

DISASTER RISK MANAGEMENT IN RECONSTRUCTION

Disaster risk management (DRM) is a systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies, and improved coping capacities to lessen the adverse impacts of hazards and the possibility of disaster. Disaster risk reduction (DRR), a related but narrower concept, is the practice of reducing disaster risks through systematic analysis and management of the causal factors of disasters, including reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness.¹ This chapter uses the broader concept of DRM.

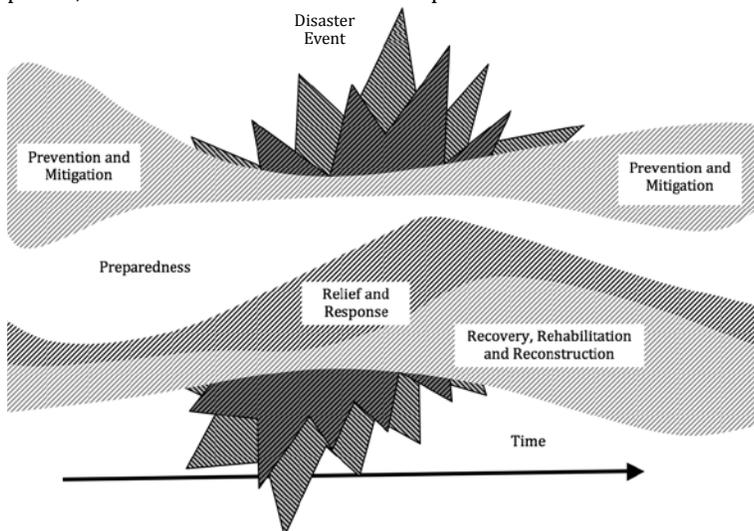
Disaster risk is the potential losses, in lives, health status, livelihoods, assets, and services that could occur in a particular community or a society over some specified future time period due to disasters. Disaster risk is created by a complex interaction of factors, both natural and human-generated, that expose people and the environment to hazards. The following types of interventions are used to manage disaster risk: (1) policy and planning measures, (2) physical preventive measures, (3) physical coping and adaptive measures, and (4) capacity building at the community level.

Policy makers and reconstruction project task managers will probably never conduct a risk analysis, but they may have to evaluate a mitigation plan for a neighborhood or infrastructure system or make a relocation decision. The commitment to reducing disaster risk must drive such decisions.

Specific DRM actions that can be taken are discussed throughout this handbook as they apply to the chapter topics. This chapter gives users of the handbook a working understanding of what disaster risk analysis entails and of how both short- and long-term mitigation measures are used to reduce disaster risk in reconstruction. It focuses on the basic principles, policies, and instruments of DRM, and on their application in a reconstruction program. Because of its post-disaster focus, this chapter principally addresses interventions 1 and 3, above.

Disaster Timeline

DRM as a discipline can be conceived of as a program of interventions whose focus and relative importance changes from the pre-disaster period to the disaster period to the post-disaster period. The figure below attempts to show the relative importance of each of these interventions at different points in time relative to a disaster event. This handbook focuses on the post-disaster reconstruction period, as does the discussion in this chapter.



(Adapted from International Recovery Platform, *Learning from Disaster Recovery – Guidance for Decision Makers*, 2007, p. 14, Fig H.)

1. United Nations International Strategy on Disaster Reduction (UNISDR), 2009, "UNISDR Terminology on Disaster Risk Reduction," <http://www.unisdr.org/eng/terminology/terminology-2009-eng.html>. Some institutions use these two terms synonymously.

Applying Disaster Risk Management Principles in Reconstruction

The key DRM decisions related to housing and community reconstruction, and the handbook chapters where these issues are discussed, are the following:

- Whether and where to relocate households (🏠 Chapter 5, To Relocate or Not to Relocate)
- The housing technology, construction procedures, and norms to be used in construction, retrofitting, and reconstruction (🏠 Chapter 6, Reconstruction Approaches, and 🏠 Chapter 10, Housing Design and Construction Technology)
- How to restore infrastructure services, including site selection and mitigation measures in both new construction and retrofitting (🏠 Chapter 7, Land Use and Physical Planning, and 🏠 Chapter 8, Infrastructure and Services Delivery).

DRR is particularly important in developing countries: 90 percent of disaster-related injuries and deaths are sustained in countries with per capita income levels below \$760 per year. In addition, losses from natural disasters are 20 times greater (as a percentage of gross domestic product) in developing countries than in industrialized countries.

UNISDR (United Nations International Strategy for Disaster Reduction), 2004, Living with Risk: A Global Review of Disaster Reduction Initiatives. Vol 1. (Geneva: UNISDR).

When making these decisions, it is important to look for opportunities to promote both short- and long-term DRM measures.

In the immediate term, there is an opportunity to analyze risk and use the outputs of the analysis to identify cost-effective risk mitigation measures to implement in the reconstruction program. In an area of habitual flooding, for example, housing may be reconstructed in-situ on stilts.

At the same time, the disaster may create an opportunity—while the public’s consciousness of disaster risk is heightened—to identify and begin to implement longer-term DRM measures. Longer-term mitigation includes strengthening DRM institutions and other measures that have a more systematic and far-reaching impact but require time to plan and implement. For example, after a flood, a commitment might be made to begin planning an early warning system to ensure evacuations under certain flooding conditions that includes rainwater monitoring and radio announcements, even though it could take time to fully implement.

Conducting a Risk Analysis

An all-hazards risk assessment (or risk analysis) is a determination of the nature and extent of risk developed by analyzing all potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods, and the environment on which they depend. The risk analysis shows vulnerabilities in a particular location and quantifies the potential impact of a disaster on a community. These factors are crucial when selecting among various mitigation options or deciding whether to relocate a community. Project managers should investigate whether a risk analysis has already been conducted for the location. It may be available from regional or international bodies. Four steps of a risk analysis and the issues they address are described below.

Step 1: Identify hazards and analyze their probability.

How frequently do different types of disasters occur here? What is the probability that they will recur?

Hazard identification. To help predict the magnitude and duration of a potential hazard, a record of similar previous hazards is developed and characteristics of those hazards are collected and compared. The data collected should show magnitude, duration, impact, date, and extent. (The table in the annex provides additional information about potential sources of data.) Changes in temperature and rainfall projected from climate change should be factored into a risk analysis using projections or global models. The 🏠 case study below explains the functions of the Central American Probabilistic Risk Assessment (CAPRA), an example of a regional organization that can provide risk assessment data.

Hazard probability. Using hazard data, the return period of a disaster in a specific area can be estimated. Recent trends, such as those produced by climate change, may not be included in historic data, but should be taken into consideration. The output of the probabilistic hazard analysis is a map of the hazard for various return periods.² Specific outputs include (1) wind speeds, (2) inundation depths and extents, and (3) ground motion.

2. A return period (or recurrence interval) is an estimated interval of time between hazard events of a certain intensity or size. It is a statistical measurement averaged over an extended period of time. The trauma of the disaster tends to cause people to underestimate recurrence intervals (i.e., assume the disaster will recur sooner than historical information would suggest).



Step 2: Create an inventory of exposure and vulnerability.

What assets of this community might be affected if the disaster recurs? How would they be affected? How likely are various outcomes?

Develop an asset inventory. Identify the buildings or infrastructure at risk, including information on the structure's use, materials, age, and dimensions. The information should be collected at a geographic level relevant to the analysis (e.g., city block, neighborhood, or region). Sources of data may include government census reports, community-level surveys, and high-resolution satellite images. (Satellite data used in any process should be validated using a second method, such as a site survey. See  Chapter 17, Information and Communications Technology in Reconstruction, for a discussion of these issues.)

Develop valuation data. Estimate replacement costs of the assets identified. If valuation data are not available, estimates based on gross domestic product and comparative country-level data can be used as proxies.

Catalogue vulnerability characteristics. Some structures withstand specific types of disasters better than others. The factors that contribute to a building's vulnerability include roof type, roof-wall connection, construction type, window protection, height, foundation type, and elevation. The prevalence of these factors must be catalogued in order to develop estimates of loss.

Identify or develop damage and loss functions. Physical vulnerability is described as the degree to which an asset may sustain damage when exposed to a hazard. A vulnerability analysis quantifies the susceptibility of an asset type to damage for each magnitude of hazard. Develop damage and loss functions for buildings, content, and infrastructure for different return periods and hazards, based on the information above, local damage data, existing vulnerability curves developed for similar structures, and expert or heuristic judgments. Historic information and community experience from past events help predict the effect of a disaster on a community, including identifying undamaged areas, hazard durations, and cascading hazards. Potential for damage is measured using the mean damage ratio (MDR), the ratio of damage incurred to the asset's replacement cost. Two outputs from this analysis include the following.

- Vulnerability or damage function: The curve that relates the MDR to the magnitude of a hazard.
- Loss function: The curve that relates the repair cost to the magnitude of the hazard.

Step 3: Estimate the probability of losses.

What could losses cost us?

A computer model is usually used to overlay the hazard and vulnerability data (using a geographic information system [GIS]) and to map loss estimates for each hazard probability developed above. Data for this step are often collected and posted by the United Nations Office for the Coordination of Humanitarian Affairs (<http://www.unocha.org/>). After this step, an at-risk community should be able to better understand what the impact could be should disaster strike. Two outputs from this analysis include the following.

- Average annual loss (AAL): The sum of all monetary losses over all return periods multiplied by the probability of a disaster occurring. Expressed mathematically, $AAL = (\$ \text{ loss}) \times \Sigma (\text{probability of occurrence})$.
- Loss exceedance curve (LEC): A curve that shows the correlation between the average recurrence interval and losses. It is used to predict losses for different recurrence intervals.

Step 4: Develop a risk atlas.

Where are losses likely to happen?

A risk atlas illustrates hazard areas and corresponding community damages and losses for a series of probable events over different return periods. A separate map is generated for each return period event. The atlas is used to identify which mitigation measures need to be considered. Specific examples of mitigation measures are provided in the next section.

Types of DRM Measures

- *Policy and planning:* e.g., institutional, policy, and capacity-building measures designed to increase the abilities of public and private institutions to manage disaster risks.
- *Physical preventative:* e.g., building sea-walls as part of flood defense mechanisms.
- *Physical coping and adaptive:* e.g., flood shelters for use during a disaster event.
- *Capacity building at the community level:* e.g., developing a community-based hazard mitigation plan.

Source: Department for International Development, 2005, "Natural Disaster and Disaster Risk Reduction Measures, A Desk Review of Costs and Benefits," <http://www.dfid.gov.uk/Documents/publications/disaster-risk-reduction-study.pdf>.

Identifying and Selecting Mitigation Measures

Hazard mitigation is any action taken to reduce or eliminate the risks from natural hazards. Once the risk analysis has been carried out, the information can be used to define and implement hazard mitigation activities and projects. To do this, the mitigation options must be identified, and the costs and benefits of each option evaluated. Based on that analysis, implementation decisions can be made.

Various mitigation measures may be considered when planning housing and infrastructure reconstruction, but the most feasible will be short-term measures that minimize the destructive and disruptive effects of disasters on the built environment. Longer-term measures should also be initiated. These are discussed in the next section.

The principal mitigation measures are:

- locational mitigation, in which damage or loss is reduced by avoiding the physical impacts of an event;
- structural mitigation, in which damage is resisted through bracing of buildings or construction of a levee;
- operational mitigation, in which damage or loss is minimized by interventions such as emergency planning, tsunami warning, or other temporary measures; and
- risk sharing, in which the cost of the damage is shared.³

The  case study on Pupuan, Indonesia, below, shows how the full range of mitigation options should be considered, even those that are political difficult.

Short-Term Mitigation for Housing

Based on the risk assessment described above, alternative mitigation measures for housing can be considered. These measures are not mutually exclusive; more than one may apply. Information in other handbook chapters can be used to support the evaluation of the options, as noted below. Site selection for housing is likely to take place in an extremely decentralized manner (at the household and village levels); therefore, communication with the public should be considered an important mitigation tool.

Choose hazard-resistant housing designs and construction technologies. For housing, design standards exist internationally and are readily available for various types of construction and disasters. Building codes are the most common regulatory instrument for ensuring safe construction methods, although they may not be promulgated or enforced. An authoritative source of model codes for residential and commercial buildings is the International Code Council.⁴ Also see  Chapter 10, Housing Design and Construction Technology, for a discussion of housing construction issues.

Relocate housing. DRM considerations should be applied in site selection for both temporary and permanently relocated housing. While reconstruction should not occur in areas frequently affected by hazards, this is admittedly difficult where nonvulnerable alternatives are scarce or land use regulations do not prevent it.  Chapter 5, To Relocate or Not to Relocate, discusses the range of issues that arise in evaluating the relocation option. Reconstruction guidelines should include the topic of site selection, as should the reconstruction communication program, so that both agencies and individuals are educated about the importance of these decisions.⁵  Chapter 3, Communication in Post-Disaster Reconstruction, explains the principles of communication with the affected community and the general public.

Rehabilitate and retrofit housing. Rehabilitation deals with structural and nonstructural modification of buildings and infrastructure facilities. Since new zoning laws and updated design and construction codes usually can't be applied retroactively, it is important that, to reduce the impact of disasters, the safety and structural integrity of existing buildings and infrastructure facilities is improved during the rehabilitation process.

Train builders in DRM. The training program should provide an understanding of how the hazards may affect the household and community and of recommended mitigation strategies for the specific affected region.  Chapter 16, Training Requirement in Reconstruction, describes some of the specific content in the training programs for the builders.

3. Charles Scawthorne, 2009, "Disaster Reduction and Recovery: A Primer for Development Managers" (Washington, DC: World Bank).

4. International Code Council, <http://www.iccsafe.org/>.

5. U.S. Federal Emergency Management Agency (FEMA), 2001, *Telling the Tale of Disaster Resistance: A Guide to Capturing and Communicating the Story* (Denver: FEMA Region VIII), <http://www.fema.gov/library/viewRecord.do?id=1762>.



Mitigate the existing site. The location or structure of a building can greatly increase its vulnerability. Mitigation measures should address the specific causes of a building's or infrastructure's vulnerability. For example, it is illogical to invest in expensive reinforcement of a structure resting on unstable soil. Removal, relocation, or elevation of in-place structures in highly hazardous areas, especially those built before building codes were established, is frequently the only option. A community must prioritize options based on the importance of a structure and its relative vulnerability. For instance, a venerated historic religious building with a high potential loss may take priority over other buildings and infrastructure.

Short Term Mitigation for Infrastructure

Based on the risk assessment described above, alternative mitigation measures for infrastructure can be considered. These measures are not mutually exclusive; more than one may apply. The information in  Chapter 8, Infrastructure and Services Delivery, complements this section, providing guidance on a DRM-oriented infrastructure project development process.

Select or change the site. DRM considerations should be applied in site selection for new infrastructure. Reconstruction should not occur in areas frequently affected by hazards, although it may be impossible to avoid if housing settlement has already taken place and services are needed and where nonvulnerable alternatives are scarce. Where site selection cannot be used to avoid risk, other mitigation measures are applied.

Mitigate the existing site. It is often difficult to relocate infrastructure to a site that does not experience hazards. For example, a road may have to cross a river or stream and therefore enter a floodplain. In this example, mitigation might consist of designing a bridge with a proper elevation and span based on an analysis of the floodplain. Using information from the risk analysis, the design of the bridge is fine-tuned to the hazards and vulnerabilities at the site (e.g., soft soils, liquefaction potential, etc.). A community must prioritize options based on the importance of the facility and its relative vulnerability. For instance, a water system with a high potential loss may take priority over other infrastructure. The  case study on Bamako, Mali, below, explains how solid waste management and storm water management were used to reduce flooding in an urban area.

Redesign or reengineer the infrastructure. Design and engineering improvements are used to retrofit in-place infrastructure. Because construction techniques and technologies are constantly improving, one should research the most recent recommended practices when considering engineering improvements for infrastructure.

Use protection and control measures (applies to both housing and infrastructure). Protective and control measures focus on protecting structures by erecting protective barriers (e.g., dams and reservoirs, levees, discharge canals, floodwalls and sea-walls, retaining walls, safe rooms or shelters, and protective vegetation belts) and deflecting the destructive forces from vulnerable communities, structures, and people. Some of these measures may be appropriate to implement during reconstruction; others may be longer-term investments that require time to plan, finance, and implement. The requirements for these measures should be incorporated into the land use planning framework, based on a rigorous assessment of risks. See  Chapter 7, Land Use and Physical Planning, for a discussion of the role of planning in risk mitigation, and the  case study on the use of a coastal protection zone as a mitigation strategy in Sri Lanka, below.

Comparing Mitigation Options

To select the preferred option for mitigating risk in a particular situation, it is necessary to compare options in an objective manner according to consistent criteria.⁶ Several methodologies can be used to evaluate and select mitigation options and rank the potential mitigation projects; two are discussed below. These evaluation tools are used after the potential hazards and vulnerabilities in a community have been identified using risk analysis. The selection of options, including the relative weighting of criteria, is ideally carried out with the participation of the affected community.

STAPLEE. One methodology that considers a comprehensive set of criteria is referred to as "STAPLEE." This methodology examines the **S**ocial, **T**echnical, **A**dmistrative, **P**olitical, **L**egal, **E**conomic, and **E**nvironmental opportunities and constraints of implementing a particular mitigation measure. To use this methodology and other similar methodologies, the mitigation project is evaluated and scored for each criterion. It may also be necessary to weight the criteria to reflect

6. The comparison of mitigation options depends on knowing the improvement in vulnerability that will result from various mitigation options, relative to a baseline, information that may be very difficult to ascertain scientifically. Therefore, subjective judgment will often need to be exercised, which may be the judgment of the affected community itself, solicited using a participatory approach to evaluating alternative mitigation measures.

their relative importance. This scoring could be in the form of a number or a “yes/no” decision. STAPLEE helps determine whether the project is feasible and can be used to compare several mitigation options to each other.

Cost-Benefit Analysis. Another way to evaluate a mitigation project is to use a cost-benefit analysis (also known as a benefit-cost analysis) to determine cost effectiveness. The cost-benefit analysis is used to assess for which alternatives, if any, the benefits outweigh the costs. The steps in a cost-benefit analysis are, for each project:

1. Conduct a hazard risk assessment and compute the AAL before mitigation.
2. Conduct a hazard risk assessment and compute the AAL after mitigation.
3. Determine the present value of the benefit using the difference between the AALs, the project lifespan, and a discount factor for the time value of the benefits.
4. Estimate the cost to implement the mitigation measure and discount those costs as well.
5. Divide the present value of the benefit of the mitigation project by the present value of the cost to mitigate.

The project with the highest cost-benefit ratio produced by this analysis is the preferred mitigation option.

Long-Term Measures

Institutional strengthening. Government agencies at the national and local government levels in disaster-affected countries may already have in place DRM policies and regulations. Implementation of the policies may fall within the jurisdiction of the ministry of public works, the ministry of land, and/or the ministry of urban development and planning departments at different levels. Enforcement may fall within the ministry of public works, civil defense, or police departments. Most disaster-affected urban areas have some type of DRM policies and regulations in place, generally under the jurisdiction of the local planning department or planning commission. The problem is that these measures are often not fully enforced or implemented. Rural areas may not have these policies or regulations in place and may not have defined DRM responsibilities within local agencies.

Although institutional weaknesses differ from country to country, there are some shared concerns that will affect the promotion of DRM principles in reconstruction. The table below provides examples of institutional DRM issues and potential solutions. These issues should be viewed as entry points where work with DRM agencies can begin.

Institutional Weaknesses and Potential Solutions

Institutional weakness	Potential solutions
Building codes have not been established or are not being enforced.	Use the expertise gathered for disaster recovery and the global media focus to promote establishing/ updating building codes. Work with the ministry of public works or municipal public works departments and involve enforcement agencies in the discussions. Work directly with builders to improve construction practices. Oversight of the construction is key.
Land use/zoning regulations have not been established or are not being enforced.	Use the expertise gathered for disaster recovery and the global media focus to promote establishing/ updating land use regulations. Work with the ministry of planning and local planning departments.
There are no clear lines of disaster risk management responsibility among government agencies.	Build on ad hoc institutional arrangements developed for response and recovery from the current disaster to institutionalize responsibilities for prevention and response to future disasters.
Disaster response and recovery plans are limited or nonexistent.	During reconstruction, develop a response and recovery plan using lessons learned from the disaster to determine needs and division of responsibilities.
Incentives for disaster-resistant building practices are weak.	Use computer models or case studies to demonstrate mitigation benefits. Perform cost-benefit analysis. Promote incentive-based, disaster-resistant programs (insurance programs, government catastrophic pools).



Regulatory measures. It is generally not realistic to implement major regulatory reforms in the immediate aftermath of a disaster; however, a revision to a key ordinance or issuance of guidelines is often feasible. At the same time, the disaster may raise awareness among decision makers such that they become motivated to begin the process for implementing more substantive reforms after the immediate recovery and reconstruction issues have been dealt with.

In most cases, regulatory measures should be considered before other measures because they provide the framework for mitigation decision making, organizing, and financing. Regulatory measures are the legal and other regulatory instruments that governments use to prevent, reduce, or prepare for the losses associated with hazard events. Examples include:

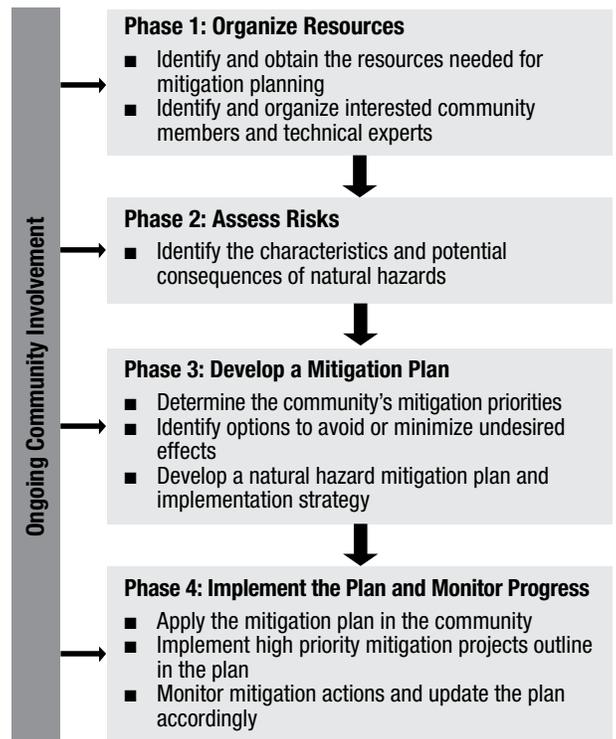
- legislation that organizes and distributes responsibilities to protect a community from hazards;
- insurance regulations that reduce or transfer the financial and social impact of hazards;
- new and/or updated design and construction codes, and land use and zoning regulations (land use planning is detailed in Chapter 6, Reconstruction Approaches); and
- regulations that provide incentives for implementing mitigation measures.

In post-disaster situations where regulatory measures do not exist, reconstruction and rehabilitation (at a minimum) should reflect the experience and standard practices and guidelines used internationally for similar disasters. For housing, such standards are readily available and can be adapted to the local conditions and environment in an emergency. See Chapter 10, Housing Design and Construction Technology, for more detail on housing standards.

Community-based hazard mitigation planning. Creating disaster-resistant communities requires community involvement. The figure at right shows the steps in a participatory hazard mitigation planning process. It is similar to the steps described for reconstruction; however, the planning process allows for more participation and longer-term thinking about priorities and options.

Stakeholder workshops conducted during reconstruction can be opportunities for local officials and the community to begin developing the outlines of the longer-term hazard mitigation strategy and planning process. The communications program related to the disaster is a valuable tool for two-way communication between the public and government about DRM. For more information on the use of community involvement in planning and reconstruction, see Chapter 12, Community Organization and Participation.

The Hazard Mitigation Planning Process



Case Studies

1999 Landslide, Pupuan, Indonesia

Not Considering All Potential Risk Mitigation Applications

In January 1999, a landslide in the village of Pupuan, Bali, killed 38 people. Local residents said the cause of the disaster was a combination of high rainfall, significant slope modifications for rice agriculture, housing construction in high-risk areas, lack of infrastructure, and removal of forest cover. The DRR strategies that had been implemented included structural approaches (e.g., levee construction, hillside terracing, hazard-resistant housing) and nonstructural approaches (e.g., strengthening communications networks, human settlement rezoning, strengthened cooperation between nongovernmental organizations [NGOs] and government agencies). However, resource management actions were not pursued (e.g., abandoning hillside rice agriculture and reforesting slopes). Land use and population pressures, in addition to a 1,000-year-old tradition of terraced rice growing, led to strong local resistance to changing the resource use practices that might have avoided the landslide.

Source: Brent Doberstein, 2006, "Human Dimensions of Natural Hazards: Adaptive Management of Debris Flows in Pupuan, Bali and Jimani, Dominican Republic," University of Waterloo, Canada, http://www2.bren.ucsb.edu/~idgce/papers/Brent_Doberstein.doc.

Disaster-Related Data Sharing and Coordination

Central American Probabilistic Risk Assessment Platform

Central America is vulnerable to a wide variety of natural hazards that present a challenge to the region's sustainable social and economic development. In response, the region has taken a proactive stance on risk prevention and mitigation. The CAPRA platform represents an opportunity to strengthen and consolidate methodologies for hazard risk evaluations supporting this stance and existing initiatives. Led by the Center for Coordination for the Prevention of Natural Disasters in Central America (Centro de Coordinación para la *Prevención de los Desastres Naturales en América Central* [CEPREDENAC]), in collaboration with Central American governments, the International Strategy for Disaster Reduction, the Inter-American Development Bank, and the World Bank, CAPRA provides tools to communicate and support decisions related to disaster risk at local, national, and regional levels in Central America. It uses a GIS platform and probabilistic risk assessment to support decisions in such sectors as emergency management, land use planning, public investment, and financial markets. Current CAPRA applications use data for (1) the creation and visualization of hazard and risk maps, (2) cost-benefit analysis tools for risk mitigation investments, and (3) the development of financial risk transfer strategies. Future applications by CAPRA partners may include real-time damage estimates, land use planning scenarios, and climate change studies.

Sources: CAPRA, <http://www.ecapra.org/en/>; and CEPREDENAC, <http://www.sica.int/cepredenac/>.

2004 Indian Ocean Tsunami, Sri Lanka

Delays in Defining Coastal Risk Strategy Affect Housing Reconstruction and Land Ownership

In the housing damage assessment conducted in Sri Lanka in February 2005, after the Indian Ocean tsunami, it was estimated that nearly 98,500 housing units had been damaged. The government of Sri Lanka (GOSL) announced the use of a coastal buffer zone as a disaster prevention mechanism. Based on the buffer zone policy, government initially estimated 55,525 housing units could be reconstructed *in-situ* through the homeowner-driven cash grant program financed by the World Bank and other donors, but that all other households would need to be relocated elsewhere. The buffer zone decision was based more on the need for government to provide an immediate response than on well-researched technical considerations and public consultation, and applying the decision to a densely populated coastal belt had profound implications on the environment, on livelihoods, and on the economy.

Almost immediately, the prohibition of reconstruction in the buffer zone set off a wave of land clearing for housing schemes in the hinterland (some in environmentally sensitive areas). No environmental assessment methodology or environmental management practices were enforced for site selection and construction. As a result, crucial environmental planning practices were ignored. Subsequently, due to many problems with implementation, the GOSL withdrew the buffer zone policy and reverted to the coastal protection zone (CPZ) setbacks stipulated in the Coastal Zone Management Plan already established by the Coast Conservation Department using scientific investigation.

Reverting to the CPZ was positive. It reduced the coastal population that needed to be relocated; the number of owner-driven *in-situ* grants was revised upward to 78,500 housing units. However, combined with poor communications with the public regarding the change, it also had negative consequences, delaying reconstruction by six months for many families who thought they would have to relocate. It also had a differential economic impact on families in the CPZ: they were offered a donor-built house irrespective of prior land ownership status when it was thought they would have to relocate, whereas families outside the CPZ were eligible for the cash grant, and only if they could document land ownership. Additionally, some poor families inside the buffer zone reportedly sold their land cheaply thinking they could not reconstruct *in-situ*. If this were widespread, it might have caused a redistribution of wealth in the coastal areas, although there is no documented evidence that this occurred.

Sources: World Bank, 2005, "Sri Lanka Post-Tsunami Recovery Program Preliminary Damage and Needs Assessment," <http://go.worldbank.org/BSJBQ6RH10>; and World Bank, 2009, "Tsunami Emergency Recovery Program, Implementation Completion and Results Report," Report No. ICR00001105.



1999 Floods, Bamako, Mali

Disaster Risk Management as Sustainable Local Development

Flash flooding throughout Bamako, Mali, in August 1999, caused death, destruction, and significant economic losses for several thousand families. The United States Agency for International Development Office of U.S. Foreign Disaster Assistance (OFDA), in collaboration with Action Contre la Faim, an international NGO that works to provide safe water, analyzed the causes of the flooding and launched a 4-year, US\$525,000 mitigation project in the city's most flood-affected district. One of the primary causes of flooding in Bamako, as in many cities, was the disposal of solid waste in waterways, which reduced the storm water capacity of waterways. The project, which aimed to reduce flooding risks by improving storm water management and solid waste management, was part of a larger effort to help local governments improve services, including flood mitigation, which was one of the most critical. Watershed management techniques included improving storm water retention, removing debris from the drainage system, and expanding solid waste management using local collection teams. The project generated livelihood opportunities for unemployed youth, and quickly became self-sustaining, with fees more than offsetting costs. As a consequence, Bamako has not since had a similar flood disaster. The project had other unanticipated impacts, including the reduction in the incidence of water- and mosquito-borne illnesses by 33 percent to 40 percent in the project area.

In a similar project in Kinshasa, Democratic Republic of Congo, in 1998, OFDA calculated that the program, rather than having a cost, produced a projected net savings of US\$426 per household, the equivalent of more than 50 percent of annual household income. The Ministry of Health of the Democratic Republic of Congo showed that the project, which included a public health education component, reduced the incidence of cholera in the community by more than 90 percent.

This model of reducing risk by improving local public services, which shows how risk reduction can contribute to broader development goals, can easily be replicated in other cities with similar challenges.

Source: Charles A. Setchell, 2008, "Multi-Sector Disaster Risk Reduction as a Sustainable Development Template: The Bamako Flood Hazard Mitigation Project," Monday Developments (April 2008), http://www.usaid.gov/our_work/humanitarian_assistance/disaster_assistance/sectors/files/Multi_Sector_Disaster_Risk_Reduction.pdf.

Resources

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World Bank, "Disaster Risk Management," <http://go.worldbank.org/BCQUXRROW0>.

Hazard Data

Hazard	Type of data/use	Potential data sources
Cyclone	Land cover data /Wind barriers (trees, buildings); damage (flying objects, fallen trees)	A, E, NR, FS, RSA, PRSF, PL
	Elevation data /Wind acceleration; coastal surge intrusion	A, E, PW, WR, RSA, PSIP
	Bathymetry (shoreline water depth) /Storm-surge hazard modeling	A, E, MA, NR, PW, WR
	Wind speed maps	PL, PW
	Coastline and still-water elevation maps /Storm-surge hazard modeling	A, E, MA, NR, PW, WR, PL
Drought	Precipitation and rain gauge data /Rainfall records and trends	A, ME, WR
	Global humidity index	UNEP/GRID University of East Anglia/ Climatic Research Unit
Earthquake	Soil maps /Ground motion patterns	A, E, I, L, NR, SS
	Soil and ground conditions maps /Liquefaction susceptibility	DM, E, SS
	Landslide potential data /Post-earthquake landslide potential	DM, E, SS
	Fault line maps	A, DM, E, I, L, NR, SS
Fire	Fuel maps, land cover maps /Fire fuel sources	A, E, F, NR, RSA, PRSF
	Critical weather data (low humidity, wind)	A, ME, WR
	Land elevation /Predict fire speed	A, E, PW, WR, RSA, PSIP
Flood	Digital Elevation Model (DEM) or Digital Terrain Model (DTM) for bare earth /Predict water flow	A, E, PW, WR, RSA, PSIP
	Contour data /Complements DEM/DTM data	PW, SW
	Historic precipitation data	A, ME, WR, PL
	Soil data /Areas of water infiltration	A, E, I, L, NR, SS
	Locations of river and hydraulic structures (bridges, dams, levees)	A, E, I, L, NR, PW
Landslide	Slope data (DEM, DTM) /Areas of susceptibility	A, E, PW, WR, RSA, PSIP
	Soils maps /Areas of high susceptibility	A, E, I, L, NR, SS
	Land cover	A, E, F, NR, RSA, PRSF, PL
Tsunami	Bathymetry (shoreline water depths) /Tsunami hazard modeling	A, E, F, MA, NR, PW, WR
	Coastline still-water elevations /Tsunami hazard modeling	A, E, F, MA, NR, PW, WR
	Elevation data /Tsunami intrusion	A, E, PW, WR, RSA, PSIP

KEY: Public ministry, department, or agency: A=Agriculture and Fisheries, DM=Disaster Management, E=Environment, I=Irrigation, L=Land Management, F=Fisheries, MA=Maritime Affairs, ME=Meteorological, NR=Natural Resources, PL=Local Planning, PW=Public Works, WR=Water Resources, FS=Forestry, RSA=Remote Sensing Agencies (such as IKONOS or NASA's ASTER), SW=Storm Water Management, SS=Soil Survey. Private sources: PRSF=Private Remote Sensing Firm, PSIP=Private Satellite Imagery Provider.



Vulnerability Data

Asset	Type of Data/Use	Potential Data Sources
Population	Census data /Population locations, vulnerable populations (e.g. young, elderly, impoverished, etc.), and demographics	CSO, MP, MS
Buildings	Critical infrastructure – medical care /Locations and capacities of hospitals and clinics	MH, MP
	Critical infrastructure – police and civil defense / Locations and capacities of responders	CD, MP
	Critical infrastructure – fire / Locations and capacities of responders	CD, MP
	Building locations /Structural damage and loss locations	CSO, MP, MS, PRSF, PSIP, RSA
	Building characteristics /Structural damage and loss quantification, building types, construction types, vulnerable characteristics (e.g. roof type, first floor elevation, foundation type, etc.)	LB, MP, PRSF, PSIP, PW, RSA
	Vulnerability functions /Structural damage and loss quantification	ACOE, FIA, U
Transportation Lifelines	Road data /Damage locations, road closures	MP, MT, PRSF, PSIP, RSA
	Bridge data /Damage locations, bridge closures	MP, MT, PRSF, PSIP, RSA
	Railroad data /Damage locations, rail closures	MP, MT, PRSF, PSIP, PRC, RSA
	Port data /Damage locations, port closures, economic loss	MA, MP, MT, PRSF, PSIP, PPC, RSA
Utility Lifelines	Electrical Data /Damage locations, power outages	MP, MPw, PW
	Potable Water Data /Damage locations, water availability	MP, MW, PW
	Communication Data /Damage locations, communication outages	MC, MP, PW

KEY: ACOE=U.S. Army Corps of Engineers, CD=Civil Defense, CSO=Central Statistical Organization, FIA=Flood Insurance Administration, LB=Local Builders, MA=Maritime Affairs, MC=Ministry of Communications, MH=Ministry of Health, MP=Ministry of Planning, MPw=Ministry of Power, MS=Ministry of Statistics, MT=Ministry of Transportation, MW=Ministry of Water, PPC=Private Port Companies, PRC=Private Rail Companies, PW=Public Works, RSA=Remote Sensing Agencies, U=Universities.