

**Future Storm Surge Control Measures in Areas  
below Sea Level  
(Recommendation)**

**January 2006**

**Panel on Storm Surge Control Measures  
in Areas below Sea Level**

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## **Introduction**

Japan, surrounded by sea, has long been suffering storm surge disasters induced by large typhoons. Areas along the Pacific coast, three large bays, Tokyo, Ise and Osaka Bays, in particular, were severely hit by large typhoons such as Typhoon Muroto (1934), Typhoon Kitty (1949), Typhoon Ise-wan (1959) and Typhoon Daini-muroto (1961) and suffered heavy storm surge disasters. Typhoon Ise-wan incurred unprecedented damage throughout the Nobi Plains leaving more than 5000 people killed or missing.

Half a century have passed since the construction of levees in waterfront areas in the wake of Typhoon Ise-wan. In the meantime, many people have not been personally aware of the threat of storm surges because no serious storm surge disasters have occurred that claimed human casualties.

Hurricane Katrina induced large-scale storm surge disasters in New Orleans, the United States last August. More than 1200 people were killed or left missing. Seventy percent of the city of New Orleans is below sea level. The incident brought home that storm surges hitting places below sea level could cause catastrophic damage.

Areas below sea level that enclose the above three major bays of Japan\* occupy a combined space of approximately 580 km<sup>2</sup> and are inhabited by nearly four million people. These areas witnessed the concentration of people and assets in and after the advanced economic growth period and now play a central role in the country's social and economic operations. They are, however, highly vulnerable to flood disasters. Once the areas are inundated in water on a large scale due to storm surges, the nerve center of the country will be paralyzed causing an overwhelming social and economic impact.

Measures to control storm surges in areas below sea level are expected to focus on the construction of levees and other structures according to existing storm surge defense plans to ensure the prevention of inundation, in view of the present level of storm surge protection or the prospect for future natural disasters. Measures to minimize the damage by large-scale inundation are essential as a safety net against risk in contingency cases. Based on the above understanding, the study panel discussed future storm surge control measures in areas below sea level in

Japan and has provided recommendations as described in this report.

It is hoped that the recommendations will trigger various efforts for the future.

\*Areas below sea level in the three major bay areas in Japan: Areas below the mean synodic high tide level

# **I. Basic aspects of storm surge control measures in areas below sea level**

## **1. Need of damage minimization against large-scale inundation**

Category 5 hurricanes had already caused heavy damage to New Orleans and surrounding areas in the Gulf of Mexico region, but levees had been designed only against category 3 storms. As a result, Hurricane Katrina with a magnitude far exceeding the design level incurred unprecedented damage.

In Japan, whenever storm surges caused damage greater than the design level, facilities were upgraded to enhance safety. In the areas below sea level in the three major bay regions, measures have been taken to control storm surges mainly by constructing facilities such as coastal or riverside levees according to storm surge defense plans against incidents of the class of Typhoon Ise-wan.

In the meantime, tides have risen to record high levels throughout Japan. Fortunately, however, the land below sea level in the three major bay regions has not experienced any disasters claiming substantial human casualties for nearly half a century. The areas have enjoyed social and economic development on a large scale based on the assumption of a high level of safety.

Judging from the above background, the scale of planning for and the progress of storm surge control efforts for the areas below sea level are considered to be generally adequate.

Some of the storm surge defense facilities constructed in the wake of Typhoon Ise-wan have long been in service and deteriorated or offer insufficient resistance to large earthquakes such as the Tokai, Tonankai and Nankai Earthquakes.

Storm surges are a natural disaster. Of concern are storm surges exceeding the design level or beyond the capacity of facilities under construction, simultaneous occurrence of storm surges and flooding, and combinations of multiple disasters such as storm surges right after a great earthquake. In the longer term, safety of coastal areas against flooding or storm surges due to rising sea level induced by global warming is likely to be deteriorated, and typhoons may gain greater strength.

Even where certain levels of facilities have been in place, the

possibility of unexpected events occurring cannot be eliminated completely.

Examples include levee breaches as a result of ships being washed away and crashing the levee or lock during storm surges and water spill through openings due to storm surges when neither floodgates nor locks can be closed.

Inundation owing to storm surges overtopping levees, unlike flooding resulting from riverbank overflow, causes floodwaters to continuously flow into areas behind the levee until the water level behind the levee becomes identical with the sea level. Inundation of the areas below sea level by storm surges is likely to cause serious damage because the areas may remain inundated in deep water for a long time and because evacuation may become extremely difficult.

Large-scale flooding of the areas below sea level around the three major bays of Japan due to storm surges will paralyze the nerve center of the country and have an overwhelming impact on its society and economy. New Orleans was inundated in water for more than a month and a half and some regions have yet to be provided with electric power and numerous residents have not yet returned home. This indicates the great socioeconomic impact of the large-scale inundation. Storm surge control in the areas below sea level should be regarded as a "national defense" measure because the existence of the country is at stake. The disaster defense poses a great challenge for administrative authorities.

Basic direction of storm surge control in the areas below sea level has been defined based on the above discussions. (i) Limited funds should be used mainly for steadily constructing storm surge defense facilities and securing their reliability in order to ensure inundation prevention according to storm surge defense plans. (ii) Measures should be taken to minimize the damage by large-scale inundation as a safety net against risk in contingency cases. In taking these actions, it is important to adequately reflect various lessons learned through the analysis of the Hurricane Katrina disaster in damage minimization.

Reducing damage to a minimum requires not only defense efforts of coastal or river administrators and port facilities managers but also self-protection initiatives of local communities. All the stakeholders should take a comprehensive approach that incorporates city planning, ways of living and individuals' disaster defense actions. The measures against large-scale flooding should focus on the protection of human lives and the

continuation or early restoration of social activities.

## **2. Future storm surge control measures in areas below sea level**

In future storm surge control, top priority will be given to ensuring inundation prevention according to existing storm surge defense plans. Appropriate involvement of national and prefectural governments is therefore required because they are responsible for coastal and river administration.

Damage will be minimized by diverse stakeholders. Organizations concerned including municipalities, coastal and river administrators and facilities managers should therefore jointly develop specific defense measures and risk management plans, disclose them in local disaster defense plans and reflect them in various local plans while considering how to keep stakeholders motivated. When defining actions for evacuation and information dissemination in particular, sufficient consideration should be given to people requiring guidance during a disaster such as the elderly.

Close coordination among administrative organizations and comprehensive implementation of disaster defense plans are necessary because measures are correlated to one another. Coordination among municipal governments in particular is essential.

In order to minimize damage, national and local governments and research institutions should collectively assume the type of damage by large-scale inundation and implement disaster defense measures while making a time-based verification of specific measures in terms of cost, feasibility and speed of project implementation for each region below sea level.

## **II. Specific measures to be taken**

### **1. Measures to fully prevent inundation through the existing storm surge defense plans**

The following measures should be taken to ensure inundation prevention through the existing storm surge defense plans.

#### **(1) Steadily constructing storm surge defense facilities and securing their reliability**

##### **(i) Steadily constructing storm surge defense facilities**

Coastal protection and river management facilities such as levees, revetments, floodgates and locks should be constructed more steadily than before. Priority should be given to securing designated functions of deteriorated facilities or facilities with insufficient seismic resistance. Construction of high standard levees (super levees) should be promoted in storm surge-prone sections of rivers designated to be provided with such levees, in the course of city planning.

##### **(ii) Securing the reliability of disaster defense facilities**

###### **(a) Ensuring the inspection of storm surge defense facilities**

Coastal and river administrators should make sure that inspections are made for the height, seismic resistance and degree of deterioration of facilities and the operability of floodgates and locks to secure the reliability of levees and other flood defense facilities.

###### **(b) Planning and plan-based implementation of emergency measures**

Based on the above-mentioned inspection results, emergency measures should be planned and implemented according to the plan for facilities that urgently require such measures.



(iii) Enhancing normal management system

(a) Enhancing inspection by coastal and river administrators and developing databases using inspection data

To ensure that disaster defense facilities operate smoothly, normal inspection by coastal and river administrators should be enhanced and databases containing inspection data should be used for plan-based maintenance.

(b) Reinforcing storm surge information collection and dissemination systems

Systems for coastal and river administrators to collect data on tide levels and water levels should be enhanced to encourage dissemination of accurate information to organizations involved in storm surge defense under normal conditions.

(c) Enhancing the efforts of flood fighting managers

Key flood fighting points should be specified in flood fighting plans for all of the coastal protection facilities. Organizations concerned constituting a flood fighting forum should check facilities in preparation for smooth flood fighting actions in the event of storm surges including the operation of floodgates and locks. The coasts as potential storm surge areas should be designated in accordance with the Flood Fight Law.

## **2. Damage minimization measures against large-scale inundation**

Measures should be prepared to minimize damage in the case of large-scale inundation as a safety net against risks in contingency cases. Lessons learned from the Hurricane Katrina disaster should be reflected in disaster defense measures wherever they are applicable to Japan.

### **(1) Minimizing inundated areas**

(i) Controlling water inflow to prevent inundation from expanding

- (a) Constructing secondary levees and using highway and railway embankments, river levees and series of buildings

In order to prevent inundated areas from expanding and to drain floodwaters quickly, separating inundated areas into several sections using structures is considered effective. Examinations should be made of the construction of secondary levees, use of highway and railway embankments and river levees and waterproofing of openings between a series of reinforced concrete buildings using cutoff plates. Installing cutoff plates as part of flood defense activities needs to be considered.

- (b) Taking measures for underground space

Measures should be prepared to prevent floodwaters from entering underground space such as subways and underground shopping malls and from spreading to other areas along subways or other paths.

- (ii) Ensuring quick removal of floodwaters

- (a) Ensuring drainage in the event of large-scale inundation

Quick drainage of floodwaters is essential to fast shift from temporary to full-scale evacuation and to early rehabilitation of local communities. Pumping stations along coasts, rivers or sewerage systems should be flood-proofed to keep them operational even where they are inundated in water on a large scale. Facilities driven by electric power should be equipped with in-house power generators to secure drainage during power failure.

- (b) Developing optimal drainage plans

In order to ensure quick drainage, the capacity of drainage facilities should be assessed and optimal drainage plan should be developed. In the process, the plan should be made of improving the discharge capacity of existing floodgates and installing new floodgates in areas where drainage capacity is insufficient.

(iii) Ensuring quick restoration of storm surge defense facilities

Channels for transporting materials should be secured for quick restoration at locations of levee breaches. For levees used for material transport, crown width should be enlarged and continuously secured. In emergency situation those levees should connect to elevated highways and ports. Information should be promptly provided to the organizations concerned on port facilities available for material transport. Material sorting facilities should also be made available.

**(2) Shifting to a way of living free from inundation damage**

(i) Disseminating lively information on the hazard in individual areas

Preparation of hazard maps should be encouraged to communicate to residents in a plain form assumed modes of inundation and defense measures. Easy to understand information on local hazard should be provided to residents by disclosing water level information including the elevation of a given point, past floodwater depths and present tide level displayed on electric message boards, in urban areas. Then, residents should be encouraged to make preparations on their own.

(ii) Providing guidance to residents in reducing damage in conjunction with city planning

Hazard maps should be reflected in the development of policies for improving, developing or maintaining city planning areas. Residents should be advised to take hazard reduction measures by regulating land use through such means as the designation of potential hazard areas and the protection of urbanization control areas. Measures should also be prepared for underground structures. Damage reduction efforts should be made in conjunction with city planning.

(iii) Recommending structural design of buildings in preparation for inundation and for facilitating evacuation

Construction of buildings highly resistant to large-scale inundation should be encouraged by regulating land use through the designation of

potential hazard areas or by granting subsidies. For example, a part of building should be raised off the ground on pilotis, or an entrance should be equipped with cutoff walls. Building should also be structured to enable occupants to easily escape from it, e.g. to the roof.

- (iv) Providing guidance to businesses in installing office equipment at appropriate positions

Guidance should be offered so that key office equipment including computers and power sources may be positioned properly to evade inundation damage. Appropriate use of buildings should be encouraged, for instance, people requiring support during a disaster should be dissuaded from occupying the bottom floor of a building.

Those handling toxic substances should be requested not to discharge them at the time of inundation.

- (v) Advising residents to keep cutoff plates and sandbags on hand

Residents should be encouraged to keep cutoff plates and sandbags on hand by providing support including subsidies.

### **(3) Ensuring quick and safe evacuation and relief**

- (i) Ensuring shelters are operational at the time of inundation

Shelters should be set up for use during large-scale inundation disasters as well as earthquakes although existing shelters have been prepared against earthquakes. In the case where no shelters are available in the vicinity, elevated sections of highways such as service areas and parking areas should be used or buildings in the neighborhood should be designated as temporary shelters while paying attention to security concerns. Permanent shelters should also be made available that can accommodate evacuees once means of transport have been secured. Goods should be regularly stockpiled in temporary shelters considering the expected number of occupants and duration of stay. Efforts should be made to secure temporary shelters in designated areas or in their neighborhood to facilitate the evacuation of elderly people who will need support during a disaster.

(ii) Ensuring evacuation routes are passable at the time of inundation

Existing facilities, if they are to serve as emergency evacuation routes, need the height above floodwater level. Evacuation and relief channels should be secured that will be operational during inundation by widening levee crown and guaranteeing the continuity of levees, ensuring emergency access to expressways and constructing pedestrian decks connected to railway stations for use as evacuation routes. Equipping local communities with evacuation and relief boats is also important.

(iii) Disseminating information for proper evacuation guidance

The following measures should be taken to disseminate accurate information in an easy to understand format on expected mode of inundation and actions to be taken in specific regions with the view to ensuring public warning and evacuation operations.

(a) Reinforcing the dissemination of storm surge information

More accurate storm surge warning and more detailed information should be provided to the heads of municipal governments to help them issue evacuation recommendations. Easy to understand storm surge information should be made readily accessible via the Internet or cellular phones. More potential flood hazard coasts should be designated based on the Flood Fight Law to facilitate smooth flood fighting and evacuation.

(b) Preparing easy to understand storm surge hazard maps

Storm surge hazard maps should be prepared by coordinated efforts of municipalities that will help residents understand large-scale inundation hazard and actions to be taken. Hazard maps should also be developed for combinations of flooding and storm surges.

(iv) Disseminating storm surge information by all the means available

Storm surge information should be provided via every media accessible by residents including television, radio, the Internet, cellular phones, and car navigation systems usable under the Vehicle Information

and Communication System (VICS). Television is a key medium for people with limited information access including the elderly, so accurate information should be provided via the medium. Systems should be established to daily disseminate information to people requiring support in the event of a disaster by talking to them by coordinated efforts of the municipality and local community.

(v) Improving storm surge defense skills of the staff of municipal governments

The staff of local municipalities should be trained on storm surge defense to equip them with skills useful in the even of a large-scale inundation disaster and to have them share disaster fundamentals.

(vi) Developing risk management action plans

(a) Developing risk management action plans

In order to help organizations involved in storm surge defense, a local council that will be established by the organizations concerned such as national and municipal governments, and facilities managers for highways, railways and infrastructure systems including water supply and sewerage and power supply utilities should develop risk management action plans for large-scale inundation disasters. Risk management action plans should be specified in local disaster prevention plans and reflected in local planning. In the process, specific evacuation methods for each region should be examined.

(b) Holding disaster drills against storm surges

Disaster drills should be held in preparation for large-scale inundation by storm surges based on the risk management action plans. Then, efforts should be made to enable people requiring help during a disaster to be evacuated smoothly by talking to them. Drills should also be conducted to prepare for combinations of an earthquake and storm surges.

#### **(4) Keeping facilities operational for rapid relief, restoration and rehabilitation**

(i) Keeping lifeline systems operational at the time of inundation

(a) Keeping lifeline systems operational

Discontinuation of operation of lifeline systems due to inundation such as water supply and sewerage, power and gas supply, information communications and waste disposal facilities should be detrimental to rapid restoration and rehabilitation over a wide area. Operability of these facilities during a large-scale inundation disaster should be checked. Facilities should be water proofed if required according to plans for maintaining systems operability.

(b) Securing routes for relief and material transport for restoration

Securing routes for relief and material transport for restoration is essential to rapid relief, restoration and rehabilitation. Levee crown should be widened and the continuity of levees guaranteed. Emergency access to elevated highways and ports should be provided. Pedestrian decks connected to railway stations should be made available or constructed whenever required. Information should be promptly provided to the organizations concerned on port facilities available for transporting relief or reconstruction materials. Material sorting facilities should also be made available.

(ii) Preventing vessels moored to port from being washed away

Vessels and containers that are washed away by storm surges are likely to hit levees or revetments causing damage. Remedial measures should be developed such as quickly ensuring the safety of domestic or foreign vessels by moving vessels and containers to waters free from danger of crash, designating areas where no vessels or automobiles should be left unattended, removing vessels or automobiles that have been left and preventing cargoes stored in the open from being washed away.

(iii) Preventing the spill of toxic materials in waterfront areas

Removing toxic materials that are spilt from petrochemical facilities in waterfront areas and overflow levees is expected to require much time and hamper restoration and rehabilitation work. Businesses possessing or storing toxic materials should be guided to develop adequate plans to prevent the spill of toxic materials.

**3. Accumulation and dissemination of storm surge defense knowledge**

Memories of storm surges are likely to fade with time regardless of how serious they were. Knowledge about storm surge defense should therefore be accumulated and disseminated for use against future events.

(i) Accumulating and disseminating storm surge defense knowledge

(a) Preparing materials and developing human resources for accumulating and disseminating storm surge defense knowledge

In order to minimize damage, individual residents should take preparedness to inundation disasters personally. Easy to understand materials should be prepared to communicate the experience of elderly people in local communities to future generations and to accumulate and disseminate storm surge defense knowledge. It should be noted that past experience may lead to inadequate response under present conditions depending on the scale of the event. Human resources should also be developed that can plainly communicate the experience and knowledge to the public.

(b) Securing bases for disaster defense activities

Disaster defense bases should be established in local meeting places or other places for residents and administrative authorities to share storm surge defense information and for local residents to take defense actions through voluntary defense organizations.



#### **4. Additional challenge to be undertaken to ensure the security against storm surge disasters**

The following efforts should be examined to increase safety against storm surge disasters.

- Investigations and studies concerning the evaluation of structural strength of storm surge protection facilities against external forces
- Investigations and studies concerning the evaluation of probability of storm surge as a design external force
- Investigations and studies concerning the refinement of storm surge protection facilities inspection methods for their efficient maintenance, repair technology and deterioration control measures
- Investigations and studies concerning the development of methods for quickly restoring levees breached by storm surges
- Investigations and studies concerning protection measures against sea level rise due to global warming and land use in coastal areas
- Investigations and studies concerning disaster protection systems (including tax and insurance systems) in coastal areas

## **Closing remark**

This document contains the first recommendations concerning storm surge defense in areas below sea level in the three major bay areas in Japan.

All the people involved in storm surge defense should be firmly aware that large-scale inundation of the areas below sea level would paralyze the nerve center of the country. The national and prefectural governments should take the initiative in developing and implementing as soon as possible specific action plans in accordance with these recommendations. Knowledge that will be obtained from further analysis of the Hurricane Katrina disaster should also be adequately incorporated into future measures.

The national and prefectural governments should also take the initiative in properly responding to specific problems to be encountered in future storm surge defense operations.

The Ministry of Land, Infrastructure and Transport, playing a central role in storm surge defense, should provide the public with information on the actions that organizations concerned have taken or will take in an easy to understand format. For example, if an increasing number of people understand that sea level rise due to global warming is a serious phenomenon that has a close bearing upon the lives and assets of people living in coastal areas, the public will take storm surge defense in the areas below sea level personally.

Storm surge defense in the areas below sea level as a "national defense" measure is related to the life and production activities of the public regardless of whether they live in coastal areas or not.

It is hoped that the recommendations will be used also as a basis for taking adequate measures in other areas below sea level according to the mode of land use or the concentration of population and assets although the recommendations have been made with the areas below sea level in the three major bay areas in mind.

## **Members of the panel on storm surge control measures in areas below sea level**

Chairperson

Masahiko Isobe, Director, Graduate School of Frontier Sciences, University of Tokyo (coastal engineering)

Kohichiro Iwata, Professor, Chubu University (coastal structures)

Yoshiaki Kawata, Director, Disaster Prevention Research Institute, Kyoto University

Takayuki Kishii, Professor, Nihon University (urban planning)

Keiko Sakurai, Professor, Gakushuin University (administrative laws)

Tomotsuka Takayama, Professor, Disaster Prevention Research Institute, Kyoto University

Masami Tada, Edogawa Ward Mayor (local administration)

Atsushi Tanaka, Professor, Toyo University

Tetsuro Tsujimoto, Professor, Graduate School of Engineering, Nagoya University (river engineering)

Kazuyuki Higuchi, Deputy Director-General of Bureau of Port and Harbor, Tokyo Metropolitan Government (local administration)

Shoji Fukuoka, Professor, Research and Development Initiative, Chuo University (river engineering)

Yohichiro Fujiyoshi, NHK news commentator and Professor, Otsuma Women's University (mass communications)

Koji Yamamoto, Chairman, Halex Corporation (meteorology)

Note: Courtesy titles have been omitted.