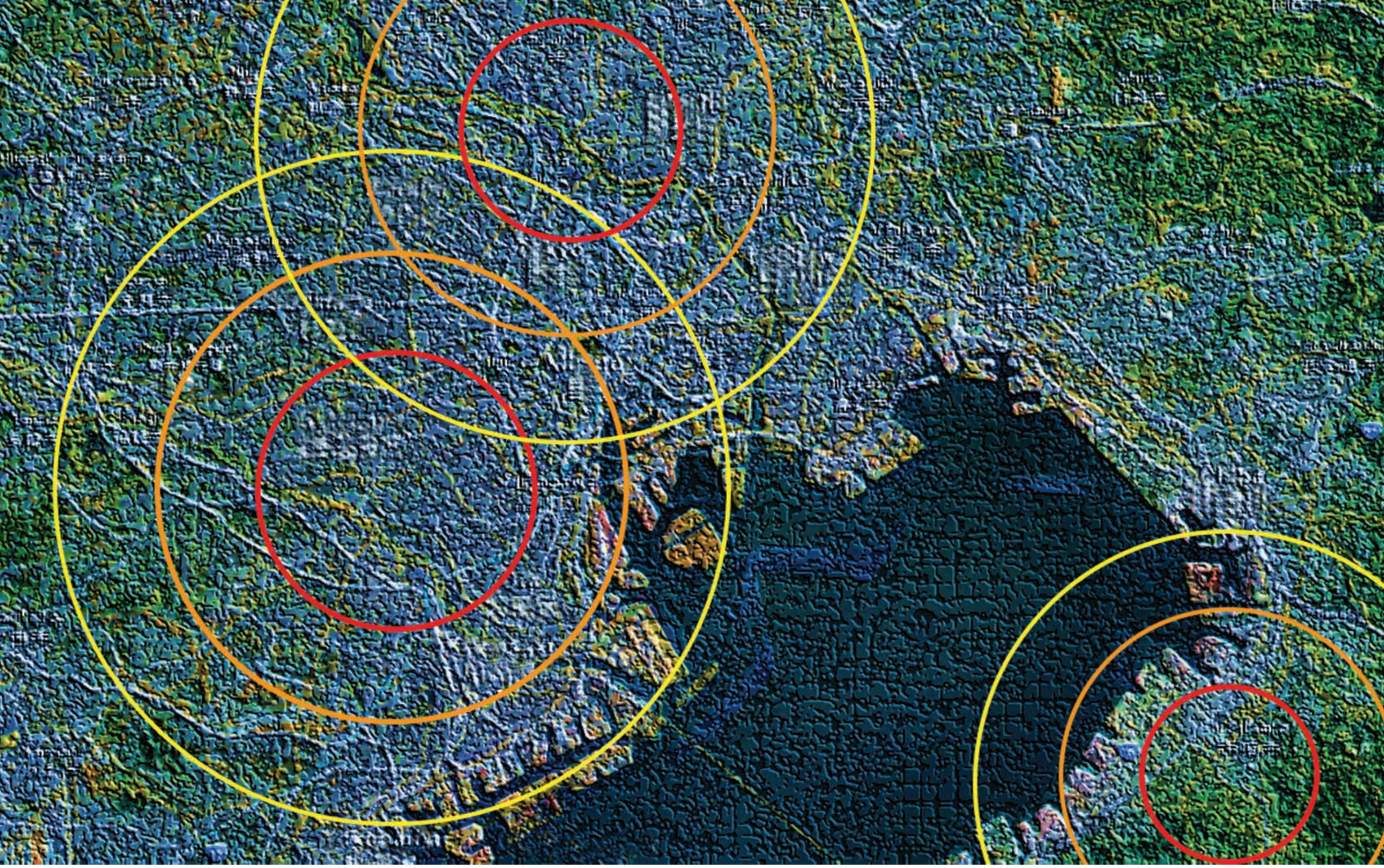

PREPAREDNESS MAP FOR COMMUNITY RESILIENCE: EARTHQUAKES

Experience of Japan

THE WORLD BANK
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GFDRR
Global Facility for Disaster Reduction and Recovery

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OBJECTIVES OF THIS TECHNICAL HANDBOOK

Perched on the edge of the intersection of three tectonic plates, Japan has been repeatedly hit and devastated by earthquakes. However, Japan has revitalized itself as a nation and a society every time, and its accumulated knowledge has served to advance its resilience and minimize future risks and losses.

This manual focuses on Japanese Seismic Preparedness Maps, one of the tools used in Japan to communicate earthquake risks for better preparedness at the community level. Produced by local governments, these maps aim to help communities prepare for future potential seismic events with information on hazard and risk levels, estimated damages, and evacuation routes and sites. Information on key contacts at government agencies where support can be provided and tips to reduce the impact from earthquakes at the community and household levels.

The intended audience of this handbook is government officials and practitioners working in seismic risk management, community-based disaster risk management, risk communications, and related areas who are responsible for preparing communities for the next big seismic event. The hope is that Japan's approach to risk communication at the community level can be leveraged in other countries with high seismic risk.

INTRODUCTION TO SEISMIC PREPAREDNESS MAPS

What Are Seismic Preparedness Maps?

Summary: Seismic Preparedness Maps are produced to inform local communities about the risk from earthquakes and their secondary hazards. As Japan is situated in an area where tectonic activity is very high, earthquake risk is high throughout the country. It is important that communities are aware of the risks they are exposed to and know how to prepare for and react to earthquakes. The so-called Seismic Preparedness Maps visualize and communicate the spatial distribution of the expected earthquake hazards and risks, the location of evacuation centers, and the types of damage expected to occur.

The main objective of this manual is to describe the components of and steps for producing Seismic Preparedness Maps, so that similar maps can be produced in other parts of the world that are vulnerable to earthquakes. By increasing awareness and knowledge of potential hazards and risks faced by communities, the maps prepare communities for the next big event and help to reduce fatalities and loss of assets.

Throughout Japan, the risk of earthquake is high. As part of the government's effort to communicate the risk from earthquakes and related hazards induced by ground shaking, Seismic Preparedness Maps are produced and distributed to every household. The aim of the Seismic Preparedness Maps is to communicate the risk from earthquakes and encourage preparedness at the household level.

This manual provides an overview of Seismic Preparedness Maps. It offers a step-by-step overview of how they are made, including the scientific data sets that are needed, and it explains how Seismic Preparedness Maps are used in Japan to promote awareness of the risks from earthquakes. The goal is to allow other countries with high seismic risks to adopt a similar approach in order to communicate these risks to local communities and protect lives.

The use of the term "Seismic Preparedness Map" in this document

Globally, the term "hazard map" is used to describe a map that shows the parameters of a likely natural hazard in a given location. However, in Japan, the term "hazard map" is applied to a particular type of map—one produced and distributed to households by local governments that shows the location of evacuation sites and includes other types of useful information designed to save lives and promote disaster preparedness. To avoid confusion, this document uses the term "Seismic Preparedness Map" to refer to this type of map, and uses the term "hazard map" in its more conventional sense.

What Does a Seismic Preparedness Map Look Like?

Figures 1 and 2 show an example of a printed Seismic Preparedness Map, produced by Anjo City in Aichi Prefecture. Anjo City is situated on the Pacific coast and is therefore exposed to very high risk from the potentially destructive Nankai and Tonankai earthquakes, historically known to occur at relatively regular intervals.

In general, the purpose of a Seismic Preparedness Map is twofold: (1) to communicate the intensity of likely earthquakes and related hazards (e.g., tsunami) in order to raise awareness of the potential risks, and (2) to provide information on action plans and evacuation centers in order to help households prepare for events. These information components are laid out in the map as seen in Figures 1 and 2. To cater to the needs of foreign residents in Anjo, versions in other languages are also produced and distributed.

The parts of the map are as follows (numbers refer to labeled sections of Figures 1 and 2):

1. Cover
2. List of major historical earthquakes experienced in Anjo City and the estimated intensity of the five major events of the past 300 years (shown in yellow)
3. Estimated damage from the probable maximum scenario earthquake for Anjo City

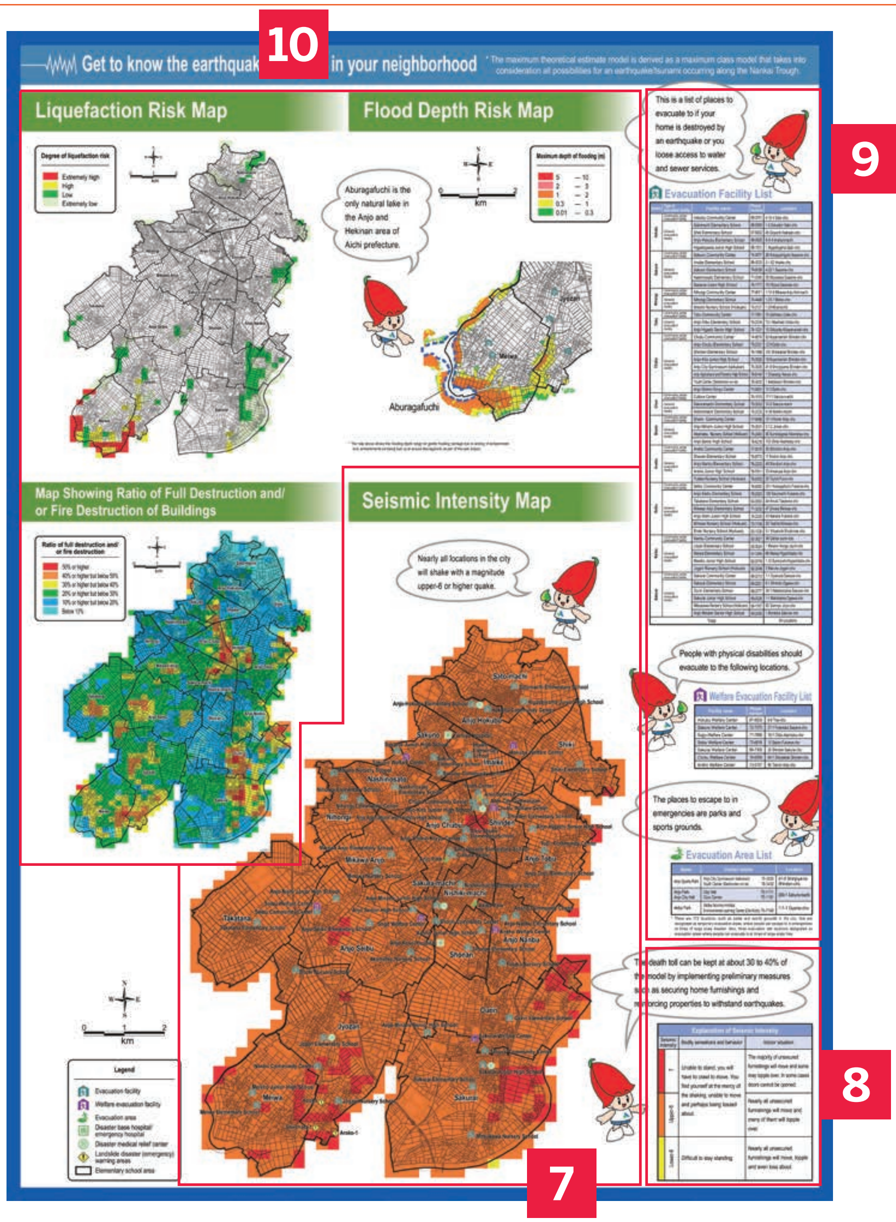
Figure 1. Anjo City Seismic Preparedness Map [front]

Source: http://www.city.anjo.aichi.jp/kurasu/bosaibohan/yakudachi/gaikokugo.html.

[1] http://www.city.anjo.aichi.jp/kurasu/bosaibohan/yakudachi/gaikokugo.html.

4. Recommendations for how households can prepare for the next big earthquake
5. Illustration of general types of damage that could occur as a result of a major earthquake
6. Evacuation tips and blank space for households to write down emergency contacts
7. Hazard (seismic intensity) map overlaid with location of emergency evacuation centers
8. Explanation of Japan Meteorological Agency (JMA) seismic intensity levels
9. List of addresses of the emergency evacuation centers
10. Visualization of potential for other earthquake-induced hazards (i.e.,

Figure 2. Anjo City Seismic Preparedness Map (back)



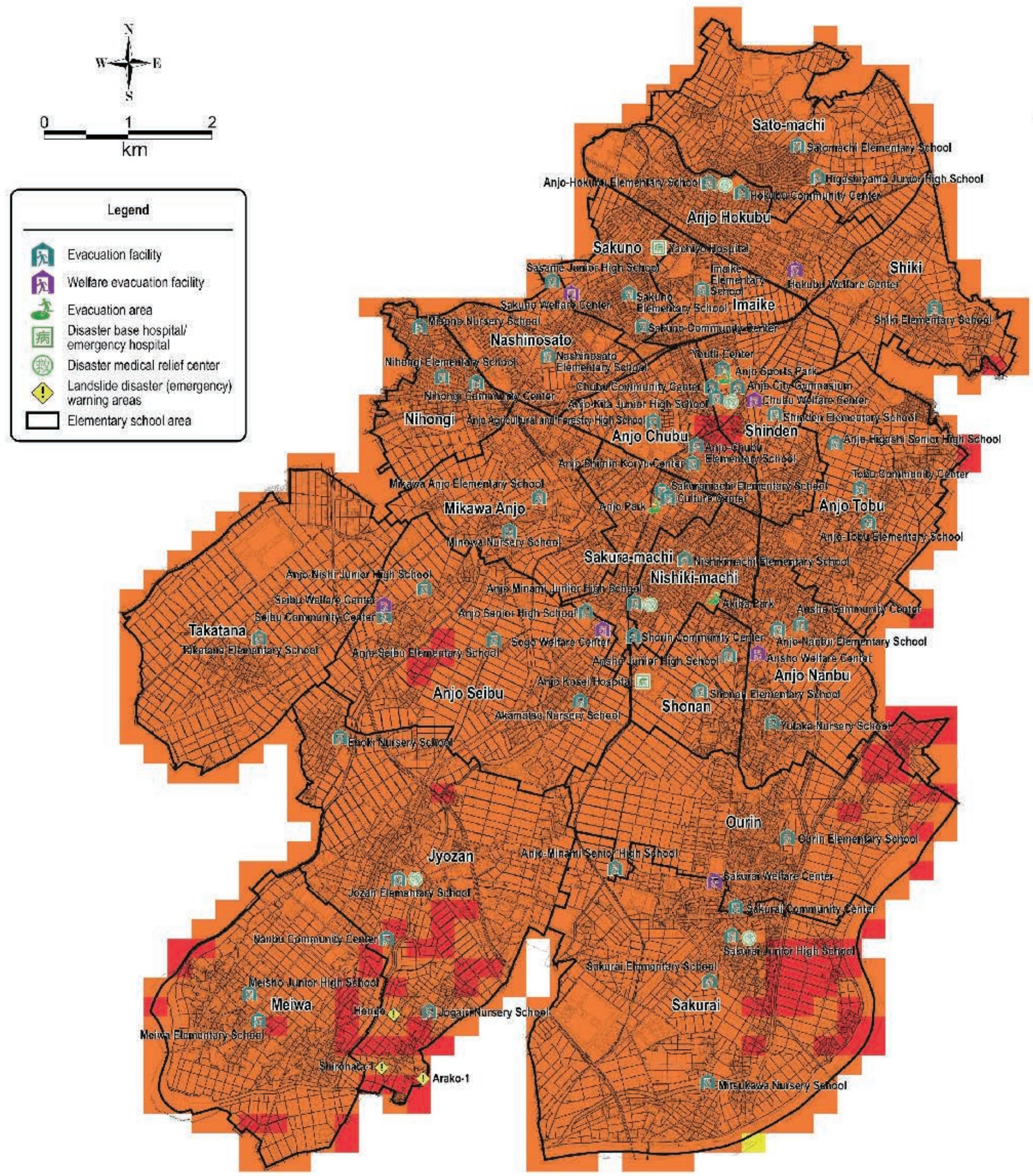
Source: http://www.city.anjo.aichi.jp/kurasu/bosaibohan/yakudachi/gaikokugo.html.

[2] Japan Meteorological Agency.

- liquefaction, inundation) and map showing share of buildings destroyed or burned

One of the main purposes of Seismic Preparedness Maps is to show the estimated likely intensity of a major earthquake, expressed in the form of seismic intensity, and the location of evacuation centers in the city (Figure 3). The seismic intensity to be shown in the map is derived using either the largest known historical earthquake of the area as a scenario, or the most probable scenario earthquake for the region. Other types of information that can be included are the locations of emergency hospitals and public facilities.

Figure 3. Estimated seismic intensity from the maximum likely scenario earthquake and evacuation areas



Source: http://www.city.anjo.aichi.jp/kurasu/bosaibohan/yakudachi/gaikokugo.html.

Information on historic earthquakes in the region

The Anjo City Seismic Preparedness Map features historical major earthquakes (Figure 4), though this is not typical of most Seismic Preparedness Maps. In addition to listing historical earthquakes, the map also describes observed damage from earthquakes in the Anjo region. Major earthquakes are known to occur once every 100 to 150 years in the Nankai Trough sea area. The yellow map (center) shows the estimated maximum seismic intensity experienced in the city based on the known estimated intensities from the six largest earthquakes between 1586 and the current day.

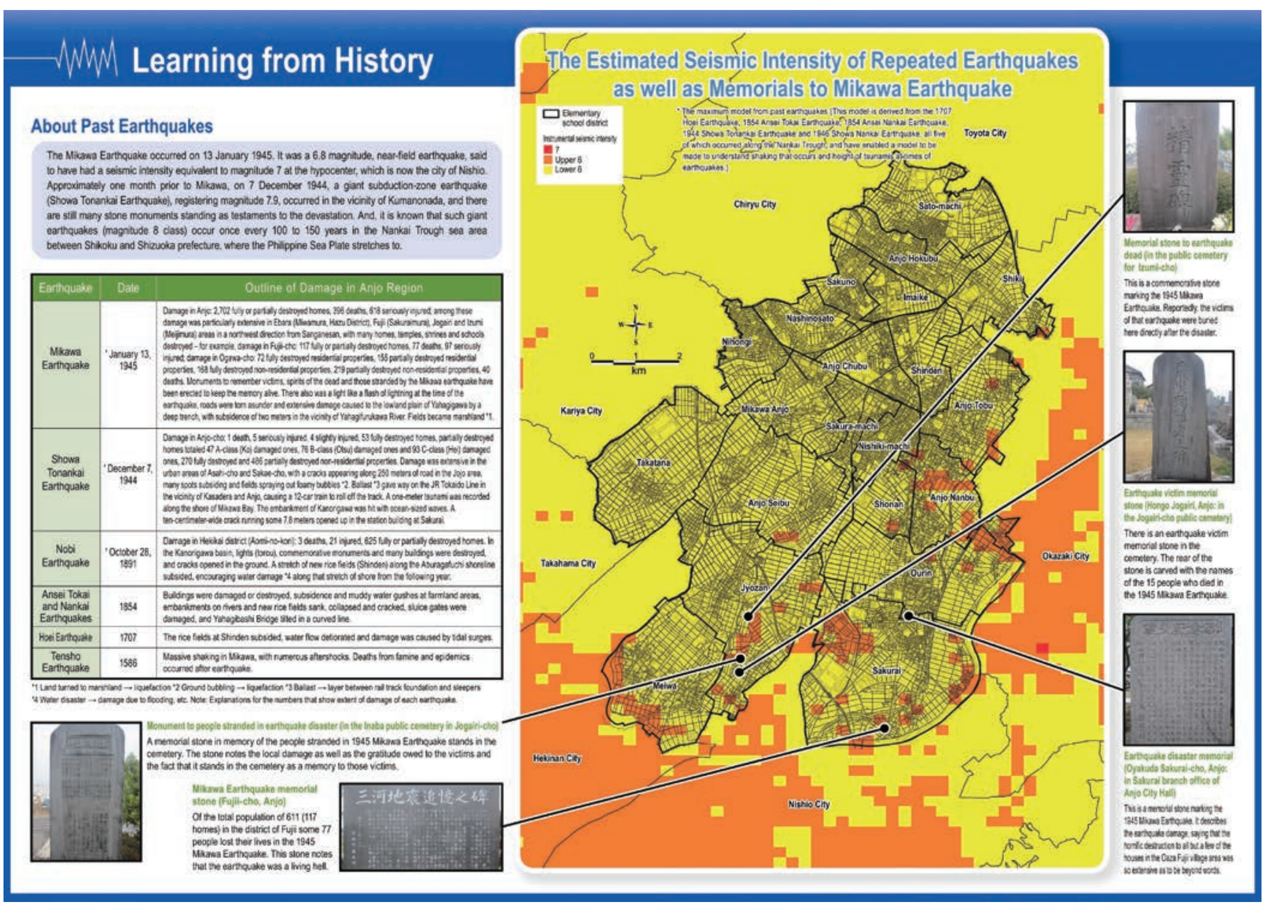
Damage estimates

Some Seismic Preparedness Maps contain damage estimates based on the largest historical scenario earthquakes (Figure 5). The damage estimates include fatalities as well as building and lifeline damage.

Preparing for earthquakes at the household level

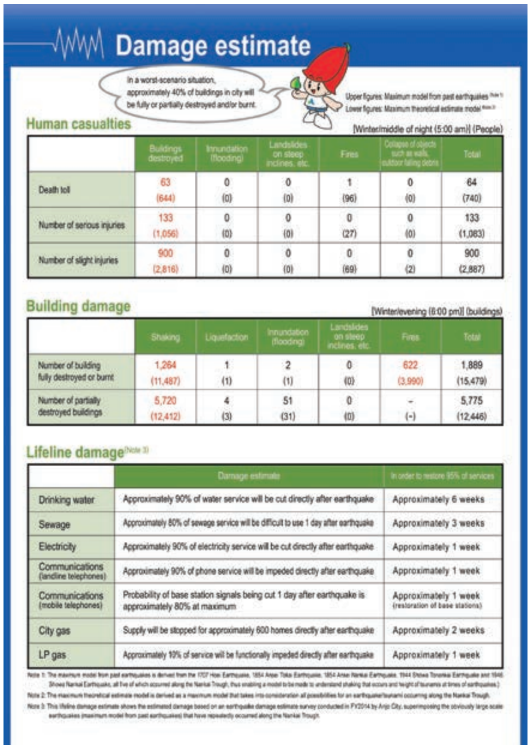
Seismic Preparedness Maps can also include information on how to prepare for earthquakes at the household level (Figure 6). Recommendations here include items such as:

Figure 4. Information on historical earthquakes experienced by Anjo City



Source: http://www.city.anjo.aichi.jp/kurasu/bosaibohan/yakudachi/gaikokugo.html.

Figure 5. Damage estimates based on the largest known historical earthquake in the Anjo area [Mw 8.7]



Damage estimate

In a worst-scenario situation, approximately 40% of buildings in city will be fully or partially destroyed and/or burnt.

Upper figures: Maximum model from past earthquakes (Note 1)
Lower figures: Maximum theoretical estimate model (Note 2)

Human casualties

[Winter/middle of night (5:00 am)] (People)

	Buildings destroyed	Inundation (flooding)	Landslides on steep inclines, etc.	Fires	Collapse of objects such as walls, outdoor falling debris	Total
Death toll	63 (644)	0 (0)	0 (0)	1 (96)	0 (0)	64 (740)
Number of serious injuries	133 (1,056)	0 (0)	0 (0)	0 (27)	0 (0)	133 (1,083)
Number of slight injuries	900 (2,816)	0 (0)	0 (0)	0 (69)	0 (2)	900 (2,887)

Building damage

[Winter/evening (6:00 pm)] (buildings)

	Shaking	Liquefaction	Inundation (flooding)	Landslides on steep inclines, etc.	Fires	Total
Number of building fully destroyed or burnt	1,264 (11,487)	1 (1)	2 (1)	0 (0)	622 (3,990)	1,889 (15,479)
Number of partially destroyed buildings	5,720 (12,412)	4 (3)	51 (31)	0 (0)	- (-)	5,775 (12,446)

Lifeline damage (Note 3)

	Damage estimate	In order to restore 95% of services
Drinking water	Approximately 90% of water service will be cut directly after earthquake	Approximately 6 weeks
Sewage	Approximately 80% of sewage service will be difficult to use 1 day after earthquake	Approximately 3 weeks
Electricity	Approximately 90% of electricity service will be cut directly after earthquake	Approximately 1 week
Communications (landline telephones)	Approximately 90% of phone service will be impeded directly after earthquake	Approximately 1 week
Communications (mobile telephones)	Probability of base station signals being cut 1 day after earthquake is approximately 80% at maximum	Approximately 1 week (restoration of base stations)
City gas	Supply will be stopped for approximately 600 homes directly after earthquake	Approximately 2 weeks
LP gas	Approximately 10% of service will be functionally impeded directly after earthquake	Approximately 1 week

Source: http://www.city.anjo.aichi.jp/kurasu/bosaibohan/yakudachi/gaikokugo.html.

Figure 6. How to prepare for an earthquake

Source: http://www.city.anjo.aichi.jp/kurasu/bosaibohan/yakudachi/gaikokugo.html.

- Reinforcement measures that can be implemented at the household level to prevent damage to homes from ground shaking
- Non-structural measures to ensure safety throughout the house (e.g., securing furniture to walls)
- Guidance on what to do if lifelines are damaged
- List of useful items to have on hand (food, water, flashlights, radio, etc.)
- Anjo City assistance schemes in case of emergencies
- Anjo City assistance schemes on seismic diagnosis and retrofit subsidies for residential houses
- Tips to protect citizens (e.g., better furniture layout and securing of furniture.)

Visualizing what may happen during and after an earthquake

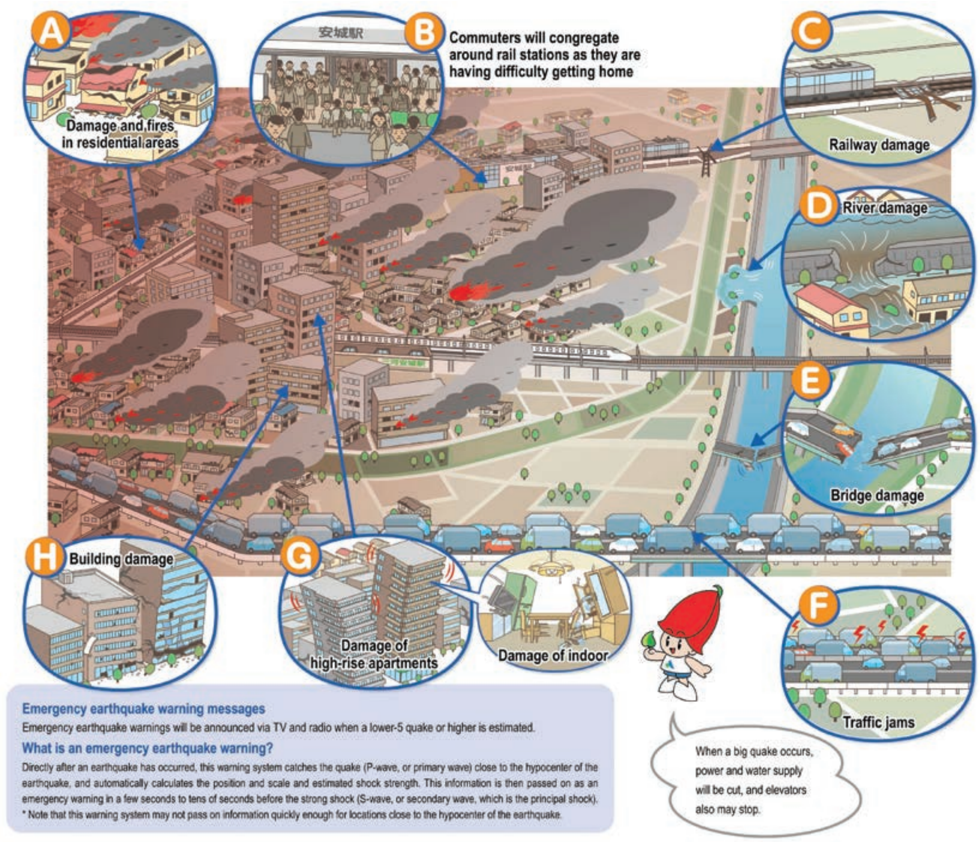
Seismic Preparedness Maps may include illustrations to communicate what could happen during an earthquake (see Figure 7).

Estimating effects from secondary hazards

Seismic Preparedness Maps also include information on secondary hazards that could be induced by the ground shaking of an earthquake. These secondary hazards could include:

- Potential building collapse (Figure 8)
- Tsunami inundation (Figure 9)
- Liquefaction (Figure 10)

Figure 7. Likely effects from a major earthquake



A Damage and fires in residential areas

Buildings with low earthquake resistance will collapse. In densely housed areas there is a fear that multiple fires will occur simultaneously. Also, many deaths and injuries will occur due to collapsing of homes and overturning of furnishings.

B Commuters will congregate around rail stations as they are having difficulty getting home

Public transport like trains and buses will stop operating, leaving many travellers/commuters stranded at stations, and some may not be able to get home.

C Railway damage

Earthquake may mishape rail tracks, requiring lengthy repairs before services can restart. Also, trains may be derailed while in service.

D River damage

Embankments could collapse causing floods. Care must be taken about tsunami wave runup.

E Bridge damage

Bridges that have not been reinforced to withstand earthquakes may collapse and cut off roads.

F Traffic jams

Expressways will close. Local roads will jam up due to transport restrictions and closures. And, jams caused by private cars will hinder rescue work being undertaken by emergency vehicles, such as fire engines and ambulances. Furthermore, some roads will be blocked by collapsed buildings.

G Indoor damage in high-rise apartments

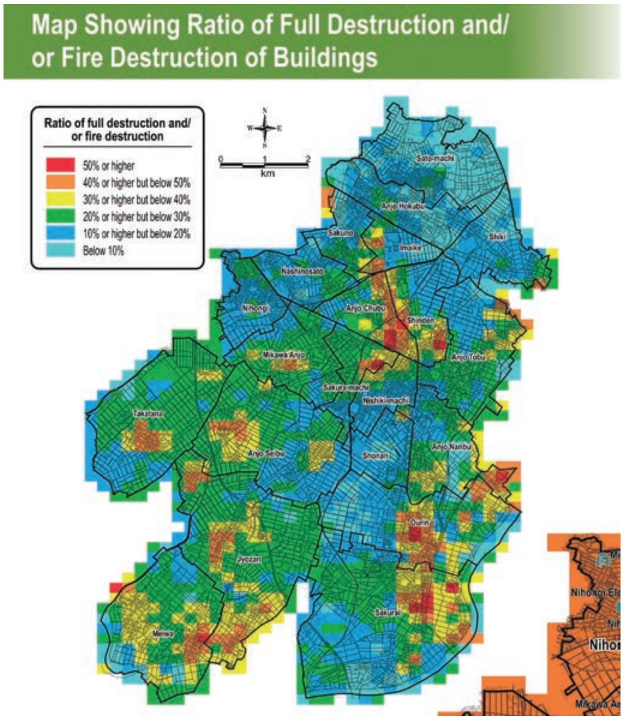
When the swaying of a building resonates with the shake of an earthquake, the upper floors (of apartments, etc.) will sway immensely, leading to the risk of furnishings overturning.

H Building damage

Buildings may collapse or exterior sections, such as glass or cladding, fall away.

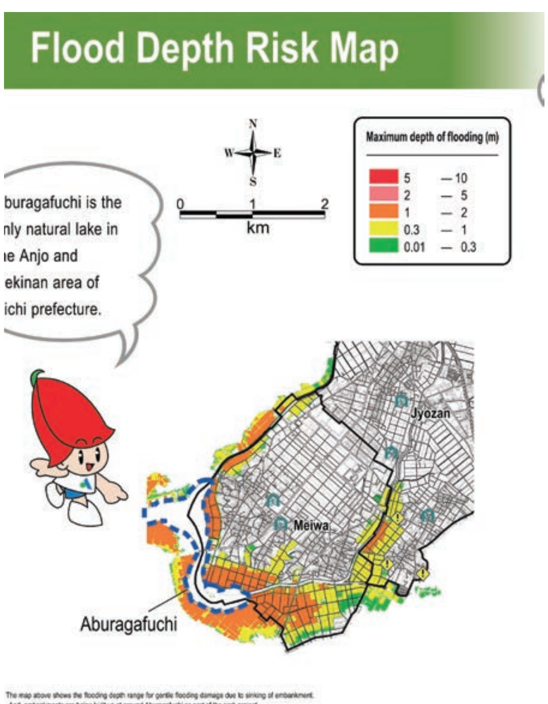
Source: http://www.city.anjo.aichi.jp/kurasu/bosaibohan/yakudachi/gaikokugo.html.

Figure 8. Building damage ratio under a scenario



Source: http://www.city.anjo.aichi.jp/kurasu/bosaibohan/yakudachi/gaikokugo.html.

Figure 9. Tsunami inundation risk map under a scenario



Source: http://www.city.anjo.aichi.jp/kurasu/bosaibohan/yakudachi/gaikokugo.html.

Checklist of actions to take immediately after an earthquake

The Anjo Seismic Preparedness Map includes a checklist of actions to take in case an earthquake occurs (Figure 11).

What Are Seismic Preparedness Maps Used for?

Seismic Preparedness Maps are used to promote disaster preparedness at the community level by illustrating and communicating the seismic events that are likely to happen in the area. Locations of the various types of designated evacuation centers and emergency facilities are also shown on the map.

In Japan the **local governments** (e.g., municipalities) are required to budget for the production of these Seismic Preparedness Maps, which they then distribute to individual households. The Seismic Preparedness Maps are often used during field walks for local residents, which local governments organize in order to raise disaster awareness and promote risk reduction.

Intended audience of the Seismic Preparedness Maps

Seismic Preparedness Maps are developed for all households and residents in the municipality. These residents include those that require special assistance, e.g., the elderly, infants and children, expectant mothers, individuals with handicaps, and tourists; information targeted at these audiences is often found in Seismic Preparedness Maps. The maps may also target foreign residents who likely do not speak or read Japanese. Increasingly, Seismic Preparedness Maps are translated into multiple languages.

Who Is Responsible for Producing the Seismic Preparedness Maps?

In Japan, a local (prefectural or municipal) government usually develops the Seismic Preparedness Map with support from seismic experts and consultants. Specific information needs of local residents should be reflected in the Seismic Preparedness Maps through consultation. Examples of consultations are discussed under Step 6.

What Type of Information Is Included in Seismic Preparedness Maps?

Many of the Japanese Seismic Preparedness Maps follow a format and contain the following types of information at a minimum:

- The intensity of the earthquake ground-shaking hazard under a scenario
- Estimates of the number of casualties and damaged or destroyed buildings
- Information on the location and capacity of evacuation centers
- Designated emergency evacuation routes and information on traffic restrictions during emergencies;[3] information on the function of key public facilities during emergencies

[3] In Japan, some key roads are reserved and passable only by emergency vehicles during emergencies.

Figure 10. Liquefaction risk map

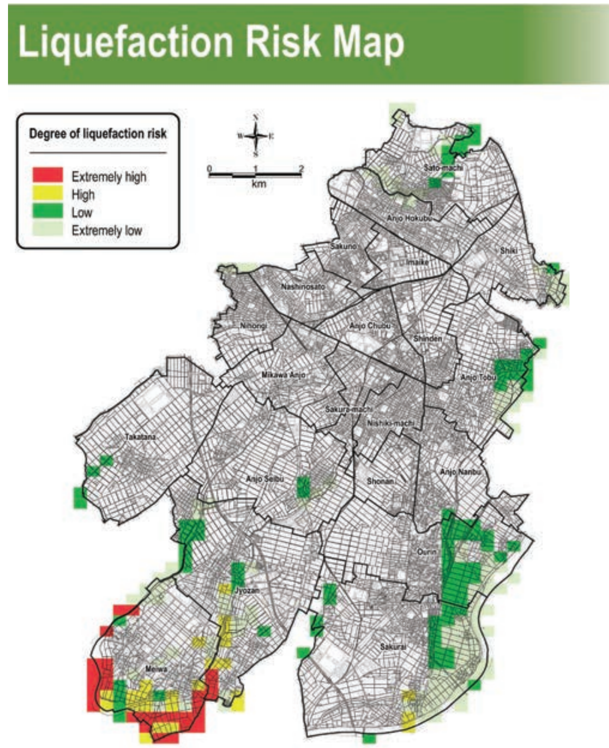
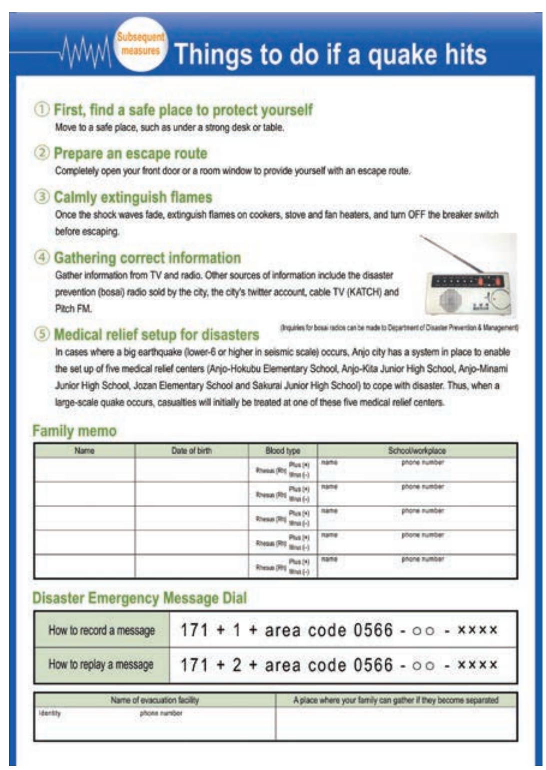


Figure 11. Actions to take during a major earthquake event


Subsequent measures

Things to do if a quake hits

① First, find a safe place to protect yourself
Move to a safe place, such as under a strong desk or table.

② Prepare an escape route
Completely open your front door or a room window to provide yourself with an escape route.

③ Calmly extinguish flames
Once the shock waves fade, extinguish flames on cookers, stove and fan heaters, and turn OFF the breaker switch before escaping.

④ Gathering correct information
Gather information from TV and radio. Other sources of information include the disaster prevention (bosai) radio sold by the city, the city's twitter account, cable TV (KATCH) and Pitch FM.

(Inquiries for bosai radios can be made to Department of Disaster Prevention & Management)

⑤ Medical relief setup for disasters
In cases where a big earthquake (lower-6 or higher in seismic scale) occurs, Anjo city has a system in place to enable the set up of five medical relief centers (Anjo-Hokubu Elementary School, Anjo-Kita Junior High School, Anjo-Minami Junior High School, Jozan Elementary School and Sakurai Junior High School) to cope with disaster. Thus, when a large-scale quake occurs, casualties will initially be treated at one of these five medical relief centers.

Family memo

Name	Date of birth	Blood type	School/workplace
		Rhesus (Rh) Plus (+) Minus (-)	name phone number
		Rhesus (Rh) Plus (+) Minus (-)	name phone number
		Rhesus (Rh) Plus (+) Minus (-)	name phone number
		Rhesus (Rh) Plus (+) Minus (-)	name phone number
		Rhesus (Rh) Plus (+) Minus (-)	name phone number

Disaster Emergency Message Dial

How to record a message	171 + 1 + area code 0566 - ○○ - ××××
How to replay a message	171 + 2 + area code 0566 - ○○ - ××××

Name of evacuation facility	A place where your family can gather if they become separated
identity phone number	

- Simple interventions that can improve the resilience of a residential structure against earthquakes
- Useful items to stock for emergency situations (food, water, flashlights, radios, etc.)
- Recommended actions to take during an earthquake
- Support available from national and local governments to improve the earthquake resilience of residential structures and to aid households following an earthquake
- Free dial service for disaster emergency message hotline[4]

These aspects will be described in more detail in the following sections.

Multi-Hazard Preparedness Maps are available from the local governments' websites as well as from the Disaster Preparedness Map portal (called "Hazard Map Portal" in Japan) operated by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

[4] In Japan, phone companies have set up a free dial number that is activated during emergencies. Anyone affected by the natural disaster can leave a message for family members to convey where they have evacuated to, etc.

STANDARD PROCESS FOR CREATING A SEISMIC PREPAREDNESS MAP

The main purpose of a Seismic Preparedness Map is to communicate to the local communities the likely level of ground shaking and impacts from a major earthquake event and to provide the information communities need to be able to respond and reduce losses.

The general steps to create a Seismic Preparedness Map are summarized here and in Figure 12. They are then explained in detail below.

Figure 12. General work flow to create a Seismic Preparedness Map

Step 1: Take Stock of Hazard and Risk Information Available for the Target Area and Define the Contents to Include in the Seismic Preparedness Map

Earthquake hazard scenario for the Seismic Preparedness Map

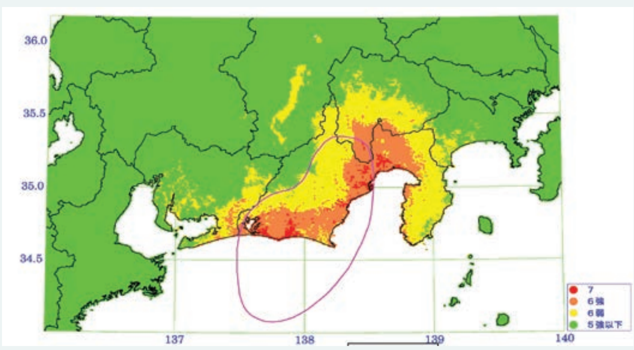
For every Seismic Preparedness Map, some assumptions must be made about the characteristics of the earthquake event that will be featured. There are a few options available to quantify and visualize the ground shaking expected from earthquakes. For Japanese Seismic Preparedness Maps, in most cases the **deterministic approach**[5] (Box 1) is adopted.

[5] From the scientific point of view, there are two approaches to quantifying hazards: deterministic and probabilistic. The difference between these two approaches is described in Box 1. It is unusual to use probabilistic approaches to communicate the risk to local communities in Japan.

Box 1: Two approaches to seismic hazard assessment

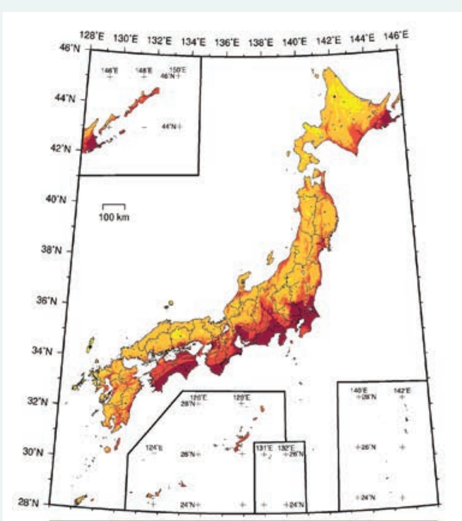
For seismic hazard assessment, there are two main approaches, deterministic (scenario based) and probabilistic. The main differences are the output and the data inputs required (see Figures 13 and 14 and Table 1). In Japan, the deterministic approach is used in most Seismic Preparedness Maps, while the probabilistic approach is used at the national level to understand the overall risk across the country. Probabilistic models are also commonly used in insurance-related applications.

Figure 13. Output of a scenario based deterministic hazard assessment



Estimated Japanese seismic intensity (JMA intensity) under the scenario of a hypothetical Tokai earthquake. For a description of JMA intensity, see Annex 1.
Source: http://www.bousai.go.jp/jishin/tokai/pdf/higaisoutei/gaiyou.pdf.

Figure 14. Output from a probabilistic hazard assessment



Probability of Japanese (JMA) seismic intensity higher than VI occurring in the next 30 years.
Source: http://www.j-shis.bosai.go.jp/shm.

Deterministic approaches select and use **a single earthquake scenario** from the many scenarios that could potentially happen, and illustrate the level of ground shaking it produces and its effects on the structures and assets on the ground.[6] There are several possible earthquake scenarios that can be used in a Seismic Preparedness Map:

- A scenario from a known historical event in the past
- The most likely scenario identified using scientific models
- The maximum probable event scenario identified using scientific models

The decision on what type of scenario to use will depend on factors such as data availability and recommendations from seismic experts.

To determine the scenario to use for the Seismic Preparedness Map being planned, the project team should first gain an understanding of the different hazard types that are likely to occur in the region, along with their intensity and frequency. From this bigger picture, the project team should then start to narrow down the focus of the Seismic Preparedness Map by prioritizing hazards based on the severity of the impact they are likely to have and other factors that are deemed important in the local context, while at the same time acknowledging that the next major event will likely not exactly follow the scenario selected. Lessons learned from past Japanese events suggest that local residents may not necessarily understand this shortcoming of the Seismic Preparedness Map, which makes them unprepared for different event scenarios.

Sources of hazard information

To understand the range and likelihood of hazard(s) occurring in the area, hazard assessments can be carried out using scientific

[6] These are expressed as earthquake "intensity."

Table 1. Comparison of the probabilistic and deterministic approaches

	PROBABILISTIC APPROACH	DETERMINISTIC APPROACH
Input data needed	Earthquake catalog	Fault parameter of scenario earthquake
Appropriate geographical scale	Whole nation	Prefecture or city
Output	Expected hazard level or probability of exceedance in given period of time	Expected hazard level (seismic intensity) due to given scenario earthquake
Application of output	Seismic design, determination of insurance premium	Disaster management planning
Advantage	All possible earthquakes are included	Easy to understand possible situations for scenario earthquake
Limitation	Difficult to communicate the meaning of the outputs	Only specific earthquakes are dealt

models. However, it is rare for a full scientific study to be conducted for the sole purpose of creating a Seismic Preparedness Map, as these studies can be costly. In Japan there are several data sources where hazard information may be readily available. These include:

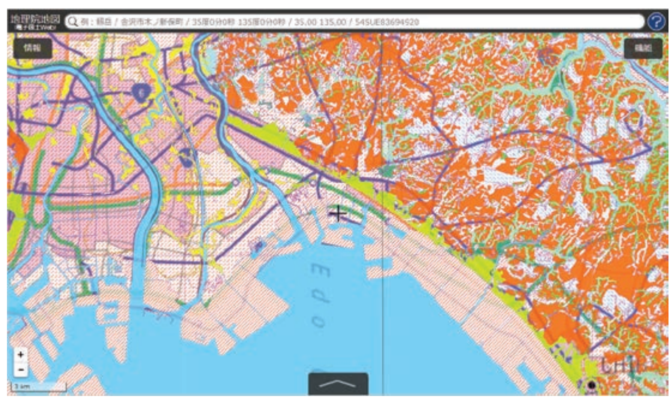
- Historical hazard information maintained by organizations such as meteorological agencies[7] and local governments
- Earthquake risk assessment studies based on scientific models carried out by national government agencies, prefectural governments, and earthquake research institutes

In the absence of information from these sources, it may become necessary to conduct hazard assessments using scientific models, though doing so is costly. The more feasible option in the absence of a scientific model is to use **historical scenarios and data** for the scenario.

Secondary hazards induced by earthquake ground shaking

To capture the full range of the possible hazards, the physical geographical context of the region should also be considered. This is because earthquakes can cause secondary hazards such as liquefaction, tsunami, and landslides; thus if the region is mountainous, for example, landslide risk should also be communicated to the communities and included in the Seismic Preparedness Map. Liquefaction can occur where there are abandoned river channels or landfills; if the area has a coastline, the risk from tsunami should also be considered. If the building stock has a high proportion of timber buildings, risk from fire should be considered.

Figure 15. Topographical map from Geospatial Information Authority of Japan



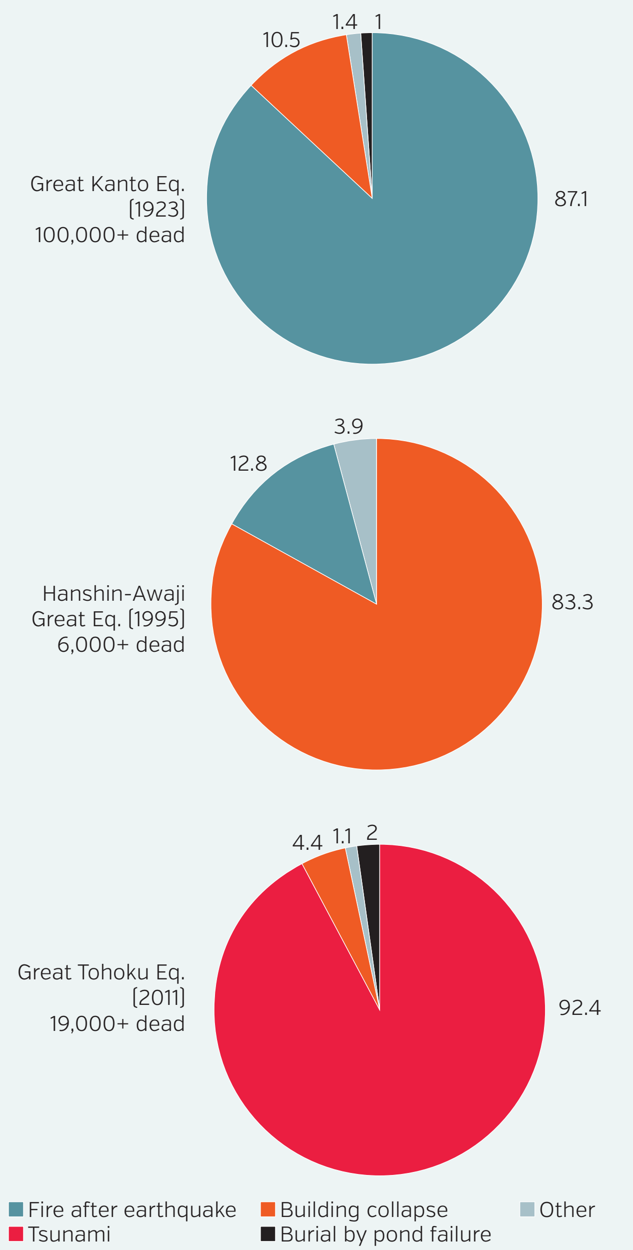
Source: http://maps.gsi.go.jp/.

[7] In Japan, this is the Japan Meteorological Agency.

Box 2: Cause of fatalities from earthquakes

The main causes of fatalities and casualties can be very different from event to event (Figure 16). The main cause of fatalities in the Great Kanto Earthquake in 1923 was fire, while for the Hanshin-Awaji Great Earthquake it was building collapse, and for the Great Tohoku Earthquake it was tsunami.

Figure 16. Cause of death from major earthquakes in Japan in the last 100 years



Where the physical profile of the region warrants it, the availability of data/information on these hazards (from past projects or risk assessments done by national government agencies) should be investigated.

Other types of information to consider including in a Seismic Preparedness Map

Once the range of hazards likely to occur in the region is screened, and stock taking of the available off-the-shelf hazard data from the various ministries and organizations is completed, consider other types of information to include in the Seismic Preparedness Map. The goal is to assist in the understanding of the potential impacts from the earthquake and its secondary hazards. This other information may include:

- Building damage estimates (Figure 8) giving the likely number of buildings that will be destroyed or damaged from the earthquake scenario being used in the Seismic Preparedness Map
- Casualty estimates from building collapse (in regions where buildings are known to be vulnerable); casualty estimates based on risk models (Box 2)
- The likely impact on utilities (e.g., water supply infrastructure, electricity grid)
- The likely impact on key facilities such as hospitals
- Potential traffic problems (due to blocked roads and railway networks) and shortages of goods

This type of information is usually derived from a scientific risk model. Carry out stock taking of existing information on these items, so that information gaps can be identified. If needed information is not readily available, it may be necessary to generate it, provided that the cost of doing so is not prohibitive.

Finalizing the hazard scenario

Following the stock taking of the available data for the earthquake and secondary hazards, narrow down and make a decision on the scenario to use in the Seismic Preparedness Map based on data availability and significance of the scenario impacts. If risk models are available to run for the purpose of creating the Seismic Preparedness Map, it may be possible to estimate more complicated scenarios such as "what would happen if a levee breaks."

Step 2: Collate Data

Data sources for hazard information

For the Seismic Preparedness Maps, hazard estimates in most cases are obtained from the following sources:

- Hazard assessments done for the same region for past projects
- Risk assessments (damage estimates) undertaken by national or prefectural governments

If the hazard-triggering environment has not changed from the time these past estimates were made, the assumptions and hazard assessment outputs can be adopted for the Seismic Preparedness Map.

Data sources for other input data sets

Other types of data sets to be collected for use in the Seismic Preparedness Maps include baseline data for the background map, such as Municipal boundaries, building footprints, location of government facilities, key infrastructure (roads, bridges, railways, hospitals, designated evacuation centers, etc.), topographical maps, satellite imagery, and land use.

In Japan basic geospatial information is open and available from the Geospatial Information Authority of Japan, downloadable as digital GIS (Geographical Information System) data. Private firms have also developed detailed data sets, particularly of buildings, which are available at cost. Road network data in Japan are also available at cost.[8]

Data sets needed for building damage and casualty estimates

Buildings can sustain damage from ground shaking, liquefaction, landslides, tsunami, and fire.

- **Building damage from ground shaking** is generally calculated based on a damage curve considering the following risk factors: old buildings, wooden or other weak structures, high-rise buildings
- **Building damage from fire** should be considered in regions where wooden buildings are concentrated. Moreover, because fire occurs simultaneously in many places during the earthquake, the operation of fire preventive functions may be insufficient. Calculate the damage amount through a simulation that considers these points.
- **The risk of building damage from tsunami** has a risk which increases depending on inundation depths and building structure type. Calculate the damage amount from the inundation depth through a simulation that considers these points.

Information on casualties and building damage estimates will only be available if risk models

[8] From the Japan Digital Road Map Association.

have been developed for the area. The potential sources for these data sets are national and local governments, research institutes, and in some cases international organizations. When data are not available, it may be necessary to carry out additional surveys.

Basic data necessary for casualty and building damage estimates as inputs into risk models are:

- Ground motion data for the scenario being adopted for the Seismic Preparedness Map, along with tsunami inundation depth
- Data on buildings, including structure type, age, number of floors, and location

Step 3: Add Information on Evacuation Sites

Once the hazard scenario is chosen and data collated, the next step is to overlay on the Seismic Preparedness Map information on the location of evacuation sites and centers (Figure 19). In Japan, there are three different types of evacuation centers. These are **temporary emergency evacuation sites, evacuation centers, and welfare evacuation centers**.[9] The general conditions that must be met by the evacuation sites are as follows, defined in the Disaster Countermeasures Basic Act.

A **temporary emergency evacuation site** is a facility or site, in many cases an open space (e.g., a park or a parking lot), that satisfies safety criteria for the different types of hazard as a temporary evacuation site where residents can escape from the unfolding event (Figure 17). In many cases existing public buildings that are designated as evacuation centers also function as temporary evacuation sites if they are considered to be in an easily accessible and safe location. Whatever the facility, the key criterion is that the location provides safety from the unfolding event. Once the event is over, survivors of the event are moved to evacuation centers, where there are facilities for water and sanitation and electricity, and where survivors can stay for a longer, sustained period during a major disaster. The site itself should also be safe during the disaster.

The following criteria are used for selecting temporary evacuation sites:

- Sufficient space for expected number of evacuees
- Night lighting
- Information equipment for communication
- Where possible, essential goods for an overnight stay (e.g., blankets) as well as food and water

An **evacuation center** (Figure 18) has the necessary facilities to accommodate affected residents when homes have been rendered uninhabitable by the event. These centers

- should have adequate space to accommodate evacuees
- should be able to provide food and water to the evacuees until assistance arrives from outside the affected area
- should be accessible by vehicles
- should be able to house survivors for a sustained length of time
- should be seismically and fire resistant
- should, where possible, ensure accessibility for the elderly and disabled

Welfare evacuation sites are special evacuation sites for people who require

[9] In the White Paper on Disaster Risk Management, published annually by the Cabinet Office of the Government of Japan, the three types of evacuation centers are translated into English as designated emergency evacuation sites, designated evacuation shelters, and welfare evacuation shelters. Here, different terminology is used that describes the nature of each facility in a more intuitive way.

additional care (e.g., the elderly, disabled people, people who require special medical attention). They provide a secure place to stay until the risk lessens and the necessary care is again available (Figure 20).

Data required for selecting evacuation centers, routes, and sites are as follows:

- **To select locations of evacuation centers:** Topographic data, elevation data, road network data, location and width of bridges

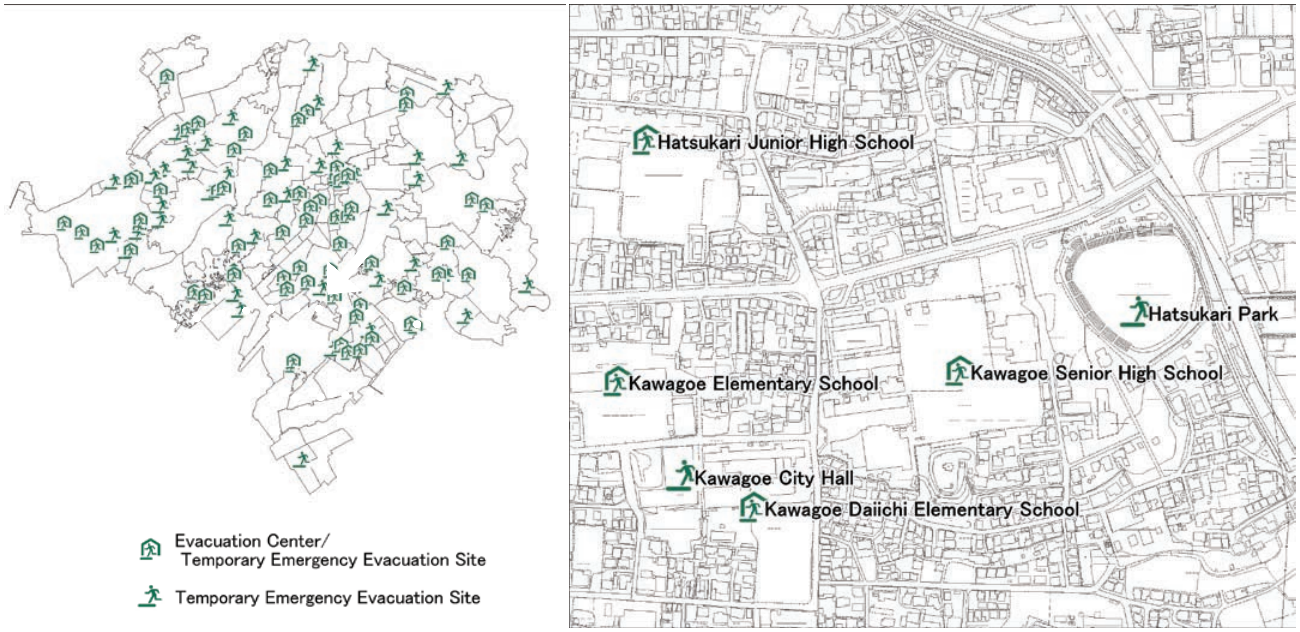
Figure 17. Examples of temporary emergency evacuation sites

Left: Example of a designated temporary evacuation site set in an open space up on a hill. Ishinomaki City, Iwate Prefecture. Right: A temporary evacuation site that also functions as an evacuation center where affected people can stay longer.
Source: Institute of Scientific Approaches for Fire and Disaster, Database of Disaster Pictures, [in Japanese] http://www.saigaichousa-db-isad.jp/drsdb_photo/photoSearch.do] [Iwaizumi Town].

Figure 18. An example of an evacuation center

Source: Tohoku Great Earthquake Project, http://archive.shinsai.

Figure 19. Example of a map showing evacuation sites and centers (Kawagoe City, Saitama Prefecture)



Source: Tohoku Great Earthquake Project, http://archive.shinsai.

Figure 20. Example of a welfare evacuation center used in the 2016 Kumamoto earthquake

In this case, the second floor of the welfare facility for the hearing impared was used as the welfare evacuation center.
Source: http://kumajou.jp/kumamoto-jishin5.html.

- **For the evacuation centers:** Maps showing building footprints, ground heights, and structure type
- **For evacuation routes:** Data on road network and location and width of bridges
- **Tsunami evacuation sites, temporary shelters:** Maps showing building footprints, heights, and structure type

Box 3: Tsunami evacuation towers

If the tsunami simulation analysis results suggest that there is not enough time for residents to evacuate to safer ground inland, building new vertical evacuation towers on the coast may be an option. Local planners must consider the capacity needed and suitable locations to build these towers (Figure 21).

Figure 21. Example of tsunami evacuation towers

Tsunami evacuation tower built by Tobishima Village, Aichi Prefecture. *Source:* OYO Corporation.

Example: Processes to select tsunami evacuation centers

The requirements for evacuation centers and sites differ depending on the type of hazard. For earthquakes, the structures must be quake-resistant. For tsunami evacuation centers, structures must be tsunami-resistant and located at a position higher than the estimated tsunami height plus the height of the increase in depth due to the presence of the building. When designating existing buildings as evacuation centers, these characteristics should be taken into account for the selection and upgrading of the buildings to meet the standards required for a building to be used as an evacuation center. Consultation with managers and owners of the candidate (public or private) buildings should be carried out. If enough evacuation sites that meet the specific criteria for the hazard cannot be found among the existing building stock, consider building new facilities to meet the capacity needs (e.g., a tsunami tower; see Box 3).

Detailed criteria to select evacuation centers are different for different hazards. Annex 2 lists two documents that describe these criteria in the Japanese context (the evacuation center guidelines and the welfare evacuation center guidelines). As an example, the process to select evacuation centers for **tsunami** is described below.[10]

1. Perform tsunami simulation to designate evacuation zones:

[10] Fire and Disaster Management Agency, "Report on the development of a tsunami evacuation manual by the Committee for the promotion of tsunami evacuation," Japan, 2013.

- Perform tsunami simulation or find existing tsunami inundation estimates to estimate tsunami inundation depths and arrival time, then designate the evacuation zones using the simulated inundation area.

2. Further evaluate within these evacuation zones the tsunami arrival time and distance to evacuate to the nearest evacuation centers from all locations along the roads. In detail:
   - In the tsunami evacuation zones, use the estimated tsunami arrival time and location of evacuation centers to identify areas that can be evacuated, assuming a person starts to evacuate 2–5 minutes after the earthquake.
   - Assume a walking speed of 1.0 m/sec; reduce this to 0.5 m/sec for people with difficulty walking (e.g., disabled, young children, and ill people)
   - Assume the distance that people can evacuate is up to approximately 500m from their location. This distance should be adjusted for local conditions.

The methodology for these calculations adopted in Japan is described in a guideline by the Fire and Disaster Management Agency (FDMA).[11]

3. From the previous steps, identify areas that are likely to have difficulty evacuating. Consider whether there is a need to increase the number of evacuation centers. If there is a need, consider the location, capacity, and layout required by these additional evacuation facilities. Consider building vertical evacuation towers near the coast if residents would have no time to move to higher ground.

4. To ensure the safety of temporary emergency evacuation sites and evacuation buildings, consider the following:
   - Temporary emergency evacuation sites can be either an open space or structure with high seismic resistance.
   - In principle evacuation centers should be located outside of the evacuation zone; however, temporary emergency evacuation sites can be located within high-risk zones as long as the location is safe and evacuees can survive the event.
   - Both temporary emergency evacuation sites and evacuation centers should be located away from slopes where landslides could occur and away from hazardous material storage sites.
   - Temporary emergency evacuation sites should preferably have an evacuation path to other areas, due to the possibility of higher than expected tsunami.
   - The site/center should be clearly identified as an evacuation site at the entrance and clearly recognizable.

   Functions that are required at **tsunami evacuation centers** (shown in Box 3) include:
   - Enough space: 1 m^2 per evacuee at minimum
   - Night lighting, information equipment (radio, etc.) for communication and data collection, water and sanitation facilities
   - Stocks of goods for overnight stays (e.g., blankets)
   - Communication facilities so that evacuees can receive information on the evolving situation and communicate any specific needs with the authorities and the outside world

5. Requirements for **tsunami evacuation centers (buildings)** are as follows:
   - In terms of their structure, in Japan the buildings will ideally be reinforced concrete[12] structures built to the Japanese building code, with more than

[11] http://www.fdma.go.jp/neuter/about/shingi_kento/h24/tsunami_hinan/houkokusho/p02.pdf.

[12] Steel-reinforced concrete is a building type seen commonly in Japan.

two floors that are equal to or higher than the estimated flood height (inundation depth) of a likely tsunami, or equal to or higher than the standard water level. This water level is defined as the estimated flood height (inundation depth) derived from tsunami models assuming no buildings, and adding the height that takes into account the increase in water level as a result of the building pushing up the water level. For more information on the formula to derive this water level, refer to Cabinet office (2005) (in Japanese).

- The building should not directly face coastal areas.
- The structure should be quake-resistant and be on a designated evacuation path so that evacuees can access the evacuation centers with ease.
- The evacuation centers should be clearly identifiable by local people as emergency evacuation sites.
- It is desirable to have stairs outside of the building that will enable evacuation.

Step 4: Add Information on How to Reduce the Detrimental Impacts from Earthquakes at the Household Level

Seismic Preparedness Maps should also consider including useful information about how communities can prepare for an event. Scientific analysis can determine the level and intensity of ground shaking that is likely to occur. However, it is useful to illustrate typical damage that is likely to occur during an earthquake, as seen in Figure 22. Seismic Preparedness Maps can also offer recommendations for preventive measures to be taken at the household level; these could include structural measures such as seismic reinforcement, and non-structural measures such as securing of furniture to the walls and ceilings. It is recommended that the Seismic Preparedness Maps organize items (see Figure 11) in chronological order (before, during, and after the event). Information on the support available from the national and local governments is also useful.

Step 5: Determine Map Design, Layout, and Format Based on Intended Usage

The final Seismic Preparedness Map can be distributed in either paper format or

Figure 22. Preparedness tips from the Anjo City Seismic Preparedness Map

Source: http://www.city.anjo.aichi.jp/kurasu/bosaibohan/yakudachi/gaikokugo.html.

Table 2. Recommended color pattern for JMA Seismic Intensity Scale

JMA SEISMIC INTENSITY	1	2	3	4	5 LOWER	5 UPPER	6 LOWER	6 UPPER	7
Recommended color									
Recommended RGB value	242	0	0	250	255	255	255	165	180
	242	170	65	230	230	153	40	0	0
	255	255	255	150	0	0	0	33	104

Source: http://www.jma.go.jp/jma/kishou/info/colorguide/120524_hpcolorguide.pdf.

electronic formats. The Japanese Seismic Preparedness Maps come in various formats and modalities and are available via either local government websites or the MLIT Hazard Map Portal (Disaster Preparedness Map portal).[13] If the material will be used in workshops and drills, consider printing a map that can be folded and distributed to the participants. For the Seismic Preparedness Maps to be used at home, consider having them in a booklet format.

To make the Seismic Preparedness Maps easy to use for the elderly and color-weak, consider using large fonts that are easy on the eye, and use appropriate color schemes. Illustrations should be visually pleasing for all ages. Follow cartographic conventions, e.g., for high risk use red, and for low risk use green or blue. Make sure to include information items for the vulnerable population, e.g., tips for evacuation preparation for pregnant women or elderly.

The color schemes shown in Table 2, Box 4 and Figures 23 and 24 are examples of recommendations by JMA[14] for illustrating tsunami inundation and seismic intensities.

The Seismic Preparedness Map for Anjo City, Aichi Prefecture, is available in Japanese, as well as in English and Portuguese (Figure 25), reflecting the diversity of the local residents.

Step 6: Distribute and Leverage Seismic Preparedness Maps for Community Disaster Risk Reduction

In Japan, Seismic Preparedness Maps are distributed to every household to maximize the communication of earthquake risks. They are also made available at community centers and other public facilities, and are on local government websites. The Seismic Preparedness Maps are also used in classrooms to raise awareness of the potential risk to students. Some local governments have developed smartphone apps that can display the risk information (Figure 26).

Seismic Preparedness Maps are used to communicate risks to local residents, so that the residents can take preventative measures. Figure 28 shows local government officials in Nagoya City, Japan, delivering a lecture on the newly developed Seismic Preparedness Map to help local residents understand their risk. Many local governments offer this type of outreach support upon request of residents. Seismic Preparedness Maps can also be used to

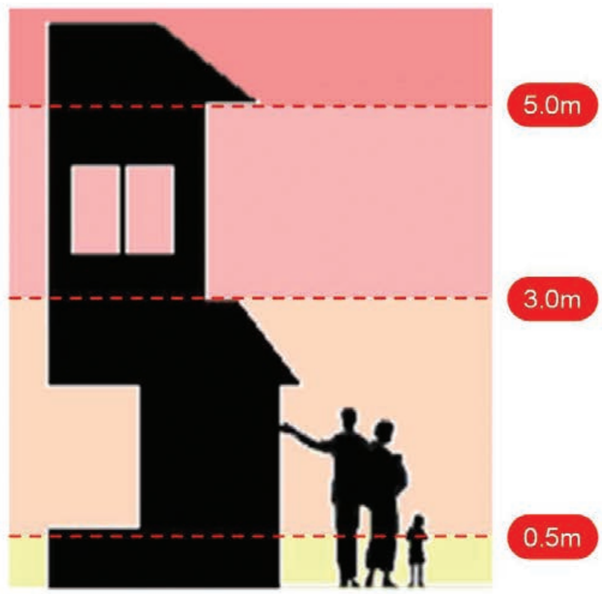
[13] http://disaportal.gsi.go.jp/.
[14] JMA (2012), Tokyo Metropolitan Government (2015).

Box 4: Sample pictograms

These pictograms are examples of those recommended by MLIT to show tsunami inundation depth and indicate evacuation sites on maps.

Figure 23. Color scheme used to show tsunami inundation depths

Water depth	RGB
20m ~	220,122,220
10m ~ 20m	242,133,201
5m ~ 10m	255,145,145
3m ~ 5m	255,183,183
0.5m ~ 3m	255,216,192
~ 0.5m	247,245,169



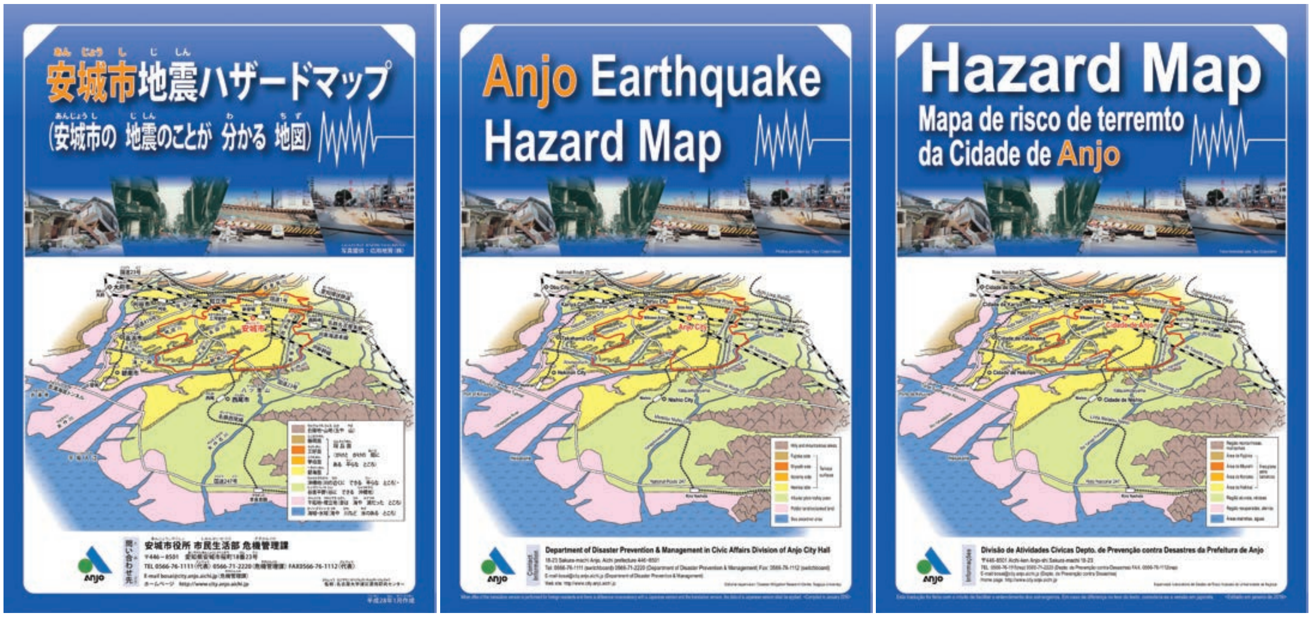
Source: Guidelines for Preparing for Flood Damage Hazard Map, April 2016, Flood Risk Reduction Policy Planning Office, River Environment Division, Water and Disaster Management Bureau [in Japanese]. http://www.mlit.go.jp/river/basic_info/jigyo_keikaku/saigai/tisiki/hazardmap/index.html.

Figure 24. Example of pictograms to indicate tsunami evacuation sites and centers

Source: http://www.gsi.go.jp/kikaku/kikaku20140423.html.

discuss and reevaluate evacuation routes with local residents, or can be used during town walks to raise awareness of potential seismic risks (Figure 27), identify evacuation routes, and point out dangers that could cause harm during earthquakes.

Figure 25. Example of multi-language Seismic Preparedness Map (Anjo City)



Japanese (Simplified writing) | English | Portuguese

Use of Seismic Preparedness Map for tsunami evacuation planning and training

Leveraging damage and loss estimation results calculated by prefectural governments, municipal governments devise tsunami evacuation plans. Cities also prepare tsunami evacuation plans for the area they are responsible for. Many local governments hold workshops where residents participate to discuss evacuation methods, location of evacuation sites, and routes to

Figure 26. Risk map of Funabashi City, Chiba Prefecture, on smartphone

Source: http://www.city.funabashi.lg.jp.e.ce.hp.transer.com/bousai/map/p015641.html.

Figure 27. Lecture on local hazard risks by experts

Source: http://www.mlit.go.jp/river/basic_info/jigyo_keikaku/saigai/tisiki/hazardmap/index.html.

Figure 28. An event hosted by a local government to promote the use of Seismic Preparedness Maps

Source: http://www.mlit.go.jp/river/basic_info/jigyo_keikaku/saigai/tisiki/hazardmap/index.html.

Figure 29. Tsunami evacuation training (Kochi City)

Source: http://www.bousaihaku.com/cgi-bin/hp/index2.cgi?ac1=B742&ac2=&ac3=3171&Page=hpd2_view.

validate tsunami evacuation plans (Figure 29, 31). As a result of these discussions, new evacuation centers and/or routes supported by the residents could be proposed to the local government.

Tsunami events are infrequent but can cause extreme destruction. Since the Great East Japan Earthquake in 2011, the Japanese government has been promoting the implementation of risk reduction activities to prepare for the maximum likely tsunami and protect communities.

Figure 30. Workshop to develop tsunami evacuation plan by the local community/resident association. Tomakomai City, Hokkaido, July 2013.

Source: OYO Corporation.

Box 5: Example of disaster prevention information

In 2014, the Tokyo Metropolitan Government published and distributed the "Disaster Preparedness Tokyo" handbook to every household in Tokyo. The handbook is a risk communication tool that contains practical guidance to reduce the potential impacts from natural disasters in an easy-to-understand way using illustrations. The handbook contains images showing likely impacts households may encounter during earthquakes, prompting people to be prepared for these situations.

Figure 31. Illustrations of earthquake situations, from the "Disaster Preparedness Tokyo" handbook

Source: The Tokyo Metropolitan Government (2015): "Disaster Preparedness Tokyo–Let's Get Prepared," http://www.metro.tokyo.jp/ENGLISH/GUIDE/BOSAI/index.htm.

ANNEX 1

DEFINITION OF THE JMA SEISMIC INTENSITY SCALE

Comparison of JMA Intensity Scale to the Modified Mercalli Intensity (MMI) Scale and Medvedev-Sponheuer-Karnik (MSK) Scale

JMA INTENSITY SCALE	DEFINITION OF THE JMA INTENSITY LEVELS	MMI SCALE	MSK SCALE
0	Imperceptible to people.	I. Not felt	I. Imperceptible
1	Felt slightly by some people keeping quiet in buildings.	II. Weak	II. Very light
2	Felt by most people keeping quiet in buildings.	III. Weak IV. Light	III. Light IV. Moderate
3	Felt by almost all people inside buildings.	V. Moderate	V. Fairly strong
4	Almost all people are startled. Hanging objects such as lights sway significantly. Unstable objects/figurines may fall.	VI. Strong VII. Very strong	VI. Strong VII. Very strong
5 Lower	Most people feel the need to hold onto something stable. Objects such as dishes or books on shelves may fall. Unsecured furniture may move and unstable objects may topple over.	VIII. Severe	VIII. Damaging
5 Upper	Walking is difficult without holding onto something stable. More objects such as dishes or books on shelves fall. Unreinforced concrete block walls, etc. may collapse.	IX. Violent	IX. Destructive
6 Lower	It is difficult to remain standing. Most unsecured furniture moves and some may topple over. Wall tiles and windows may sustain damage and fall. For wooden houses with low earthquake resistance, roof tiles may fall, and the houses may tilt or collapse.		X. Devastating
6 Upper	People need to crawl to move, and may be thrown through the air. Almost all unsecured furniture moves and more start toppling over. Large cracks may form in the ground, and large-scale landslides and massive collapse may occur.		
7	There are more cases of wooden houses with low earthquake resistance tilting or collapsing. Even buildings with high earthquake resistance could tilt. More reinforced concrete buildings with low seismic resistance collapse.	X. Extreme	XI. Catastrophic XII. Very catastrophic

The three scales shown here—MMI (used in many countries, including the United States and Republic of Korea), MSK (used in India, Israel, the Russian Federation, and throughout the Commonwealth of Independent States), and JMA—have slight differences in the way they classify intensities. *Source:* JMA (2012), Tokyo Metropolitan Government (2015), USGS, Andrew Alden: MSK64 Seismic Intensity Scale, Takuzo Hirono and Kaoru Sato (1971).

ANNEX 2

LIST OF HAZARD AND RISK MODELING REFERENCES

International Institute of Seismology and Earthquake Engineering (IISEE): Methodology of Microzoning (examples in Japan)
http://iisee.kenken.go.jp/net/yokoi/methodology/.

Cabinet Office (Disaster Management) et al. (2004): Tsunami and Storm Surge Hazard Map Manual
https://www.pwri.go.jp/icharm/publication/pdf/2004/tsunami_and_storm_surge_hazard_map_manual.pdf.

Flood Control Division, River Bureau, Ministry of Land, Infrastructure and Transport (MLIT) (2005): Flood Hazard Mapping Manual in Japan
https://www.pwri.go.jp/icharm/publication/pdf/2005/flood_hazard_mapping_manual.pdf.

Cabinet Office (2005): Earthquake Hazard Map Technical Manual (in Japanese)
http://www.bousai.go.jp/kohou/oshirase/h17/pdf/050513siryou.pdf.

Catalog of Damaging Earthquakes in the World (through 2012)
http://iisee.kenken.go.jp/utsu/index_eng.html.

Ministry of Land, Infrastructure, Transport and Tourism of Japan: Hazard Map Portal Site (in Japanese)
http://disaportal.gsi.go.jp/index.html.

Disaster Management, Cabinet Office of Japan
http://www.cao.go.jp/en/disaster.html.

Japan Seismic Hazard Information Station (J-SHIS), NIED
http://www.j-shis.bosai.go.jp/en/.

Japan Meteorological Agency
http://www.jma.go.jp/jma/indexe.html.

Evacuation center selection guidelines being used in Japan (Iin Japanese)
http://www.mext.go.jp/b_menu/shingi/chousa/shisetu/013/007/shiryo/icsFiles/afieldfile/2013/12/26/1342793_1.pdf.

Welfare evacuation center guidelines being used in Japan (In Japanese)
http://www.bousai.go.jp/taisaku/hinanjo/pdf/1604hinanjo_hukushi_guideline.pdf.

JMA Guideline for Color schemes to use for weather related information (2012)
http://www.jma.go.jp/jma/kishou/info/colorguide/120524_hpcolorguide.pdf

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