITORING AND REVIEW

Verification and assessment of the warning services after a severe weather event are essential to measure performance, identify and correct deficiencies, and capture best practices, which can be shared with other parts of the NMS or with other risk management partners. In addition to quantitative measurement, objective assessment is also valuable. Interviews or surveys conducted with partners and stakeholders can yield significant insight into how products and services are received, interpreted, and what actions have been taken as a result of the warning. This feedback can then be used to make adjustments for similar future warning events.

Publishing verification scores and post-event assessments can add to the credibility of the NMS and, for stakeholders and partners, reinforce the perception of the NMS as being user-oriented and dedicated to the cause.

Chapter 6
SUCCESSFUL INITIATIVES OF NMSs

6.1 EXAMPLES OF SUCCESSFUL RISK MANAGEMENT INITIATIVES

The following sections describe initiatives by several NMSs using risk management principles to improve their warning systems. These examples provide practical applications of some of the principles summarized in these guidelines, and may trigger other NMSs to implement, expand upon, or create their own applications within their organization or country.

6.1.1 EXAMPLES FROM HONG KONG, CHINA

Hong Kong is a metropolis with over 6 million people and frequented by tropical cyclones and heavy rain. Tropical cyclones could bring gales or even hurricane force winds as well as torrential rain to the city. It is not uncommon to register more than 100 mm of rain a day in tropical cyclone or monsoon trough situations, causing landslips and flooding. The following examples illustrate how the Hong Kong Observatory, the NMS in Hong Kong, China, mitigates the impacts of these and other natural hazards.

Tropical Cyclone Warning Signal System as a Triggering Mechanism for Protective Actions Against Hazardous Weather

On average, six tropical cyclones affect Hong Kong each year. To mitigate the impact of tropical cyclones, Hong Kong operates a graded Tropical Cyclone Warning Signal System to warn the public of the threat of winds associated with a tropical cyclone. The System consists of five numbers representing increasing levels of wind strength. The Tropical Cyclone Signal No. 1 is issued whenever a tropical cyclone is within 800 km of Hong Kong and may affect the territory later. Signals No. 3 and No. 8 warn the public of strong and gale/storm force winds in the city respectively. Signal No. 9 signifies increasing gale or storm force winds, while No. 10 warns of hurricane force winds.

In view of the stringent building codes in Hong Kong, home is generally considered the safest place for people to take refuge from a tropical cyclone. When Signal No. 8 is issued, the Hong Kong Observatory advises the public to stay home or return home. Practically all activities in the city move towards shutdown. All schools, government offices, banks, the stock market, and courts are closed. Most public transport services will start to cease operation. When Signal No. 9 goes up, even the underground train stops. With Signal No. 10, the city grinds to a complete halt to prepare for the onslaught of a full-fledged typhoon.

However, the issuance of Signal No. 8 itself has the potential of causing chaos as millions of people try to go home all at once. To facilitate an orderly shutdown, a special announcement to the public (the Pre-8 Announcement) about the impending No. 8 is issued two hours before the actual issuance of the Signal. This enables transport operators to take measures to cope with the surge in demand for public transport and to allow the public to go home in a safe and orderly manner before the cyclone hits.

The tropical cyclone warning system has been in use for many years and the public is already familiar with it. Together with the well-coordinated response actions taken by relief agencies, the system has proved very effective in reducing the loss of life and property due to tropical cyclones.

Linking Rainstorm Signals to School Operation

Hong Kong is affected by severe local rainstorms, typically between April and September. The rainstorms can develop explosively with very intense rainfall. The instantaneous rainfall rates can exceed 300 mm/hr. Heavy rain, together with landslip and flooding, will lead to chaos, particularly during rush hours, in a densely populated city if the situation is not properly managed.

Since 1992, the Hong Kong Observatory operates a colour-coded rainstorm warning system which consists of 3 levels, namely: Amber, Red, and Black. The Amber signal is issued to give alert on potential heavy rain which may develop into Red/Black rainstorms. The Red and Black signals are issued to warn the public about the occurrence of heavy rain (50 and 70 mm/hr respectively) which can be hazardous and may result in major disruptions.

By the time the Red signal situation is reached, road conditions are considered unsuitable for students to commute between home and school. The issuance of the Red signal will trigger a series of response measures in relation to school operation. Prior instructions are given to school administrators, school-bus operators and parents on the actions to take. Students are advised to stay home if they have not left for school. For those on the way to or already at school, the schools will be open and have sufficient staff to take care of them until conditions are safe for them to return home. Classes already in session will not be affected by the issuance of the signals and students will only be released when the threat recedes. Forecasters will liaise closely with the education authority when heavy rain is expected and the Red signal is imminent. Such close coordination has been in operation for over ten years and there is practically no death nor injury of students as a result of such inclement weather conditions.

Very Hot and Cold Weather Warnings and Temporary Relief Centres for the Needy

In the subtropical climate of Hong Kong, extreme temperatures are rare, seldom exceeding 36°C and never falling below 0°C. Nonetheless, social consequences and health impacts can still be felt whenever temperatures rise above or drop below certain "comfort" levels during heat waves or prolonged cold spells that may affect Hong Kong several times each year. The elderly and patients with chronic illnesses are particularly at risk. Hypothermia and heat stroke could lead to death for people who are over-exposed to the elements or engaged in outdoor activities.

To alert the public of such risks, the Hong Kong Observatory operates the Very Hot and Cold Weather Warnings. Taking into account the combined effects of wind and humidity, the reference urban temperature criteria for operating the warnings are usually around 33°C and above for the Very Hot Weather Warning, or around 12°C and below for the Cold Weather Warning. The warnings are broadcast on radio and TV, with advisories on actions to take. Upon the issuance of such warnings, temporary relief shelters operated by the Home Affairs Department, where accommodation is provided with air conditioning in very hot weather and blankets as well as hot food in cold weather, will be opened to help the needy through difficult times.

6.1.2 The French Vigilance System After the Heat Wave of August 2003

Following the exceptional heat wave that struck several countries in Western Europe, particularly France, during the first fortnight of August 2003, a thorough revision of the risk management plan for such situations was made.

Apart from various socio-economic effects, the overwhelming impact was the increase of mortality among elderly people, either living in pensioners institutions that were not equipped with adequate resources to deal with such unusual weather conditions, or in isolation in the big cities, suffering from over-heating and deadly dehydration and were detected too late by neighbours, medical or special rescue services. During that fortnight of August 2003, the number of deaths attributable to the heat wave was numbered by the [French] National Statistics Institute to be almost 15,000 people.

One of the lessons learned (Lalande, 2003) was that the weather warnings, though scientifically correct and timely, were not assigned enough weight in the risk management plan and other decision making processes, and were not given sufficient exposure by the media coverage at the time.

In France, a combined risk management tool, named the "Vigilance System", is jointly managed by the Civil Security Authorities and Météo France, and directed towards local authorities, the media, and the public at large (through two Internet sites). Details of this system are described in a WMO publication (WMO, 2003). The Vigilance System was initially built for short-range warnings (with 24-hour lead time, updated twice a day) and a limited set of phenomena (heavy winds and rains, snow falls/avalanches and thunderstorms). Other hazards have also been considered, including cold or heat waves, but their characteristics in lead-time and societal impacts were thought at the time to be too different from those of other considered hazards, and as such the related information communication was left to another kind of procedure in the form of press releases.

This conclusion was clearly reversed after the event in 2003, and the partners in the Vigilance System decided to add new indicators and adopt new procedures to take account of this kind of menace. The basic view was that the potential of the Vigilance System, already a corner stone in the "risk culture" of the French people, would be enhanced rather than blurred with the introduction of new concepts and procedures.

Accordingly, Météo France in collaboration with researchers from the "Institut de Veille Sanitaire" (Institute for Sanitary Watch) expedited a study so that relevant indicators were soon integrated into the popular four-color mechanisms of the Vigilance System. The new procedures take into account heat or cold waves forecast over three days of the onset, and the persistence of maximum and minimum temperatures above relevant thresholds in different cities studied where the statistics of "excess number of deaths", or a proxy of it, were correlated with the observed meteorological conditions. They were tested during the summer of 2004; and are now part of the overall Risk Management Plan, with a comprehensive set of downstream actions organized by Civil Security authorities, rescue services and health institutions under the aegis of the "Prefects" (governors).

6.1.3 Examples from United States of America: All Hazards Emergency Message Collection System

In the United States, the National Oceanic and Atmospheric Administration (NOAA) is assigned responsibility by the Department of Homeland Security's (DHS) Federal Response Plan to "provide public dissemination of critical pre and post event information on the all hazards NOAA Weather Radio (NWR) system, the NOAA Weather Wire Service, and the Emergency Managers Weather Information Network (EMWIN)"(Federal Response Plan, 2003). In 2002, in support of the nation's homeland security efforts, NOAA's National Weather Service (NWS) submitted a Fiscal Year 2004 Federal Budget funding initiative to streamline the creation, authentication, and collection of all types of non-weather emergency messages in a quick and secure fashion for subsequent alert, warning, and notification purposes. NWS received specific funding to develop the All Hazards Emergency Message Collection System (HazCollect) in its Fiscal Year 2004 (FY04) budget.

HazCollect will improve NWS's support to DHS's Federal Response Plan by integrating the automated collection and acceptance of non-weather related emergency messages into the NWS Information Technology (IT) infrastructure. NWS will implement a new, centralized point of collection for non-weather related emergency messages broadcast over NWS dissemination systems. A critical component of NOAA's Homeland Security Initiative, HazCollect will reduce the time to disseminate non-weather emergency messages from 7 to 2 minutes.

HazCollect will replace the existing system, which is a manual, error-prone process. Currently, the non-weather related emergency message is received at the local Weather Forecast Office (WFO) by telephone or fax from local and/or state government agencies. The author of the information is manually authenticated and authorized by the WFO by validating a verbal password and/or checking the author or agency name against an approved source and scope list. The message is evaluated for reasonableness, manually typed by WFO staff into their workstation, and then disseminated using the existing NWS dissemination systems, including NOAAPORT, NOAA Weather Wire Service, Family of Services, Emergency Managers Weather Information Network, and NOAA Weather Radio.

The current system has grave shortfalls. The manual security and message composition process is time-consuming and error-prone. Even in the best circumstances during emergencies, when time is most critical and seconds can be the difference between life and death, manual intervention by the WFO staff adds minutes to the interval between the time the emergency manager desires to warn the public and the time the public actually receives the message. Additionally, the manual text entry process is prone to typographical and grammatical errors when transcribing the emergency manager's input and composing a message for transmission.

HazCollect will meet emergency managers' requirement for a fast, reliable way to inject non-weather related emergency messages into the United States' Emergency Alert System (EAS), which is operated on commercial and public radio and television stations nationwide; until now, no single technical solution has been federally mandated or locally selected to do this. Each state is currently free to choose any system it prefers. When implemented, HazCollect will be able to import emergency managers' critical non-weather emergency messages into the NWS dissemination infrastructure and ensure efficient distribution to other national systems and to EAS for re-broadcast. NWR is the NWS' entry point into EAS, and DHS and the Federal Emergency Management Agency (FEMA) recognize NWR as a critical component of the U.S. Warning Dissemination Infrastructure.

NWS expects to deploy HazCollect in the summer and fall of 2005. HazCollect will provide an information technology interface between state and local computer systems and the NWS communications and dissemination infrastructure utilizing FEMA's Disaster Management Interoperability Services. Through agreements with local and state governments and at the request of government officials, NOAA's NWS accepts emergency messages of non-weather related nature, such as chemical spills/releases, abducted child alerts, and radiological events, and informs/warns the public of these events through the various existing NWS dissemination systems.

6.1.4 Examples from Australia

Standard Emergency Warning Signal

In 1999, Australia's lead disaster management authorities reached agreement on the need for a Standard Emergency Warning Signal (SEWS) to be used in assisting the delivery of public warnings and messages for major emergency events. The SEWS is a wailing siren sound used in northern Australia for many years to attract attention to cyclone warnings where a destructive impact was expected. The SEWS is intended for use as an alert signal to be played on public media to draw listeners' attention to an emergency warning immediately following.

It is considered vital that the status and effectiveness of the SEWS are preserved as a "disaster mitigation" mechanism by ensuring that it is used for serious events only. As a general rule, the following 4 factors should be present:

(i) potential for loss of life and/or a major threat to a significant number of properties or the environment; usually the threat/impact would be the lead item in local news bulletins;
(ii) a significant number of people need to be warned;
(iii) impact is expected within 12 hours – or is occurring at the time; and
(iv) one or more phenomena are classified as destructive.

When the SEWS is to be used, the following advice to the media is included in the warning header: "Transmitters serving the area (defined) are requested to use the Standard Emergency Warning Signal before broadcasting this message". The media is requested to isolate the use of the SEWS to the threatened defined area to reduce the risk of unnecessarily alarming others. In regard to severe weather and flood warnings, the use of the SEWS is authorized by the State/Territory Director of the Australian Bureau of Meteorology. Below are a number of severe weather and flood examples where the use of the SEWS could be authorized:

(i) wind gusts > 125 km/h;
(ii) storm tide > 0.5 m above (effectively) high water mark;
(iii) large hail > 4 cm in diameter (i.e. > golf-ball size);
(iv) tornado(s);
(v) major flood in a river or creek system;
(vi) intense rainfall leading to flash floods and/or landslides; and
(vii) major urban and rural fires.

The information above is largely extracted from a multi-authored booklet on the SEWS, reprinted in Queensland in 2004, and available online at:
http://www.disaster.qld.gov.au/disasters/warning.asp

Disaster Mitigation Initiative After the Sydney to Hobart Yacht Race 1998

Of the 115 yachts that set sail on Boxing Day 1998 in the Sydney to Hobart Yacht Race, only 44 reached their destination. The destruction caused by a storm encountered by the fleet triggered a massive search and rescue operation involving numerous personnel from the defence forces and disaster management authorities. Even so, it resulted in the abandonment of several yachts and the death of 6 people. It was the most disastrous event in the 54-year history of the yachting classic.

While the issuance of warnings on weather and sea conditions independently assessed at the subsequent Coroner's enquiry were considered to be "excellent forecast by world standards", the investigating Coroner did include one recommendation concerning the terminology used in weather forecasts and warnings to be specifically provided for yacht-racing fleets. Since many yacht crews did not appreciate how forecasts and warnings are to be interpreted despite the various Bureau publications handed out to them prior to the race, the recommendation called for the inclusion in forecasts and warnings of additional information on maximum wind gusts and maximum wave heights likely to be encountered by yacht-racing fleets.

Consequently, the Australian Bureau of Meteorology started to include the following safety preamble in the headers of all marine forecasts and warnings: "Please be aware – Wind gusts can be a further 40 percent stronger than the averages given here, and maximum waves may be up to twice the height". On the basis of surveys, this "disaster mitigation" initiative has proven popular with mariners and the practice continues today.

The information above is extracted mainly from the Bureau's "Preliminary Report on Meteorological Aspects of the 1998 Sydney to Hobart Yacht Race" (Bureau of Meteorology, 1999).

6.2 EXAMPLES OF PROJECTS FUNDED FROM INNOVATIVE SOURCES

The following sections describe initiatives by several NMSs to improve their warning system with funding and cooperation from partners or organizations outside the usual funding mechanisms. These examples may inspire other NMSs to find creative and innovative sources for funding improvements within their organization or country.

6.2.1 World Bank Loan to the Algerian Government to Improve Flood Warnings, Infrastructure Improvements, and Enhance the Relationship with Disaster Response Agencies

The Algerian meteorological service, Office National de la Météorologie (ONM), has been successful in securing funding through their national government for a World Bank loan. This followed a devastating flood in 2001 in which more than 700 people drowned and 24,000 were left homeless. The funding will pay for, among other developments, a meteorological component which will help enhance ONM's capability to forecast such events and to make recommendations for infrastructure improvements - both technical and personnel. This meteorological component is part of a broader project, which will also help to improve the liaison with other disaster response agencies to improve future response to severe weather warnings.

6.2.2 Grant from the European Development Fund to the Caribbean Forum of Africa, Caribbean and Pacific States to Reduce Vulnerability to Floods and Hurricanes

The Caribbean Forum of Africa, Caribbean and Pacific States (CARIFORUM) has been awarded a grant from the European Development Fund through the Caribbean Regional Indicative Programme (CRIP). This grant is to fund a project to reduce the vulnerability of the Caribbean region in relation to adverse weather - primarily floods and hurricanes. Four new weather radars will be added to the existing network of five. The composite images and data will be made available to the participating meteorological services.

6.2.3 Central America Flash Flood Warning System Funded by the United States Agency for International Development's Office of Foreign Disaster Assistance

Following the catastrophic flooding of Hurricane Mitch in 1998 in Central America, the United States Agency for International Development (USAID) provided funding for the re-construction of damaged infrastructure. The National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) provided technology transfer, training, and technical assistance to the meteorological and hydrologic services in the countries hardest hit (Honduras, Nicaragua, El Salvador, and Guatemala). The USAID/Office of Foreign Disaster Assistance (OFDA) also initiated a project in 2000 to have NWS develop and implement a Central America Flash Flood Guidance (CAFFG) system. This prototype system was developed with the Hydrologic Research Centre, a public-benefit non-profit research, technology transfer, and training corporation in San Diego, California, United States. The purpose of this system is to provide operational meteorological and hydrological services in the seven Central American countries (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama) with guidance to provide flash flood warnings for small river basins. This system became operational in August 2004.

The flash flood warning system uses real-time Geostationary Operational Environmental Satellite (GOES) imagery and in situ rain gauge data captured by a Digital Direct Readout Ground Station (DRGS) downlink located in Costa Rica. Hourly rainfall estimates are calculated on a 4-km grid. Flash Flood guidance, which is the rainfall required to produce flash flooding, is calculated daily for river basins from 100 sq km to 300 sq km. A distributed hydrologic model is run hourly to simulate flows and soil moisture for the region. Graphical and text rainfall, soil moisture, and flash flood guidance products are created and posted to the Internet for access by the NMSs and disaster preparedness response agencies in the seven Central American countries. The next steps in this project are to evaluate the effectiveness of this new approach and to continue with the training initiatives to ensure sustainability of the technology.

6.2.4 Examples from Hong Kong, China

The basic source of funding for meteorological service warning projects in Hong Kong is from the Hong Kong Special Administrative Region Government (HKSARG). A few recent examples in which projects are funded by other sources are given below:

(i) Partnership with Higher Education Institutions on Research Projects

The Hong Kong Observatory recently collaborated with the Hong Kong Polytechnic University in the development of real-time estimation of the integrated precipitable water vapour (PWV) content in the atmosphere based on Global Positioning Satellite (GPS) measurements to support the operation of the rainstorm warning system in Hong Kong. The project attracted funding support from the Hong Kong Research Grants Council. The project started in September 2000 and the first phase was successfully completed in December 2003.

Funding support has also been obtained from the University Grants Council for partnership with the Hong Kong University to jointly develop automatic identification and tracking of tropical cyclone centres using radar imagery in support of the Tropical Cyclone Warning Service. The project has yielded fruitful results.

(ii) Cooperation with Engineering Departments and Emergency Response Agencies to Promote Public Awareness of Natural Disasters

Improvements in the drainage and slope safety systems, as well as stringent building codes, have in recent years successfully reduced the loss of life and property due to severe weather. However, the awareness of potential hazards among the general public has fallen.

To counter this decline in awareness, a large-scale public education programme on natural disaster preparedness and prevention was organized jointly by the Hong Kong Observatory, engineering departments and other emergency response agencies in Hong Kong. The programme aims to promote public awareness of weather-related disasters and to raise the community's preparedness to deal with natural disasters in Hong Kong.

The year-long "Safer Living – Reducing Natural Disasters" public education programme commenced in March 2005, prior to the rain and tropical cyclone season. Activities included a tropical cyclone naming contest, exhibitions, public seminars, open days, emergency operation drills, carnivals, feature stories on TV and newspapers, etc. Resources of the participating organizations were pooled together to support this programme, without which such a large-scale endeavour would not be possible.

6.2.5 Examples from France: Building a Comprehensive Mainland Hydro-meteorological Radar Network

One of the most prominent and recurring hazards in France is flooding. Heavy tolls in lives and property were recorded, for example in Nîmes (1987) and Vaison-la-Romaine (1992). More recently, severe disasters (fortunately with a lower loss in lives) repeatedly struck the south of France in 2000 (the Aude département), 2002 (the Gard département) and 2003 (the Rhone Delta).

Recognizing the importance of a focused and integrated approach to this kind of hydro-meteorological risk, Météo France and the relevant ministry in charge of hydrology (now the Ministère de l'Ecologie et du Développement Durable, or the Ministry of Ecology) have established two five-year programmes to install a comprehensive radar network, thereby enhancing the existing network assembled by Météo France over the years.

The first programme, completed in 2001, set up five new radars in the most vulnerable part of France, the so-called "Mediterranean arch". This resulted in almost all of the radar coverage gaps in the region being filled and increased the total number of radars to 18. The cost of this programme was co-financed and shared by the two institutions involved, with marginal extra funding coming from the European Union (because of the international relevance of the coverage by some of the radars).

As a follow-up of this first fruitful partnership, a new programme (called PANTHERE) was launched for 2001-2006 with new installations totalling 12.2 million Euros (almost US$15 million). The main part of the programme will be another five new radars, completing the coverage both in the southern and northern parts of the country. The programme also includes components for research and development in new technologies.

For implementation, the project is undertaken by a team of Météo France scientists and managers, under the control of a bi-partite board of the two main partners. Regional branches of the Ministry of Ecology and of Météo France are actively required to help the core team in gathering local users' requirements, soliciting additional funding, looking for adequate locations for the radars; assisting in tendering processes, and supervising the building of necessary infrastructure. This mechanism is very effective: bulk tendering for the equipment lowers the unit price; centralized management by a highly qualified and experienced team ensures good coordination and progress; while the local initiatives generate interest from new partners. It has been so successful that funds collected from local authorities, the European Union, and a Belgian Ministry now account for one-third of the total funding. As a result, a sixth radar can also be accommodated within the time frame of the present PANTHERE programme, which is on schedule and due to be completed in 2006.

6.2.6 Examples from Australia: Studies on Climate Change and Tropical Cyclone Vulnerability

The Queensland east coast in Australia is threatened by one or two tropical cyclones most seasons. Tropical cyclones typically form in the Coral Sea and cause on landfall severe winds, storm surge, and extreme wave conditions in the impact zone. In 1999, an opportunity arose to further study the risks posed by these phenomena when the Queensland State Government provided A$1M funding under the "Greenhouse Special Treasury Initiative" through the

Department of Natural Resources and Mines. The Australian Bureau of Meteorology in partnership with the Queensland Department of Emergency Services was successful in bidding for project funding (totalling A$265K). The study was titled "Queensland Climate Change and Community Vulnerability to Tropical Cyclones", with coastal engineers from the Queensland Environmental Protection Agency subsequently joining the project team.

When the study was partially completed, the Project Management Team led by the Australian Bureau of Meteorology assessed that there were insufficient funds to complete the study. On this occasion, a successful bid for supplementary funding (totalling A$80K) was made under the Federal/State Natural "Disasters Risk Management Studies Program". More recently, another successful bid (totalling A$105K) was made under the same program to undertake a similar study in the Gulf of Carpentaria where the coast is also cyclone prone. Without the funding provided under the "Greenhouse Special Treasury Initiative" and the "Disaster Risk Management Studies Program", a "disaster mitigation" study of this magnitude and complexity would not have been possible.

Incidentally, the project has already won three prestigious awards – an Engineering Excellence Award in 2002 and both Queensland and Australian Safer Communities Awards in 2004. Both awards were shared with the project consultants/contractors – Systems Engineering Australia Pty Ltd and James Cook University (Marine Modelling Unit and the Cyclone Testing Station).

Chapter 7
REFERENCES, FURTHER READING AND USEFUL WEB SITES

I. REFERENCES AND USEFUL READINGS

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II. USEFUL WEBSITES

Billion Dollar U.S. Weather Disasters, 1980 - 2003
http://www.ncdc.noaa.gov/oa/reports/billionz.html

Central America Flash Flood Guidance (CAFFG) system (available in English or Spanish):
http://www.hrc-web.org/Whats_New/

Early Warning Systems
http://www.esig.ucar.edu/warning/

HAZUS.org
www.hazus.org

NOAA Economic Statistics
http://www.publicaffairs.noaa.gov/pdf/economic-statistics2004.pdf

Partnership for Public Warning
http://www.partnershipforpublicwarning.org

[United States] Federal Response Plan, 9230.1-PL, January 2003. Available online at:
http://www.fema.gov/pdf/rrr/frp/frp2003.pdf
NOTE: This document will be absorbed into a more comprehensive plan named the National Response Plan

[United States] Natural Hazards Centre
http://www.colorado.edu/hazards/

Appendix A
UNDERSTANDING PROBABILITIES OF OCCURRENCE AND CALCULATION OF BENEFIT COST RATIO (BCR): AN EXAMPLE

The ratio **La**/**Cp** can provide a decision threshold for action.

Suppose that, on each occasion, loss avoided (**La**) is $10,000 and the cost of protection (**Cp**) is $4,000; then **Cp**/**La** = 0.4. Consider the financial implications over 10 events for 5 different forecast probabilities. If action is taken on each of the 10 events, then the total cost of protection (Σ**Cp**) remains the same at $40,000, but the total loss avoided (Σ**La**) increases:

Forecast Probability **P**	Number of occasions loss avoided	Total Loss Avoided Σ**La** ($)	Total cost of Protection Σ**Cp** ($)	**BCR** over 10 events
0.1	1	10,000	40,000	0.25
0.2	2	20,000	40,000	0.50
0.3	3	30,000	40,000	0.75
0.4	4	40,000	40,000	1.00
0.5	5	50,000	40,000	1.25

So there is a break-even point (i.e. **BCR** = 1) when probability is 0.4 or P ≥ **Cp**/**La**. This becomes the decision point for taking action. Emergency authorities can then put in place a whole range of options and strategies depending on the likely impact of an event. These will start with relatively low-cost preparatory actions such as ensuring equipment and manpower are available if needed and raising the state of awareness amongst responders. These may be initiated even with a low probability of occurrence because the BCR will still be high. Similarly, when confidence (probability) is high, more expensive strategies can be brought into play.