

THE GREAT EAST JAPAN EARTHQUAKE

LEARNING FROM MEGADISASTERS

Knowledge Notes Executive Summary



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Executive Summary

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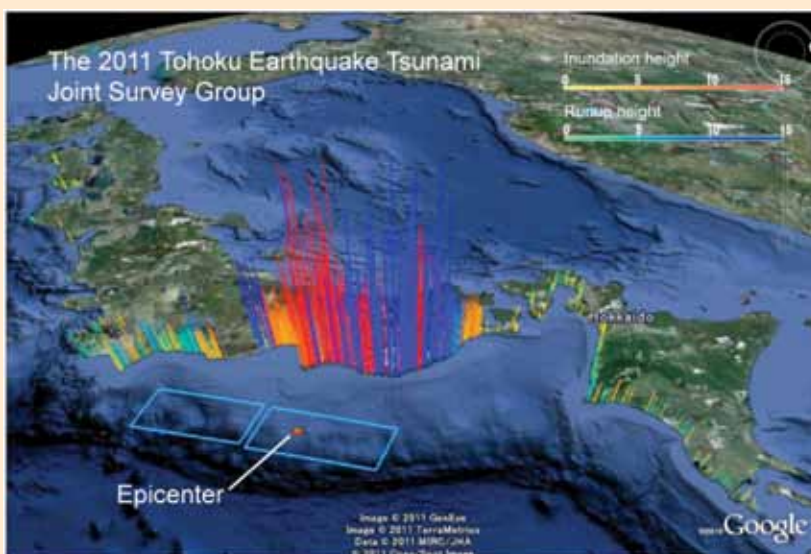
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KNOWLEDGE NOTES: EXECUTIVE SUMMARY

THE GREAT EAST JAPAN EARTHQUAKE OF 2011

On March 11, 2011, an earthquake of magnitude 9.0 occurred in the Pacific Ocean off the coast of Japan's Tohoku region. The quake shook the ground as far away as western Japan and lasted for several minutes. A half hour later, a tsunami of unprecedented force broke over 650 kilometers of coastline (figure 1), toppling sea walls and other defenses, flooding more than 500 km² of land, and washing away entire towns and villages.

FIGURE 1: **The tsunami struck a wide area of Japan**



Source: The 2011 Tohoku Earthquake Tsunami Joint Survey Group <http://www.coastal.jp/ttjt/index.php>

The devastation left some 20,000 people dead or missing, with most of the deaths caused by drowning (table 1). The tsunami leveled 130,000 houses and severely damaged 260,000 more. About 270 railway lines ceased operation immediately following the disaster, and 15 expressways, 69 national highways, and 638 prefectural and municipal roads were closed. Some 24,000 hectares of agricultural land were flooded. The areas worst hit were the Fukushima, Iwate, and Miyagi prefectures.

WHAT THE DISASTER TAUGHT JAPAN—AND WHAT IT CAN TEACH OTHER COUNTRIES

The Great East Japan Earthquake (GEJE) was the first disaster ever recorded that included an earthquake, a tsunami, a nuclear power plant accident, a power supply failure, and a large-scale disruption of supply chains.

Learning from Megadisasters, a knowledge-sharing project sponsored by the Government of Japan and the World Bank, is collecting and analyzing information, data, and evaluations performed by academic and research institutions, nongovernmental organizations, govern-

TABLE 1: **The Great East Japan Earthquake of 2011 in Figures**

| | |
|---|--------------------------|
| Casualties as of August 8, 2012 | |
| Dead | 17,500 |
| Missing | 2,848 |
| Injured | 6,109 |
| Building damage as of August 8, 2012 | |
| Total collapse | 129,316 |
| Half collapse | 263,845 |
| Partial damage | 725,760 |
| Evacuees | |
| Maximum | 470,000 (March 14, 2011) |
| Current | 343,334 (August 2, 2011) |
| Estimated economic damage | |
| Buildings | ¥10.4 trillion |
| Public utilities | ¥1.3 trillion |
| Social infrastructure | ¥2.2 trillion |
| Other (agriculture, forests, fisheries) | ¥3.0 trillion |
| Debris | 31.2m tons (July 2012) |

Source: Cabinet Office and Reconstruction Agency.

ment agencies, and the private sector—all with the objective of sharing Japan’s knowledge on disaster risk management (DRM) and postdisaster reconstruction with countries vulnerable to disasters. The Bank and the Japanese government hope that these findings will encourage countries to mainstream DRM in their development policies and planning.

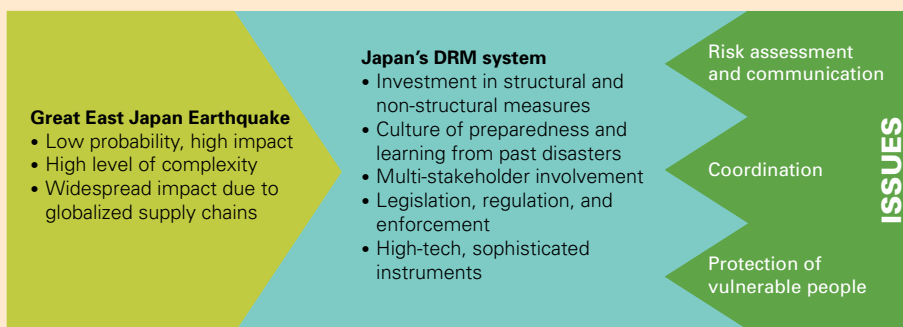
Japan had not foreseen an event of this magnitude and complexity.

- ***It was a high-impact event with a low probability of occurrence.*** Because of enormous damage from the tsunami and moderate but widespread geotechnical damage, the GEJE event was the costliest earthquake in world history. Japan’s Cabinet office has estimated the direct economic cost at ¥16.9 trillion, or \$210 billion.
- ***It was a highly complex phenomenon, the effects of which cascaded to sensitive facilities.*** The earthquake and ensuing tsunami provoked fires at damaged oil refineries and a potentially catastrophic nuclear accident. The effects of the accident at the Fukushima Daiichi nuclear power plant have compromised Japan’s energy supply, imperiled its environment, and threatened public health.
- ***Direct damage to major Japanese industries rocketed through supply chains around the world.*** In the second quarter of 2011, Japan’s GDP dipped 2.1 percent from the previous year, while industrial production and exports dropped even more sharply—by 7.0 percent and 8.0 percent, respectively. Japan experienced a trade deficit for the first time in 31 years. In the wake of the tsunami, businesses that relied on Japanese electronics and automotive parts faced disruptions and delays in production, distribution, and transportation; they had to scramble to find alternate supply lines and manufacturing partners.

In coping with the GEJE, Japan’s advanced DRM system, built up during nearly 2,000 years of coping with natural risks and hazards, proved its worth. The loss of life and property could have been far greater if the country’s policies and practices had been less effective. The main elements of that DRM system are:

- Investments in structural measures (such as reinforced buildings and seawalls), cutting-edge risk assessments, early-warning systems, and hazard mapping—all supported by sophisticated technology for data collection, simulation, information, and communication, and by scenario building to assess risks and to plan responses (such as evacuations) to hazards
- A culture of preparedness, where training and evacuation drills are systematically practiced at the local and community levels and in schools and workplaces
- Stakeholder involvement, where the national and local government, communities, NGOs, and the private sector all know their role
- Effective legislation, regulation, and enforcement—for example, of building codes that have been kept current
- The use of sophisticated instrumentation to underpin planning and assessment operations.

FIGURE 2: Summary of findings and lessons learned from the project



Certain improvements would have made the Japanese reaction even more effective. Three are particularly important and are singled out here (as well as being included in the section on lessons learned that appears further on):

- ***Spreading a better understanding of the nature and limitations of risk assessment*** among local authorities and the population at large would improve collective and individual decision making, especially in emergencies. Communication about the unfolding disaster could and should have been more interactive among local communities, governments, and experts. Distributing hazard maps and issuing early warnings were not enough. In the event, the magnitude of the tsunami was underestimated, which may have led people to delay their evacuation, if only for a fatal few minutes. If local governments and community members had been more aware of DRM technologies and their margins of error, fewer lives might have been lost.
- ***Coordination mechanisms on the ground should be agreed on before the fact.*** During the GEJE, coordination among various groups, such as governments (national, prefectural, and local), civil society organizations (CSOs), and private entities was often poor—or at least not optimal. Local governments, whose facilities in some cases were wiped out by the disaster, had little experience working with other organizations on a large scale, and they received insufficient support from the central government in managing the new forms of cooperation. As it turned out, coordination with international relief agencies and donors offering exceptional assistance was simply not up to the unprecedented task.
- ***Vulnerable groups must be not only protected but also engaged.*** Understanding and meeting the challenges of the elderly, children, and women, both during the emergency and in its aftermath, are priorities for effective postdisaster response. Culturally sound solutions that take account of special needs among segments of the population should be planned in advance to enhance resilience and facilitate recovery and reconstruction.

SHARING EXPERIENCES WITH DEVELOPING COUNTRIES

Other countries can protect themselves from major disasters by adopting—and adapting as necessary—some of the measures taken by Japan, and by understanding the strengths and weaknesses of Japan’s response to the GEJE. To help them do that, the Learning from Megadisasters initiative will provide data, analysis, and insight in printed and Web-based formats (including e-learning), in face-to-face activities, in seminars presented through the good offices of the Global Development Learning Network,¹ and through a dedicated community of practice—all designed to build the capacities of government decision makers and other stakeholders in developing countries. A searchable set of online materials at various levels of depth and detail will serve as a focal point for this community of learning and practice on DRM. The knowledge base will grow as practitioners from around the world contribute their insights and expertise.

The first phase of the project delivered a set of 32 “Knowledge Notes” grouped into six thematic clusters:

- Structural measures
- Nonstructural measures
- Emergency response
- Reconstruction planning
- Hazard and risk information and decision making
- Economics of disaster risk, risk management, and risk financing.

The notes analyze and synthesize what worked, what did not, and why in the response to the March 11, 2011, earthquake and tsunami, offering recommendations for developing countries that face similar risks and vulnerabilities.

The Notes were prepared by more than 20 Japanese and international experts, assisted by advisers and reviewers. The team included developing country practitioners, academic experts, and government officials. The KNs will provide a basis for knowledge sharing and exchanges with developing countries experts and practitioners in the coming years.

Key lessons derived from the 32 Knowledge Notes are offered in the pages that follow, after which the six thematic clusters are reviewed in turn.

¹ The GDLN, headquartered at the World Bank Institute, is a network of video-conferencing facilities in many locations around the world that can be mobilized on short notice for real-time meetings and workshops.

KEY LESSONS LEARNED FROM THE PROJECT

The successes of Japan's DRM system, as well as the ways in which that system could be improved, are reflected in the lessons drawn from the GEJE and presented in the initial reports from the Learning from Megadisasters project.

EXTREME DISASTERS UNDERScore THE NEED FOR A HOLISTIC APPROACH TO DRM

Single-sector development planning cannot address the complexity of problems posed by natural hazards, let alone megadisasters, nor can such planning build resilience to threats. Faced with complex risks, Japan chose to build resilience by investing in preventive structural and nonstructural measures; nurturing a strong culture of knowledge and learning from past disasters; engaging in wise DRM regulation, legislation, and enforcement; and promoting cooperation among multiple stakeholders, between government agencies and ministries, between the private sector and the government, and between multiple levels of governance, from local to national to international.

Today, Japan is placing even heavier emphasis on recognizing and respecting complexity and residual risk, designing and managing systems that “fail gracefully”—that is, that mitigate damage to the greatest extent possible before succumbing to overwhelming force. The essence of the approach is to design and maintain resilient infrastructure capable of absorbing damage from natural disasters to some extent, even when an event exceeds all feasible and affordable measures. In the wake of the GEJE, Japan also recognized that additional efforts were required to plan and design measures capable of countering events of low probability but high impact.

PREVENTIVE INVESTMENTS PAY, BUT BE PREPARED FOR THE UNEXPECTED

Japan's extensive structural precautions were very effective in protecting buildings and people from the earthquake. Although 190 kilometers of the 300 kilometers of dikes in the area collapsed, they decreased the force of the tsunami and, in some areas, delayed its arrival inland. All bullet trains stopped safely without casualty, thanks to a cutting-edge system of detecting the earliest sign of ground movement. The GEJE, however, exceeded all expectations and predictions in the extent of its ensuing tsunami, demonstrating that exclusive reliance on structural measures will ultimately prove ineffective and must be supplemented with nonstructural measures and a basic understanding of the uncertainties surrounding the estimation of events such as earthquakes and tsunamis.

Because it is not practical—from a financial, environmental, or social perspective—to build tsunami dikes 20 to 30 meters high, Japan's government intends to accelerate the current paradigm shift in its thinking about disaster management, complementing its structure-focused approach to prevention with soft solutions to achieve an integrated approach to disaster risk reduction. Understanding that the risks from natural hazards can never be completely eliminated, the new, balanced approach incorporates community-based prevention and evacuation and other nonstructural measures such as education, risk-related finance and insurance, and land-use regulation.

LEARNING FROM DISASTER IS KEY, AS JAPAN HAS SHOWN FOR THE PAST 2,000 YEARS

Japan has used the lessons of past disasters to improve its policies, laws, regulations, investment patterns, and decision-making processes, as well as community and individual behaviors. Investing in preparedness and a strong culture of prevention made all the difference in the Tohoku region when the GEJE struck. The Meiji-Sanriku Tsunami of 1896 killed 40 percent of the population in the affected zone, whereas the GEJE claimed only 4 percent.² Evacuation drills and DRM education, staples of the country's schools, kept children safe in Kamaishi City. The famous "Kamaishi Miracle" was not really a miracle at all, but rather the result of a sustained effort to instill a culture of resilience and prevention based on continuous learning.

DRM IS EVERYONE'S BUSINESS

Japan's disaster management system addresses all phases of disaster prevention, mitigation and preparedness, and emergency response, as well as recovery and rehabilitation. It specifies the roles and responsibilities of national and local government and enlists the cooperation of relevant stakeholders in both the public and private sectors. This comprehensive approach secured a quick and effective mobilization of forces at multiple levels after the 2011 tsunami struck, while also revealing certain problems of coordination that are discussed further on. Since the tsunami, the capacity of local DRM planning systems to prepare for and react to large-scale disasters has been assessed, and revisions have been proposed through new legislation.

Japan's central government plays a leading role in mitigating the risks of disaster across the country, but local governments have the principal responsibility for managing the country's DRM systems. The central government encourages local governments to promote structural measures by providing financial support, producing technical guidelines and manuals, and conducting training for technical staff in planning, design, operation, and maintenance.

Japan's tradition of community participation in preparedness was a key factor in minimizing the number of lives lost to the GEJE. Community-based DRM activities are well integrated into the daily lives of most Japanese, ensuring that awareness of natural hazards is never far from their mind. The national and local governments formally recognize and support the involvement of the community in DRM through laws and regulations that define roles and commitments, through linkages with local institutions (such as *jichikai*, or neighborhood associations), and through participation in meetings at which decisions are made.

Although dikes and communication systems suffered partial failures and forecasting systems underestimated the height of the tsunami, local communities and their volunteer organizations were front and center in responding to the disaster. The GEJE showed that each community needs to explore and identify its best defense, mixing various soft and hard measures, policies, investments, education, and drills, through sound analysis and stakeholder consultations.

2 The Meiji tsunami occurred at night, whereas the GEJE struck during the day.

FIGURE 3: **The many roles of the community in multihazard DRM**



The role of the community goes far beyond evacuation, especially in multihazard DRM (figure 3). Successful evacuations depend on prior measures such as hazard mapping, warning systems, and ongoing education, all of which proved essential in the evacuation that followed the GEFE. During the GEJE, local governments and communities in affected areas served as first responders, managed evacuation centers, and promptly began postdisaster reconstruction. Partnerships with the private sector were also critical. Rehabilitation could begin the day after the earthquake because agreements with the private sector were already in place. Quick payment of insurance claims allowed individuals and businesses to contribute fully to the rehabilitation effort.

ASSESSING RISKS AND COMMUNICATING THEM CLEARLY AND WIDELY HELPS CITIZENS MAKE TIMELY DECISIONS TO PROTECT THEMSELVES

Accurate risk assessment and interactive communication systems that connect local communities, government agencies, and experts make people less vulnerable and more resilient. But although risk assessments and DRM technologies (including prediction systems) can add enormous value, governments and community members should be aware of their limitations and never stick to a single scenario.

HAZARD MAPS CAN GIVE THE PUBLIC A FALSE SENSE OF SAFETY, IF NOT PROPERLY COMMUNICATED

Although hazard maps showing risk areas and evacuation shelters had been distributed before the disaster to households in the tsunami-stricken areas, only 20 percent of the people had seen them. Still, 57 percent (which is a relatively high number by international standards) left immediately after the earthquake tremors. In some areas, the tsunami of 2011 proved far greater than indicated on the hazard maps. Warnings that underestimated the size of the earthquake and tsunami may have caused people to delay their evacuation, prolonging their exposure to danger. Because the magnitude of the GEJE and tsunami far exceeded the predisaster estimates, the Japanese government has been revising its methods of assessing earthquake and tsunami hazards, combining historical evidence, topographical and geological studies, and predictions and forecasts based on scenarios for events of low probability but high impact. Manufacturers and other companies are rethinking their strategies for business continuity. Many Japanese companies are already investing in redundancy and diversification within their supply chain, despite the expense of such measures.

BETTER MANAGEMENT OF INFORMATION AND COMMUNICATION IS CRUCIAL IN EMERGENCIES AND RECOVERY OPERATIONS

The GEJE points to two common information problems: (i) the lack of real-time information on conditions and on coordination among parties (that is, on who is doing what); and (ii) the loss of critical public records vital to reconstruction. With regard to the first point, during the GEJE the national government collected information from municipal governments, while additional information was crowd-sourced and channeled through social media and the Internet. On the second point, even though some local governments lacked a formal backup system, data on land ownership were restored fairly quickly, thanks to other official and private backups. Nevertheless, health records in some cities were destroyed, and new policies to avoid a recurrence are needed.

Many postdisaster situations are made worse by the lack of a communications strategy that makes use of appropriate media to deliver critical messages. Good information enables individuals and communities not only to stay safe, but also to contribute more effectively to relief and recovery. It also ensures that citizens have a realistic set of expectations about relief and reconstruction. If communication is to help people stay safe and minimize the disruption to their lives, they must be able to trust the information and its source. During the GEJE, communication about evacuation, temporary shelters, and emergency food distribution was handled fairly well, but confusion about the scope and extent of the nuclear accident led to public dissatisfaction, as noted in a report from Japan's Nuclear and Industrial Safety Agency.

COORDINATION MECHANISMS MUST BE DEVELOPED AND TESTED IN NORMAL TIMES, SO THAT THEY ARE READY FOR USE IN AN EMERGENCY

Although the national government established the rescue headquarters very quickly, and interprefectural emergency and rescue units and technical forces were deployed in record time, mechanisms for formal coordination among the various stakeholders (government

agencies at all levels, CSOs, and private entities) were inadequate. The GEJE drew an unprecedented level of assistance from 163 countries and 43 international organizations. In all, Japan received \$720 million from other countries, almost half of all humanitarian disaster funding dispensed around the globe in 2011. The weakness of coordination observed on the ground during the GEJE demonstrates that coordination mechanisms should be established through advance agreements and clear definitions of responsibility.

VULNERABLE GROUPS MUST BE PROTECTED—AND ENGAGED

Culturally appropriate services and social safety nets for vulnerable groups are needed in times of emergency and during reconstruction. They should be planned in advance. Two-thirds of the deaths during the GEJE occurred among people over the age of 60, who accounted for just 30 percent of the population in the affected areas. At evacuation centers, the needs of women and the disabled were not fully met. New measures are under consideration to assure privacy and security for women, maternal care and gender-balanced policies, and better nursing care for the disabled at evacuation centers. These measures call for empowering marginalized groups for long-term recovery and including a gender perspective in planning and managing shelters, which will require women to be more deeply involved in shelter management. Women should be encouraged to participate in DRM committees, center management, and risk assessment. National and local DRM policies and strategies should be reviewed from a gender perspective.

DETAILED FINDINGS AND RECOMMENDATIONS

The Knowledge Notes that make up the main body of this report were built around the disciplines employed in the traditional DRM cycle. Grouped into six clusters that track that cycle, the Knowledge Notes treat structural measures (cluster 1) and nonstructural measures (cluster 2) as preventive options. They also cover the emergency responses put in place after March 11 (cluster 3) and describe how the recovery process started (cluster 4). The handling of risk assessment and communication before and after the disaster are the subject of cluster 5. Cluster 6 deals with risk financing, insurance, and fiscal and financial management. This section of the Executive Summary provides the reader with additional information and details about the main findings of the project and the lessons learned from it, following the scheme of thematic clusters used in the Knowledge Notes. Those Notes may be downloaded from www.worldbank.org/wbi/megadisasters.

CLUSTER 1: STRUCTURAL MEASURES

Dikes are both necessary and effective in preventing ordinary tsunamis, which are relatively frequent, but they are of limited use against the extreme events that occur less frequently. Japan's Tohoku region built 300 kilometers of coastal defense over the course of 50 years. National and local governments invested a total of \$10 billion to build coastal structures and breakwaters in major ports. During the GEJE, the defensive structures along the coast suffered unprecedented damage: 190 of the 300 kilometers of coastal structures collapsed under the tsunami (figure 4). In some areas they did serve to delay the arrival of the waves, buying extra minutes for people to evacuate. Because many tsunami gates designed to reduce flooding along rivers were toppled, the Government

FIGURE 4: **Dikes in Sendai before and after the tsunami of March 11, 2011**



Source: Ministry of Land, Infrastructure, Transport and Tourism

of Japan launched a structural assessment to better understand the causes of failure. The assessment concluded that construction standards and stability performance under worst-case scenarios should be further investigated. Structures should be able to withstand waves that exceed their design height, reducing the force of the water before they collapse and thereby mitigating damages.

Reinforced infrastructure and buildings erected according to current codes were not seriously damaged. Thanks to Japan's strict and rigorously enforced building codes, earthquake-related losses from the March 2011 disaster were limited, with most of the deaths and economic damage being caused by the ensuing tsunami. Since Japan's first building code was adopted after the Great Kanto Earthquake of 1923, the government has made regular revisions in light of experiences with a range of natural disasters. During the GEJE, most damage to buildings was caused by phenomena other than the earthquake itself. Liquefaction occurred on building lots that had not been treated against liquefaction, and in reclaimed lands and on riverbanks, damaging small buildings that lacked pile foundations.

Tsunami damage to crucial facilities, including the Fukushima Daiichi nuclear power station, had cascading effects in several sectors, such as power and energy, petroleum refining, steel production, the automobile industry, fishing, health and medicine, farming, and telecommunications. Critical facilities should be built in safe locations and secured by the most sophisticated disaster management plans. The sea wall protecting the Fukushima

Daiichi nuclear power station had not been designed to withstand the enormous force of the GEJE tsunami, because the worst-case scenario had not been taken into account, as stated by the official committee formed to investigate the accident.

The Interim Report of the Government Investigation Committee on the Accident at the Fukushima Nuclear Power Station identified three main causes of failure: (i) DRM plans were focused on earthquakes and not tsunamis, (ii) complex scenarios with multiple hazards consisting of earthquakes and tsunamis, compounded by simultaneous transport and communication failures, had not been foreseen, and (iii) the complex systems at the nuclear power station had not been managed in an integrated way. The generally accepted myth that nuclear power stations are “safe” had led to an underestimation of certain important risks. The analysis has prompted a reevaluation of risk assessment methods and DRM planning and countermeasures, which is likely to shape future policies and procedures.

A multilayered approach to DRM is needed, employing both structural and nonstructural measures. Defensive infrastructure alone is not enough to cope with infrequent disasters of high impact. Nonstructural measures also need to be established, including early-warning systems, rigorous planning and regulation, prompt evacuation of residents, and a variety of institutional and financial measures, such as insurance, rehabilitation funds, and emergency teams.

CLUSTER 2: NONSTRUCTURAL MEASURES

Japan has had a disaster management system in place since the Disaster Relief Act of 1947 and has long used disasters as opportunities to continuously improve that system. The initial emphasis was on disaster response, later complemented by prevention, mitigation, and preparedness; emergency response and recovery; and rehabilitation and rebuilding. Over the years, the country’s investments in disaster preparedness have been wide ranging, covering seismic and tsunami detection, early-warning systems, multichannel systems for disseminating warnings, hazard mapping, evacuation planning (routes and shelters), regular disaster training and drills in schools and at workplaces, and improved signage. Municipal governments have the main responsibility for disaster management, including formulating and implementing local disaster management plans based on the national plan, establishing community-based organizations, distributing hazard maps to the public, raising public awareness, and developing evacuation procedures.

EARLY WARNINGS AND COMMUNICATION

The risk of underestimating a disaster’s impact can be extremely costly. The warnings issued on March 11 underestimated the tsunami’s height and likely caused people to delay their evacuation. Warning systems were effective in mitigating damage, but experience showed that they have to be better aligned with the communities’ evacuation procedures. More than half of the fleeing population evacuated by vehicle, and a third of them got stuck in traffic jams before reaching emergency evacuation shelters. Many people and their vehicles were swept away by the tsunami. Although the general rule is to evacuate on foot, vehicles are also needed, particularly to move the elderly and disabled. New measures to facilitate evacuation by vehicle—for example, rules to mitigate traffic jams and training for drivers on evacuation during disasters—should be considered.

The early earthquake detection system saved thousands of passengers in the Shinkansen. Nineteen bullet trains (Shinkansen) were running when the GEJE occurred, including two at 270 kilometers per hour, almost top speed. All were able to stop safely thanks to early earthquake detection systems. The Japan Meteorological Agency issues earthquake information based on nationwide seismography and observations of seismic intensity. The agency operates an earthquake early warning system that quickly estimates an earthquake's focus and magnitude and forecasts seismic intensities and the arrival time of ground shaking.

HOW COMMUNITIES AND THE PRIVATE SECTOR SAVED LIVES AND ASSETS

Community-based organization saved lives and needs to be nurtured. When the tsunami overwhelmed coastal defenses, local communities were forced to use their own knowledge and resourcefulness to survive on March 11. Fortunately, throughout the Tohoku region, communities had been intently engaged in tsunami preparedness. Given the unreliability of predictions and the limitations of defensive structures, community engagement should be put at the center of the disaster-response system.

The “Kamaishi Miracle” was not a miracle at all. Evacuation drills and DRM education are a fixture in Japan's schools. In Kamaishi City, where the tsunami claimed 1,000 of the population of 40,000, the casualty rate among school children was low: only 5 out of 2,900 primary and junior high school students lost their lives, the rate 20 times lower than for the general public. Regular practice drills, education in the schools, and hazard maps are the keys to preparedness. DRM education saves the lives of schoolchildren.

Well-prepared business continuity plans prevent disruptions. A business continuity plan (BCP) identifies an organization's critical operations and the potential effects of a disaster, specifying the response and recovery measures the business can take to avoid or minimize disruptions and continue operations at an acceptable level. The GEJE caused 656 private companies to go bankrupt within a year. Fully 88 percent of those businesses were located outside the Tohoku region and failed because of supply-chain problems. A BCP is essential regardless of where a business is based. According to a recent survey, between 80 and 90 percent of medium-sized and large companies indicated that their BCPs had been effective during the response and recovery phase.

RELOCATION AND NEW REGULATIONS

Land-use regulations, including those that relocate houses to higher ground, are successful but sometimes difficult to implement. For that reason, alternative measures need to be considered. Relocation deeply affects the livelihoods and daily lives of many people. Houses that had been relocated after the previous tsunami to hit Yoshihama Village were not affected by the GEJE. But in the coastal village of Taro, identifying suitable relocation sites proved problematic, since its economic activities were situated on the coast. The case of Touni-hongo perhaps best illustrates the benefits of relocation and the challenges of land-use regulation. Houses that had been relocated to higher ground after an earlier tsunami were unharmed by the GEJE tsunami, whereas newly constructed houses in the unregulated lowlands were hard hit. These examples highlight the importance of alternative measures when relocation is not a realistic option, such as disaster-preparedness education, evacuation drills, accessible evacuation routes, and appropriately designed structures.

Japan's Basic Disaster Management Plan, as revised after the GEJE, aims to rigorously enforce earthquake and tsunami countermeasures. Addressing a new set of scenarios that take into account the largest possible disaster and multiple simultaneous hazards, the plan calls for the development of disaster-resilient communities, the promotion of disaster awareness, increased research and scientific observation, and stronger systems to warn of tsunamis and deliver evacuation information.

CLUSTER 3: EMERGENCY RESPONSE

PROMPT REHABILITATION OF INFRASTRUCTURE

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) set up its emergency headquarters at 15:15 (about 30 minutes after the quake). Thanks to the dedicated service of well-trained and experienced government staff, prior agreements with private sector, and advance financial arrangements, the roads leading to towns on the affected coast were cleared in less than a week, a relatively short period. Also, by March 15, all 14 ports were either entirely or partially usable and began accepting vessels delivering emergency supplies and fuel. By April 29, the entire Tohoku Shinkansen line was in operation, as were most of the other railways except for those along the coast. Water supply services were resumed for about 90 percent of residents within a month, while electric power was 90 percent restored within a week.

GOVERNANCE IN TIME OF EMERGENCY

The GEJE revealed institutional and legislative features of Japan's governmental system that enabled it to take speedy action toward recovery in coordination with various agencies. In many developing countries, rapid recoveries are more challenging owing to shortages of dedicated agencies and highly skilled and experienced staff. Despite Japan's strengths, local governments in areas hit by the GEJE tsunami have faced difficulties in responding to the disaster. The GEJE affected 62 municipalities in six prefectures in northeastern Japan. Among them, 28 municipalities in the three worst-affected prefectures (Iwate, Miyagi, and Fukushima) suffered serious damage to their office facilities. Computer servers in some of these municipalities were seriously damaged or destroyed, resulting in a loss of data essential for the provision of municipal services. To make matters worse, many municipalities lost their public officials: 221 officials died or remain missing from 17 municipalities in the three hardest-hit prefectures.

Fukushima's case was unique. Nine municipalities near the crippled Fukushima Daiichi nuclear power station had to relocate their offices relatively far from the plant (but mostly within the same prefecture), because of concerns about radiation levels in their jurisdictions, even where the physical damage from the earthquake and the tsunami were very limited.

Many prefectures and municipalities outside Tohoku took the initiative to quickly send their own public officials to help the localities deal with postdisaster relief activities and other emergency operations. About 79,000 local government officials were dispatched from all over Japan to the affected prefectures and municipalities until the end of 2011. After one year, many of them are still serving there in capacities ranging from civil engineering and urban planning to social work and finance.

FIGURE 5: Otsuchi city hall after the tsunami struck



PARTNERSHIPS TO FACILITATE EMERGENCY OPERATIONS

Twinning arrangements between localities in disaster-affected areas and their counterparts in unaffected areas proved to be effective in dealing with the emergencies. Some of these arrangements were based on formal agreements, while others were based on good will. Where local governments are concerned, it is advisable to formalize such mechanisms before disasters strike, obtaining the necessary legal backing and clarifying cost-sharing arrangements. In a large-scale disaster, this kind of counterpart system—in which an unaffected local government provides support to another local government that has been affected by the disaster—allows support and assistance to be provided to all affected areas. For obvious reasons, it is essential that the linked prefectures and municipalities be geographically distant. Support agreements with localities in the same region may not be effective, particularly in a large-scale disaster like the GEJE that affected almost an entire region.

Coordination among government, CSOs, and other stakeholders to deal with the emergency on the ground was an overwhelming challenge. Expert teams, CSOs, volunteers, and military forces from around the world mobilized to help those of Japan, with 163 countries, 43 international organizations, and countless CSOs offering aid and relief. Foreign assistance far exceeded that provided in the wake of the Kobe earthquake in 1995. Considering the difficulties faced by local governments after the GEJE, coordination mechanisms should be established in the central government, or under an umbrella organization.

The system for delivery of relief goods encountered several problems, but measures have been identified to address them. The main problems in the delivery of relief goods

were fuel shortages, interruption of telecommunication services, and mismatches between supply and demand that caused goods to be stockpiled in prefectural and municipal depots instead of being delivered promptly to people in need. Several measures can be taken to address these issues, including prior surveys of depots, advance estimation of the quantities of emergency goods that will be required, guidelines on relief goods that are not likely to be culturally acceptable, support from professional logistics specialists, and logistics management support from local governments in unaffected areas.

EVACUATION CENTERS AND TEMPORARY HOUSING

At the peak of the relief effort, more than 470,000 people were housed in evacuation centers. After the disaster struck, nearly 2,500 evacuation facilities were established in the Tohoku region, with additional shelters located outside Tohoku. Most facilities, such as schools and community centers, were publicly owned and had already been designated as evacuation centers. After the GEJE, however, private facilities, such as hotels and temples, were enlisted, because the need for centers far exceeded expectations. Many evacuees stayed with relatives or friends. As construction of temporary housing progressed, evacuees gradually moved out of the centers. Four months after the disaster, about 75 percent of evacuation facilities had closed, although some in Tohoku stayed open as long as nine months. Because a megadisaster is likely to interrupt essential services such as water and power, it is critical to install alternatives such as portable toilets and power generators. Sendai City plans to equip its shelters with solar panels and other renewable energy options for backup power.

In Fukushima, many had to relocate from one evacuation center to another as the government expanded the mandatory evacuation zone. Some 82 percent of evacuees changed centers at least three times, and one-third changed more than five times. People in Fukushima have continued to migrate to other areas in and out the prefecture. At the end of 2011, more than 150,000 people had been evacuated, at least 60,000 of whom relocated to other prefectures across the country.

At many centers, a self-governing body emerged, with leaders and members of various committees selected by the evacuees themselves. Although managing evacuation centers is a municipal responsibility, most municipalities in the disaster-affected areas suffered staff losses, seriously weakening their capacity to cope with the emergency. At the beginning, most centers were supported by local teachers, volunteers, and other civil society groups. As the evacuation period lengthened, evacuees themselves started taking initiatives to manage their communities.

One of the problems cited at many shelters was lack of gender sensitivity. There was not enough privacy for anyone, but particularly not for women, many of whom did not have private spaces where they could change their clothes or breast-feed their babies. Many shelters eventually installed partitions, but these improvements often were late in coming. It has also been reported that relief goods delivered to the shelters were biased in favor of male evacuees. The lack of gender sensitivity has been attributed to the fact that men were largely responsible for managing the shelters, whether in facilities owned by municipalities or those managed by the evacuees themselves. In Japan, the overwhelming majority of the leaders of community organizations are male.

The special needs of vulnerable groups—including the elderly, children, and the disabled—need to be included in transition-shelter initiatives. The disabled often were not provided with proper care at evacuation shelters. The earthquake and tsunami left children feeling frightened, confused, and insecure. Following the GEJE, the number of incoming calls to *Childline*, a free counseling service for children, increased fourfold in Fukushima, Miyagi, and Iwate prefectures. The government plans to send some 1,300 mental health counselors to public schools in the affected areas. But the experience points to the importance of bringing in professional staff to care for the disabled and vulnerable.

Japan has learned many lessons about temporary housing from past experience with disaster recovery. In Kobe, for example, large tracts of temporary housing were built too far from the city center. The housing was allocated through a lottery system that created more hardship for those residents (especially the elderly) who wound up far from their old neighborhoods and suffered from the loss of community. The housing should be easily accessible, and complementary care services should be provided. Community-based organizations (such as Japan's *jichikai*) can help community members cope with the stresses of extended stays in transition shelters.

NEW CROWDSOURCED INFORMATION AND THE USE OF SOCIAL MEDIA AND FM RADIO

Social media were extensively used for searches, rescues, and fundraising. Social media are Web-based applications that use the Internet to connect people (prominent examples are Twitter and Facebook) as well as Web sites and computer applications that enable users to collaborate and create content, such as Wikipedia and YouTube. Emergency FM radio also played a crucial role in the aftermath of the GEJE (figure 6). When the

FIGURE 6: **Broadcasting at RINGO Radio**



Source: Kyoto University.

emergency communication systems in many cities broke down because of power failures and lack of emergency backup power, community radio stations were able to get useful information out to residents. In fact, about 20 emergency broadcasting stations dedicated to disseminating disaster information were set up in the Tohoku area. In the immediate aftermath of the disaster, these community radio stations began to provide information about times and locations for the distribution of emergency food, water, and goods. In the following months they gradually shifted to providing other information to help victims in their daily lives or to raise the spirits of people in local communities. Radio was particularly appreciated by the elderly, who were less likely than younger people to have access to Internet information.

With the relatively high levels of mobile phone penetration in developing countries, social media could be very useful during disasters, at least to the extent that they are already used in normal times. They can also serve to link up with communities outside the stricken areas to facilitate the acquisition and allocation of aid and assistance. In many developing countries, lack of physical accessibility to disaster-affected sites is a key issue. Mobile networks and social media can be used to collect and share localized information to improve access. Reliability or trustworthiness of information is an extremely important factor in the use of social media. Local governments and relevant national government agencies should, therefore, consider using social media in their public relations activities during normal times. When disasters occur, those channels can be used to share disaster-related information with the public.

CLUSTER 4: RECOVERY PLANNING

A NEW LAW FOR RECONSTRUCTION

Based on the recommendations of Japan's Reconstruction Design Council, the national government issued the Basic Act for Reconstruction and the Basic Guidelines for Reconstruction. The Reconstruction Agency, which the prime minister heads, was established under the oversight of the cabinet to promote and coordinate reconstruction policies and measures in an integrated manner. At the prefectural level, the three disaster-affected prefectures developed their own recovery plans. At the municipal level, most of the disaster-affected municipalities developed recovery plans based on the recovery policies of the national and prefectural governments. Municipalities have focused on land-use planning to build more resilient communities, including relocation, reconstruction projects, and consensus-building among residents on relocation and reconstruction plans.

Special reconstruction zones will be identified based on proposals by local governments in the disaster-affected areas, where concessions and incentives (regulatory, fiscal, budgetary, and financial) will be granted to companies that set up new facilities.

HASTENING RECOVERY AND RECONSTRUCTION THROUGH COOPERATION BETWEEN COMMUNITIES AND LOCAL AND NATIONAL GOVERNMENTS

Communities should be involved from the outset in planning reconstruction. In the areas affected by the GEJE, consultations between governments and communities were the rule, and community representatives were invited to serve alongside experts on recovery planning committees from the earliest stages. The most common ways of

collecting residents' opinions were surveys and workshops. The central government and local governments outside the disaster-affected area helped affected municipalities plan their recovery by conducting research, seconding staff, and hiring professionals to provide technical support. University faculty members, architects, engineers, lawyers, and members of NGOs participated in the municipal planning process.

DEBRIS AND WASTE MANAGEMENT

There is an urgent need to dispose of 20 million tons of debris left behind by the GEJE and tsunami, some of it contaminated by radioactivity. The debris was an enormous obstacle to rescue and it still impedes reconstruction. The amount of tsunami-related debris in Iwate was 11 times greater than a normal year's waste. In Miyagi, it was 19 times greater. To hasten recovery, local governments across Japan worked together to remove debris. Among the many issues that arose were the availability and selection of storage sites,³ methods of incineration, decisions about recycling, and waste treatment and disposal. Under Japan's Local Autonomy Act, municipal governments are expected to treat disaster-related waste in accordance with the prefectural government's waste-management plan, and different treatment and disposal methods must be used depending on the composition of the debris. The possibility of recycling should be considered. In general, authorities should prepare for disasters by designating temporary storage sites, traffic routes for transporting waste, and so forth. The role of the private sector in debris management, as well as cooperation with organizations and government bodies outside the affected areas, should be explored.

LIVELIHOOD AND JOB CREATION

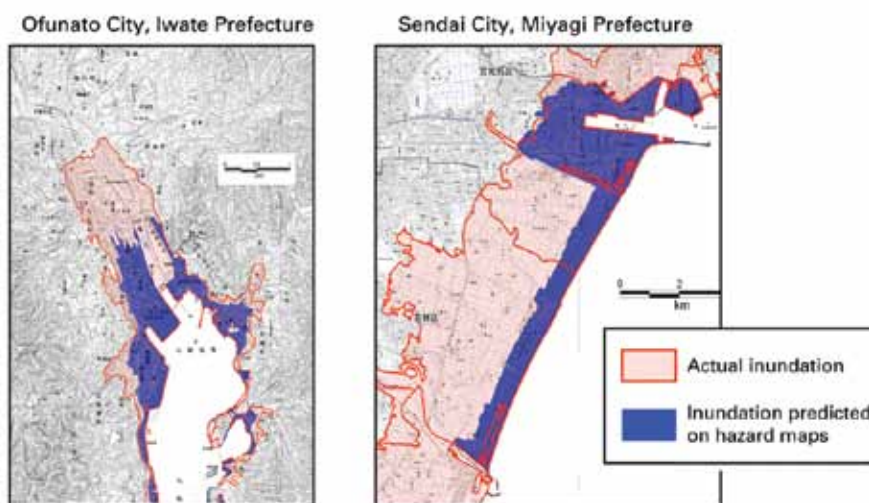
Maintaining existing sources of income and creating jobs are crucial during the reconstruction phase. When reconstruction is delayed, income normally generated by neighborhood shops or restaurants will be lost. Under the "Japan as One" work project, local governments in priority areas can avail themselves of job-creation funds. The town of Minami-sanriku, for example, received financial support for fiscal year 2011. As of January 2012 it had undertaken 47 job-creation projects employing 460 people. The town will likely receive more financial support for additional employment and livelihood projects.

CLUSTER 5: HAZARD AND RISK INFORMATION AND DECISION MAKING

The limitations of predictive and risk-assessment technologies need to be understood. In Miyagi, the government predicted a high probability of an earthquake occurring but underestimated its size and the ensuing tsunami risk. The official hazard map depicted risk areas that were small than the area actually affected by the GEJE. Given the uncertainties associated with hazard prediction and risk assessment, earthquake and tsunami risks should be assessed based on multiple scenarios, taking into account every conceivable eventuality and utilizing all the tools science has to offer. They should also be informed by historical records going back as far as possible, combined with a thorough analysis of the literature in the field, topographical and geological studies, and other scientific findings.

³ Waste treatment outside the affected area is usually required but difficult to arrange. Previous experience in Tohoku suggested that finding dumping sites would be a problem.

FIGURE 7: **Actual inundation areas were much larger than predicted**



Source: Cabinet Office.

All districts along the Tohoku coast had prepared tsunami hazard maps prior to GEJE, but the extent of flooding experienced in some areas far exceeded the maximum extent of inundation predicted on the maps (figure 7). Hazard maps are used by local governments in their disaster-preparedness plans to raise awareness of the risks of disaster among local residents. The hazard map is a crucial tool for communicating information on risks and countermeasures. Involving the community in its preparation helps raise awareness and maximize engagement when a disaster strikes.

The sharing of information among governments, communities, and experts left much to be desired. For example, only 20 percent of the population had seen the hazard maps before the March 11 disaster. Effective risk communication does not necessarily require a sophisticated communication system. Although science-based early-warning systems are important during a disaster, regular sharing of predisaster information at the local level is equally important. The sharing should be accompanied—over time and with the community’s involvement—by disaster drills, community mapping, and other measures. In recent years, remote-sensing data has been used around the world to rapidly map the damage resulting from natural disasters. Japan has a well-established track record in disaster mapping: As early as 1995, remotely sensed data were used to map the damage from the Kobe earthquake.

CLUSTER 6: THE ECONOMICS OF DISASTER RISK, RISK MANAGEMENT, AND RISK FINANCING

PROMPT GOVERNMENT INTERVENTION TO KEEP DAMAGE FROM SPREADING ACROSS SECTORS AND COUNTRIES

In 2011 the GEJE contributed to a 0.7 percent contraction of Japan's GDP. But the full extent of GEJE's economic impacts will not be known for some time. Manufacturing and services suffered significant direct and indirect impacts. Direct damage to buildings has been estimated at approximately ¥10.4 trillion, or 62 percent of total damages. The amount of damage to the capital stock (asset base) of agriculture, forestry and fisheries is estimated as ¥2.34 trillion, while damage to the tourism industry amounts to approximately ¥0.7 trillion.

Although the Tohoku and Kanto regions were the most directly affected by the earthquake, the entire manufacturing sector in Japan and some industries abroad were forced to suspend production, as the impact of supply-chain disruptions triggered by the disaster spread through the globe's networked production system. A dense network of supply chains runs throughout Japan, enabling manufacturers to engage in highly efficient production while keeping inventory to a minimum. But this efficiency-oriented management of supply networks backfired in the wake of the earthquake. Although Japanese companies were remarkably responsive, restoring supply chains and getting production almost back to normal by the end of summer 2011, the need still remains to create more resilient supply chains both in and outside Japan.

The auto industry recorded the greatest fall in production but recovered rapidly as facilities reopened and vital transport networks were repaired. After an initial 15 percent drop in March, industrial production rebounded from April onward, with growth of 6.2 percent in May and 3.8 percent in June.

Because of the accident at the Fukushima Daiichi nuclear power plant and damages to other power plants, the government had to cut power consumption in the Tohoku and Kanto regions in the summer of 2011. The government ordered large-scale users to cut their consumption by 15 percent, and called on smaller electricity users and individual households to curb their consumption voluntarily.

The government played an important role in alleviating the disaster's impact on households and businesses through measures to ensure the stability of the financial system, timely approvals of supplementary budgets, and provisions for rapid disbursement disaster assistance, all of which helped citizens and firms jumpstart their recovery processes. The financial resources for recovery and reconstruction are being funded by taxes to avoid leaving the cost to future generations.

Earthquake insurance helps people get back on their feet. Dual earthquake insurance programs, consisting of private nonlife insurers and cooperative mutual insurers, cover about four in ten Japanese households. These programs do not provide a one-size-fits-all solution, however. They offer a range of coverage based on level of risk and other factors. Data on natural disasters by country show that both industrialized and developing countries have the same probability of suffering a disaster. The difference is that developed countries

tend to have more comprehensive and effective central government policies and better-developed insurance markets, which protect lives and preserve economic assets. A functioning market in catastrophic risk insurance requires major investments in risk models, exposure databases, product design, pricing, and other basic infrastructure of the system. Governments can play an important role in fostering the growth of this kind of infrastructure, thereby enabling the private insurance industry to offer cost-effective and affordable insurance solutions.

CONCLUSIONS

The global cost of natural hazards in 2011 has been estimated at \$380 billion—resources that could have been used in productive activities to boost economies, reduce poverty, and raise the quality of life. No region or country is exempt from natural disasters, and no country can prevent them from occurring. But all can prepare by learning as much as possible about the risks and consequences of devastating events, and by making informed decisions to better manage both. Disaster management is increasingly important as the global economy becomes more interconnected, as environmental conditions shift, and as population densities rise in urban areas around the world. As the GEJE showed, proactive approaches to risk management can reduce the loss of human life and avert economic and financial setbacks. To be maximally effective, and to contribute to stability and growth over the long term, the management of risks from natural disasters should be mainstreamed into all aspects of development planning in all sectors of the economy.



