OFFICE OF NATIONAL ECONOMIC AND SOCIAL DEVELOPMENT BOARD (NESDB)

ROYAL IRRIGATION DEPARTMENT (RID)
MINISTRY OF AGRICULTURE AND COOPERATION (MOAC)

DEPARTMENT OF WATER RESOURCES (DWR)
MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT (MNRE)

KINGDOM OF THAILAND
PROJECT FOR
THE COMPREHENSUVE FLOOD MANAGEMENT PLAN FOR
THE CHAO PHRAYA RIVER BASIN
COMPONENT 3

Final Report

October 2013

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
FOUNDATION OF RIVER AND BASIN INTEGRATED COMMUNICATIONS, JAPAN

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ABBREVIATIONS

BMA	Bangkok Metropolitan Administration
DDPM	Department of Disaster Prevention and Mitigation
DDS	Department of Drainage and Sewerage, BMA
DWR	Department of Water Resources
EGAT	Electricity Generating Authority of Thailand
EOC	Emergency Operation Center
FROC	Flood Relief Operations Center
GISTDA	Geo-Informatics and Space Technology Development Agency
GOT	Government of the Kingdom of Thailand
HAII	Hydro and Agro Informatics Institute
ICHARM	International Center for Water Hazard and Risk Management
IEAT	Industrial Estate Authority of Thailand
IMPAC-T	Integrated Study on Hydro-meteorological Prediction and Adaptation to Climate Change in Thailand
M/M	Minutes of Meetings
MNRE	Ministry of Natural Resources and Environment
MOSTE	Ministry of Science, Technology and Environment
MST	Ministry of Science and Technology
NDWC	National Disaster and Warning Center
NESDB	National Economic and Social Development Board
ONBT	Office of The National Broadcasting and Telecommunications Commission, Ministry of Information and Communication Technology
OPM	Office of the Prime Minister
SAO	Subdistrict Administrative Organization
SCWRM	Strategic Committee for Water Resources Management
PAT	Port Authority of Thailand
R/D	Record of Discussion
RID	Royal Irrigation Department
THB	Thai Baht
TMD	Thai Meteorological Department
WMSC	Water Watch and Monitoring System for Warning Center

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I. INTRODUCTION

1. An exceptional flood took place in 2011. Four tropical storms and a typhoon associated with recorded rainfall hit Thailand one after another between June and October 2011. It brought an unprecedented flood inundation in the Chao Phraya River Basin. According to a report titled "Thailand Flooding 2554 Rapid Assessment for Resilient Recovery and Reconstruction Planning" by the Ministry of Finance, Royal Thai Government and the World Bank, the total damages and losses amount to THB 1.4 trillion approximately, and industrial estates in Ayutthaya and Pathumthani were severely affected in particular.

2. The Government of the Kingdom of Thailand (GOT) moved towards preparation for the 2012 rainy season and also launched discussions on a long-term water management plan. On January 20, 2012 the Prime Minister of Thailand unveiled the Master Plan on Water Resources Management for both urgent and long-term periods to ensure the continuity of the country's development even with future drought and flood. The Master Plan was elaborated by Strategic Committee for Water Resources Management (SCWRM).

3. However, under the influence of climate, land use and other changes, there will be a high possibility of similar extent of or even more extensive flood compared to the one in 2011. In preparation for extensive flood, rehabilitation of damaged facilities, construction of new facilities and examination of countermeasures based on medium- to long-term perspective were required.

4. The Project had been implemented in accordance with the Minutes of Meeting dated December 22, 2011 and the Record of Discussion (R/D) dated January 13, 2012 among JICA, the Royal Irrigation Department (RID), the Department of Water Resources (DWR), the National Economic and Social Development Board (NESDB). It was a holistic project which consisted of the following components,

Component 1: Comprehensive flood management plan considering the effect of the climate change and land development
- Subcomponent 1-1: Preparation of a detailed map
- Subcomponent 1-2: Formulation and Evaluation of the Master Plan for Water Resources Management prepared by SCWRM

Component 2: Outline design for Japanese Grant Aid for Disaster Prevention and Reconstruction

5. The progress of the study conducted under the Project clearly showed the necessity of the improvement of flood management and flood forecasting system. RID, DWR, NESDB and JICA thus agreed to implement a technical assistance or technical cooperation additionally on the improvement of flood management system by amending the R/D by means of the Minutes of Meetings (M/M), which were signed on May 31, 2012. Thus Component 3, Improvement of a Flood Management System and its operation capacity for the Chao Phraya River Basin, commenced. This is the Final Report of the Component 3.

II. COMPONENT 3

6. The following paragraphs describe the outline of the Component 3 defined in the M/M.

2.1 Objectives

7. The objectives of the Component 3 are to implement properly a flood countermeasure (response and recovery, emergency countermeasure) in 2012 and beyond in combination with other components, and to mitigate flood damage in Chao Phraya River basin.

2.2 Expected Goal

8.. The expected goal of the Component 3 is to promote sustainable economic growth by reducing water related disaster risk through Integrated Water Resources Management.

2.3 Expected Output

9. The expected output of the Component 3 is that a plan of flood management is improved through preparations of plans, development of flood operation capacity (RID and DWR), and practical operation of flood management.

2.4 Implementation Structure

10. RID and DWR will be responsible for implementing the Component 3.

2.5 Target Area

11. The target area of the Component 3 is all regions of Thailand. Though the flood data analysis/flood forecasting system and the flood management system will be developed for the Chao Phraya River Basin in the component, they are to be applicable to the other basins in Thailand, as well.

2.6 Outline Activities

12. Under the Component 3, following activities are implemented.

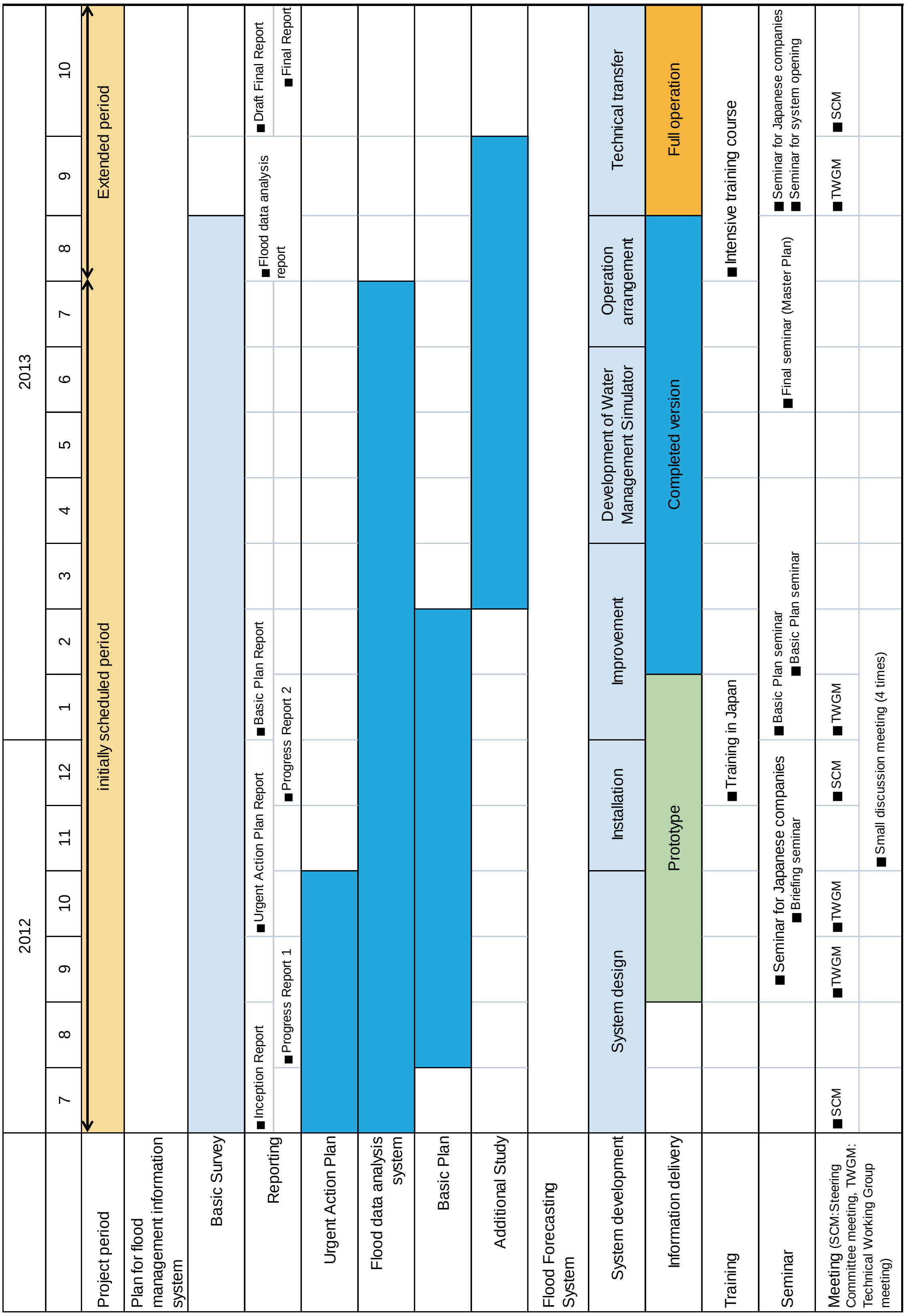
(1) Development of basic concept of flood management system
(2) Development of basic plan of flood management system
(3) Development of action plan for establishment of flood management system[1]
(4) Development of implementation plan to carry out the urgent activities
(5) Establishment of flood data analysis/flood forecasting system

[1] Instead of developing action plan, some additional studies were conducted for realizing the Basic Plan of Flood Management System.

III. PROJECT IMPLEMENTATION

13. The Component 3 commenced in July 2012. It was completed in October 2013. The table below describes the work flow chart of the Component 3 as implemented.

Table 1 Work Flow Chart as Implemented



IV. BASIC CONCEPT OF FLOOD MANAGEMENT SYSTEM

4.1 Issues

14. Thailand, in its long history, had developed a water information management system with water utilization in the center, which was unique in the world. By controlling and operating the system, it had achieved huge success resulting in the national development. On the other hand, the information system on flood control was not necessarily enough. During the 2011 flood, if proper information on right time was shared among government organizations, municipalities, citizens, companies, and farmers, better countermeasures would have been taken leading to less damage. River management for the Chao Phraya River in Thailand, aside from the inland water countermeasures in Bangkok, was conducted by organizations and systems based on their use of the river and its water. For example, RID secured water for agricultural use; the Electricity Generating Authority of Thailand (EGAT) managed water for hydroelectric power; DWR managed rivers as a natural resource; and the Port Authority of Thailand (PAT) conducted dredging of rivers to facilitate shipping.

15. Including the Thailand Meteorology Department (TMD), the Ministry of Information and Communication Technology, each of the above organizations measured rainfall and river water level for its own purposes. These measurement data were publicly available in summary form over the Internet, but no mechanism existed for integrating all these data in real time. Furthermore, even within individual organizations, different systems had been constructed for each project depending on the year of procurement, measurement location etc., making it difficult to integrate all the data. For these reasons, there was no system in place for sharing the vital hydrological, meteorological and flooding data etc., essential for disaster countermeasures, among relevant organizations and the public. This presented a major obstacle to effective flood control measures. The detailed description on the distribution of the hydrological observation stations in the Chao Phraya River Basin is found in <u>Attachment 01 "Hydrological Observation Stations in the Chao Phraya River Basin"</u>.

16. Each organization had developed its own numerical models for calculating river flow rate from rainfall. Even within a single organization, different models are sometimes in operation; for example, the RID used different models to calculate river flow in the major tributaries as opposed to the lower reaches of the Chao Phraya River. This presented a major hindrance in grasping the situation across the entire watershed area for the purpose of flood control.

17. The Single Command Authority was to be an integrated supervisory body for flood control, as well as promoting integration of all the data with analysis systems. GOT also sought to give the body sufficient authority and capacity to oversee appropriate operations of facilities for reducing flood damage, to make judgments in time of emergency, and to give evacuation directions.

18. After the events of 2011, it was understood that similar flooding occurring in 2012 or beyond would have a significant economic impact not only on the Kingdom of Thailand, but also on the Japanese companies which had situated their production bases in Thailand, as well as possibly reducing popular support for the Thai government and damaging its international credibility. GOT was reviewing its large dam reservoir operations and taking action to

strengthen its levees and embankments, but in addition to these efforts, it urgently needed better information sharing among government agencies, as well as provision of accurate information to enable effective damage control actions for its citizens and municipalities.

4.2 The 2011 Flood and After

19. In 2011, the dyke of the Chao Phraya River broke at eight places over the maximum length of 1,300 m, and flood water ran out of the river for the duration of 2 weeks - one month. Inundation water traveled from the levee break point near the Chao Phraya Dam to Ayutthaya in two weeks. This meant that forecasting the movement of floodwater would have been possible, if proper inundation calculation model had been constructed. Such forecast information on inundation would be valuable for decision making on evacuation. Inundation began around 23 August near Nakhon Sawan. By end October the flood water in the east side of the Chao Phraya River reached close to the sea, and it took two more weeks for the flood water in the west side of the river to reach close to the sea.

20. During 2011 flood time, the following websites were available for people to know the flood situation.

- The picture from radar updated every hour for the rain of the whole country in the past 24 hours (data of TMD collected by the Hydro and Agro Informatics Institute (HAII), and the Naval Research Lab USA);
- Flood Monitoring Website (Geo-Informatics and Space Technology Development Agency (GISTDA));
- Water level of main rivers and main dams in the country, discharge into the Gulf go Thailand (RID, HAII, Department of Drainage and Sewerage (DDS) of Bangkok Metropolitan Administration (BMA));
- Water level on main roads and canals in Bangkok (DDS);
- Sea water level forecast at the river mouth of the Chao Phraya River (Samut Prakarn Provincial Government) and sea water level report (Hydrographic Department, Royal Thai Navy, HAII); and
- Three days rainfall forecast picture (HAII cooperated by TMD).

It could be pointed out that, during 2011 flood time, while the upper most forecast (on rainfall) and the lower most forecast (on the sea water level) were made public over internet by government agencies, forecast on water level of rivers, discharge, or inundation situation was not available. In particular, short-term forecast of the direction of floodwater was most wanted after the capacity of a river section was exceeded by the runoff. RID had hydrological models to calculate and forecast river and inundation situations of the Chao Phraya River. However, the operational use of such calculations for disaster preventive actions by the decision makers, government organizations, and the general public were difficult, probably because there was not a proper mechanism of systematically utilizing the outcome of such calculations.

21. Private and academic sectors and volunteers had important role to provide real-time information via TV broadcasting, websites, social networks, and Short Message Service (SMS). Because the government's operation was limited, relevant private sector and academics took a part of responsibilities by providing flood monitoring data, flood maps and flood forecasting analysis to warn people in advance in order to prevent damage, and prepare evacuation in case of serious situation, along with providing flood protecting and relief methods. People also shared their information through social networks (Facebook, Twitter, etc.) and uploading their video record on YouTube to report the real-time situation. They, however, were not necessarily

responsible for the quality/accuracy of the information.

22. During and after the flood in 2011, there were outcries for the government to provide more accurate flood information; some claimed that inaccurate and even contradictory information was disseminated by different government agencies. People required information on the broader situation, both in space and time, rather than knowing only the present level of flood water in front of them or nearby.

23. During 2011 flood, there were requests for information on (i) the accurate present situation; (ii) forecast information; and (iii) schedule and effects of countermeasures.
Specific questions could be;

- When will my land get inundated?
- How bad is the inundation?
- Which land is risky?
- What will be the problem?
- When will water recede?

With forecast information following damage alleviation action would have been taken;

- Preparation for inundation (evacuation, sandbagging, moving cars);
- Cropping (even prematurely) before damaged; and
- Evacuation of products, safety of employee.

With forecast information flood defense organizations would be able to undertake the following;

- Effective countermeasures by emergency sandbagging and pumping;
- Effective operation of water gates and dams; and
- Damage estimate of a levee break (in some cases selection of a break point).

24. In the Master Plan on Water Resources Management formulated by the SCWRM, as one of 8 work plans "Work plan for Information Warehouse as well as Forecasting and Disaster Warning System" was included. Under the work plan,

- developing data system;
- creating hypothetical scenarios based on technical principles; and
- increasing the efficiency in the warning system

were aimed by the followings:

(i) Setting up the national water information center;
(ii) Constructing hypothetical water scenarios, forecasting and disaster warning systems; and
(iii) Enhancing the national disaster warning system to be capable of monitoring and analyzing water situation in a timely manner by improving and increasing the number of water monitoring stations in major rivers, installing CCTVs at the water gates and pumping stations, upgrading satellite and remote sensing systems, and reorganizing and developing disaster warning systems.

The Minister of Science and Technology, and RID were responsible for the work plan.

25. It was expected that the Office of the National Water and Flood Management Policy (ONWF, alias Single Command Center) would take the responsibility of integrating the government's observation data. ONWF created a website (http://www.waterforthai.com/) for this purpose. The main page of the website was "the situation of rain, dam water, river water and flood on the date" described in one page with images of speedometers indicating the dam storage, colors on the map indicating rainfall of last 24 hours, color-coded squares and stars

indicating river water levels at different stations. The website also had links to different organizations for water situation including volume of rainfall, weather map, weather and storm, volume of water in main reservoirs, chart of water flow rate, CCTV at key places, high tide, and important information about water management was presented.

26. The Prime Minister addressed, during an interview about water management made on 27 August, 2012, that the government learnt from the previous year's lesson that presenting concluded information would confuse people since the information might have been interpreted in different ways (thus different conclusions might be reached by different government agencies). She continued that as a result, the best way should be the presentation of facts, and, in the case of dam, the water level in the dam should be fully accessed in the website. The website of ONWF indicated above corresponded to this view of the Prime Minister.

27. The website of the HAII (http://www.thaiwater.net/) presented Thailand's integrated water resource management information including weather monitoring from various resources, water situation, records of drought and flood situation, including related researches and knowledge such as flow rate analysis method, etc. A team of researchers from the HAII was developing a new hydrological model to predict flooding around the country over any seven day period. The new model was a combination of weather forecasting and hydrological modeling which would help researchers get a more accurate picture on a flood situation.

4.3 Integrated Approach

28. For proper management of flood events, integrated approach of disaster prevention and mitigation is essential: Structural and non-structural measures are to be taken in harmony. Basic principles of disaster prevention/mitigation, applicable wherever in the world, against whatever sorts of disasters, are;

- (i) Not to live in dangerous place, so as not to sustain damages even if phenomena occur (e.g. land use control, water-proof house)
- (ii) Defend with disaster prevention facilities, or adjust phenomena (e.g. dyke, estuary water gate, dam)
- (iii) Escape from risks of, or rescue from, dangerous situation (i.e. evacuation, damage alleviation actions, rescue)

Integrating effective non-structural measures with structural measures and seeking for the best mix of them were emphasized after the Great East Japan Earthquake in 2011.

29. Damage alleviation actions and required information for the decision making can be summarized as Table 2. Different users have different information requirements. Forecast flow rate, water level of up to 7 days later are required by many users. With regard to inundation, area and depth are wanted. As the needs for prediction/forecast of floods are considered high, it is a natural course of actions to promote development of technologies of operational flood forecasting in Thailand, seeking comprehensive disaster prevention combining structural and non-structural measures.

4.4 Flood Forecasting Model

30. When selecting a model for operational flood forecasting, several factors are to be evaluated. They are, among other things;

- Accuracy in reproducing past events;

- Flexibility in accommodating changes in local conditions;
- Robustness in dealing with abnormal data;
- Readily available input data required;
- Speed of generating output; and
- Reasonable (or free) license fee.

It should be noted that the model should run real-time using observed data and actual operation status of facilities.

31. The Chao Phraya River has a vast inundation area, especially in the downstream part of the basin. Detailed model representation of the area increases calculation time. As ordinary computing resources are used, and the purpose is "real-time" forecast to be conducted daily, the best mix of model representation and calculation time should be sought. As some simplification of ground features is unavoidable, the priority should not be given to accurate model representation but to production of efficient and operational information.

4.5 Flood Management System

32. The flood management system should not be regarded as only an IT system that runs hydrologic and hydraulic models and gives the outcome of the calculations. It involves a series of actions starting from observation finishing with delivery of information to the users for actions. The information is archived in a database for use in the statistical analysis and as references in planning. It should also include human resources, organizational set-up. Even information delivery mechanism involving mass media could be considered a part of it. Therefore multiple organizations, parties (public/private), and facilities are involved in the system. If interactive information operation is designed, even users could be a part of it.

33. The basic constituents of flood management system are:

- Monitor;
- Collect;
- Integrate/Quality Check (QC)/Validate;
- Analyze/Process;
- Deliver; and
- Archive.

Points of attention in each action are described below (Fig. 1).

Table 2 Damage Alleviation Actions and Required Information for the Decision Making

Decision, Action		Present Status	Forecast Information
Residents	Evacuation Sandbagging Preparation (living with flood type) Other preparation	Rainfall distribution, Water level Water level changes (speed) Inundation area & depth	Water Level of 1-day later (evacuation) Water Level of 1 to 7-day later (preparation) Timing of flood reaching the levee top Inundation area & depth
Factories	Products evacuation Sandbagging Other preparation	Rainfall distribution, Water level Water level changes (speed) Inundation area & depth	Water Level of 2-day later Timing of flood reaching the levee top Inundation area & depth
Farmers	Cropping, moving Other preparation	Rainfall distribution, Water level Water level changes (speed) Inundation area & depth	Water Level of 7-day later Timing of flood reaching the levee top Inundation area & depth
Flood defense	Sandbagging Drainage Pumps Rescue, relief Others	Rainfall distribution, Water level Water level changes (speed) Inundation area & depth (map)	Discharge of 1 to 7-day later Water Level of 1 to 7-day later Timing of flood reaching the levee top Inundation area & depth (map)
Government	Comprehensive management Decision making on unexpected Others	Rainfall distribution, Water level Risk distribution Inundation area & depth (map)	Discharge of 1 to 7-day later Water Level of 1 to 7-day later Timing of flood reaching the levee top Inundation area & depth (map)
Relevant organizations	Water gate, dam, pump operation Retarding basin management Recovery work Forecast and warning others	Rainfall distribution, Water level Water level changes (speed) Inundation area & depth	Discharge of 1 to 7-day later Water Level of 1 to 7-day later Timing of flood reaching the levee top Inundation area & depth
Municipalities	Forecast and warning Flood defense	Rainfall distribution, Water level Water level changes (speed) Inundation area & depth	Discharge and Water Level of 1 to 7-day later Timing of flood reaching the levee top Inundation area & depth

4.5.1 Monitor

34. The flood management system should monitor the natural phenomena of rainfall, water level, and discharge properly and continuously. It should monitor events and situations related to flood, including levee breaks, gate openings, dam operation, and inundation extent and depth. The monitoring (observation) points should be sufficient for grasping the phenomenon and situations. However, if point monitoring only is exercised, it would be difficult to obtain the overall picture of the events, as the extent of some natural phenomena are extremely localized. Different devices including satellite images should be utilized.

4.5.2 Collect

35. For flood management purpose, data and information are to be collected in conformity with the use of them. In the Chao Phraya River, whose normal response time to rainfall is longer than a day at the shortest, and the change in water level is not fast, collection of once a day would suffice in general. Continuous and stable ways of collection are required. To avoid missing data due to troubles in transferring information, redundancy would be incorporated in the mechanism. For example, in RID, while rainfall data are transmitted every 15 minutes directly from the observation station to the headquarters through the telemeter system, rainfall data measured manually once a day are reported to the regional office, where these data are tabulated with other points data, then reported to the headquarters.

4.5.3 Integrate/QC/Validate

36. Data and information should be integrated to give a collective picture of the situation. It often happens that different organizations monitor same events/phenomena for different purposes. If these data are combined and shared among concerned parties properly, they can be better utilized for the overall purpose of flood management.

37. Abnormality in data is checked to validate the values. While abnormal values often derive from defective observation, the possibility should be kept in mind that an event corresponding to the value actually happened. Extremely localized heavy rainfall or abrupt water level changes due to facility operation nearby could present seemingly abnormal values, which are very important from the flood management viewpoint, and should not be blindly discarded.

4.5.4 Analyze/Process

38. Data and information are analyzed and processed to generate scientific information, including forecast water level, discharge, and inundation extent/depth. It should be noted that these generated values include errors and uncertainties due to insufficient observation points, observation errors, limited model representation of the real world, and others. For example, it is virtually impossible to predict the water level of the Chao Phraya River at Nakhon Sawan a month in advance, while it is rather simple task to predict it a few hours in advance within a range of 10 cm.

39. Uncertainty involved in simulation output is a big issue in prediction, forecast, and warning based on model calculation of any phenomenon and in any part of the world. In Japan, the issue is examined and understood before implementing flood forecasting and warning, debris flow disaster warning information, earthquake early warning, foretelling earthquake information, and volcanic eruption caution information. Close examination on the issue should be made before introducing the flood forecasting system in the Chao Phraya River Basin for achieving the original purpose of reducing flood damage.

4.5.5 Deliver

40. In delivering messages, it should be noted that proper use of the analysis output as disaster information is vital. When information, even if it is numerically accurate, is used improperly from the viewpoint of disaster prevention, it may give adverse effects in reducing flood damage. The calculation outcome of simulation models should not to be presented blindly, should be altered to effective and not misleading information, for example by presenting a range of forecast values, or employing smoothing operations on area display, with due consideration taken to its delivery technique.

41. Various ways of information delivery should be employed. Internet is a powerful tool in delivering detailed data and information, and communicating with users. However, data/information literacy of end-users should be always kept in mind. Unless the web pages are carefully designed, layperson could have difficulties in picking valuable information up out of a flood of data/information.

42. The nature of floods in the Chao Phraya River may not require a decision making on actions, such as evacuation, within a matter of hours. Considering that a popularization rate of Internet in remote areas is not very high, other forms of information delivery, including bulletin boards, group meetings, could be employed there.

4.5.6 Archive

43. A database should be constructed and operated as one function of the flood management system. The information on the current situation is valuable source for decision making and planning in the future. It should be stored and arranged in an easily retrievable manner. Statistic values, such as the maximum monthly rainfall observed at a particular station, are calculated and updated regularly.

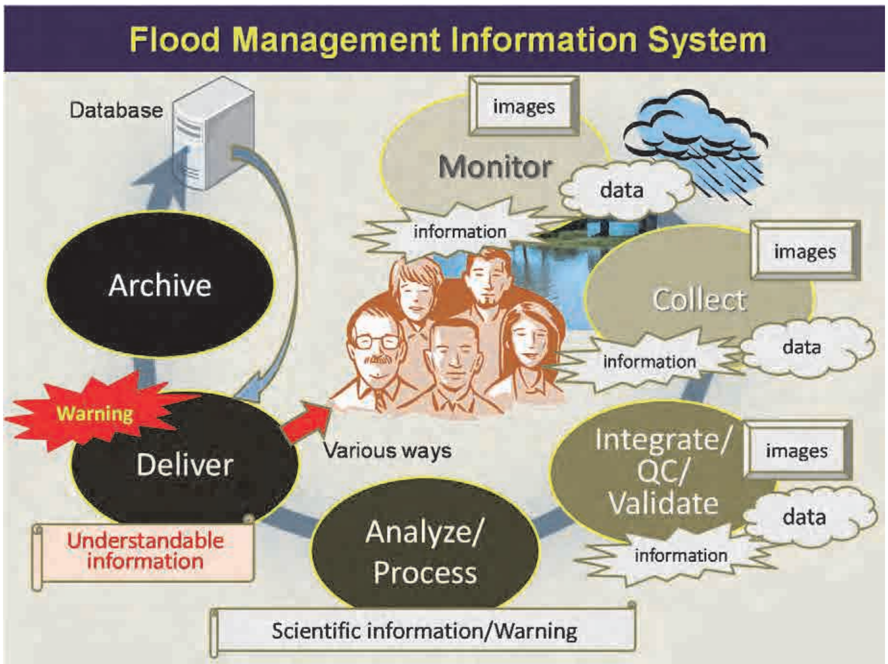


Fig.1 Constituents of Flood Management Information System

V. URGENT ACTIVITY ACTION PLAN

44. The Study Team proposed, in the Progress Report 1, presented at the Technical Working Group Meeting on 5 September, 2012, the urgent activities to be implemented during 2012 flood season as follows;

- Flood forecasting system;
- Tablet information display system; and
- Delivery of flood information to companies.

A flood forecasting system would be operated as one of urgent activities during 2012 flood season. The system would be first monitored by limited members of government organizations and private firms to examine its contents, usability, understandability and user-friendliness. The system would be operational on tablet information display system.

5.1 Approach from Information Needs

45. The flood forecasting system was to aim at clearly indicating short-term risks of inundation over the whole area of the Chao Phraya River Basin by collecting various observation data of different organizations and introducing them into analysis models suited for the characteristics of rivers in Thailand. The information sent by the system should not be "sender-oriented", in which the administrative side decides the contents based on the availability and capacity, but rather "receiver-oriented", approached from the necessity of actions/judgment of users (various individuals and groups) with a series of questions; starting from (i) "what is the actions necessary for damage alleviation?"; considering (ii) "what kind of information is required for that?"; then studying (iii) "what kind of processing or simulation is required?" to get the information properly and constructing analysis system; and finally decide input/output data based on (iv) "what are the required data for that?".

5.2 Information to Be Provided

46. Based on the experience in the 2011 flood, GOT was improving information system on present status of water level, flow rate and inundation area. To work collectively with the present status information for alleviating damages in Thailand, the system, to be built under the technical cooperation between Thailand and Japan, was designed to forecast water level, flow rate and inundation area, providing the following information.

(i) Forecast water level and flow rate at major points of the Chao Phraya River of 1-7 day(s) after today, and their observed values of past 7 days; and

(ii) Forecast inundation area of 1-7 day(s) after today.

The structure of the website was simple: Absolutely no manual was required to use the system.

5.3 Characteristics of the Chao Phraya River

47. Forecasting flow rate of a river requires consideration of the characteristics of the river. Fig. 2 shows the flow rate at Nakhon Sawan and the daily average rainfall over the upstream basin during the 2011 flood season (June - November). Small circles in the figure are observed flow rate values (daily): The graph indicates the flood duration of a few months.

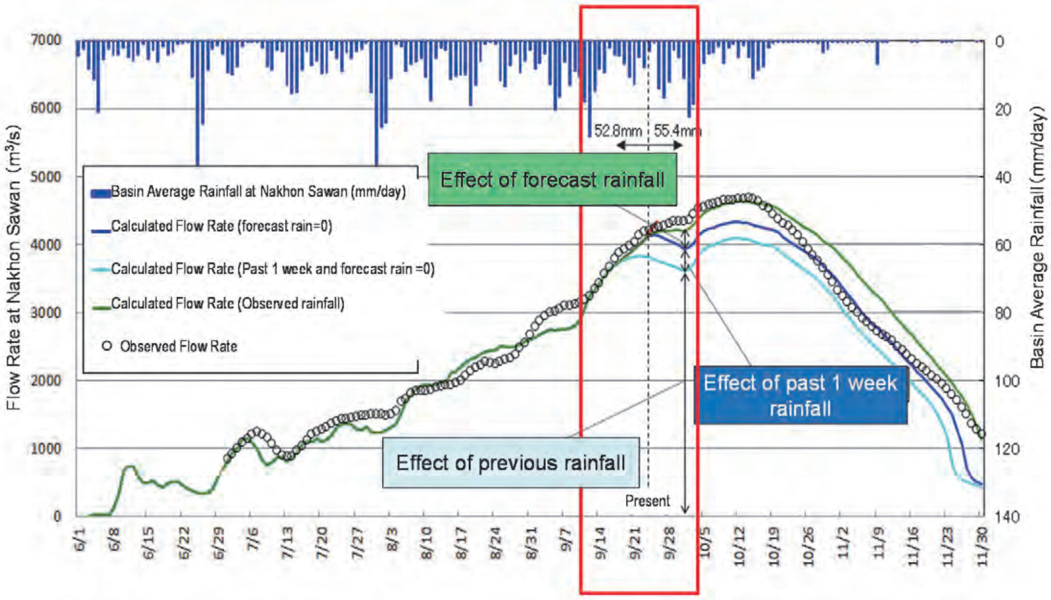


Fig. 2 Flow Rate at Nakhon Sawan and Daily Average Rainfall (2011 Flood Season)

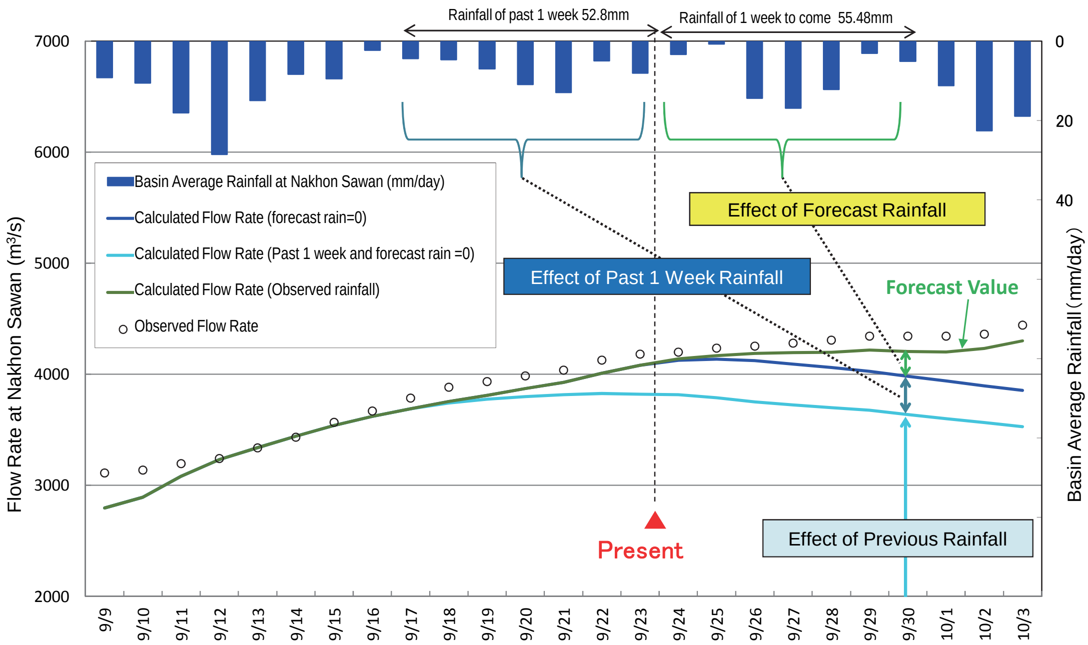


Fig. 3 Flow Rate at Nakhon Sawan and Daily Average Rainfall
(9 September - 3 October, 2011)

48. A part of Fig. 2 around 23 September, 2011 was enlarged to get Fig. 3. When the flow rate of 30 September (1 week later) was to be forecast on 23 September, the value could be divided into the following three components; (i) the effect of rainfall between 23 and 29 September (forecast rainfall), (ii) the effect of rainfall between 16 and 22 September (observed rainfall), and (iii) the effect of rainfall before 16 September (observed upstream flow rate). The magnitude of three components had the general relationships of (i) >< (ii) < (iii) in the Chao Phraya River (at Nakhon Sawan), with the long-term discharge from large upstream basin dominating the flow rate at Nakhon Sawan. On the other hand, from the viewpoint of the certainty,

the magnitude of certainty could be (i) forecast rainfall with meteorological analysis < (ii) forecast flow rate based on observed rainfall < (iii) forecast flow rate from observed upstream flow rate. This indicated that relatively stable flow rate forecasting would be possible in the Chao Phraya River.

49. The hydrograph at Nakhon Sawan consisted of a big wave with a length of 2 - 6 months and small waves that relatively quickly rise in a few days. The latter corresponded to rainfall concentrated near Nakhon Sawan. For risk management, it would be particularly important to detect the quick rise in water level properly, and to deliver/share the information with users. This was why forecast rainfall data were used as input data in addition to observed flow rate and observed rainfall in the system.

5.4 Uncertainty of Natural Disaster Information

50. Forecast information regarding natural disasters involves uncertainties arising from uncertainties of natural phenomena, as well as insufficient simulation techniques. While simulation uncertainties might decrease through technology development, the uncertainty originally accompanied by natural phenomena would be difficult to decrease technically.

51. Uncertainty involved in simulation output is a big issue. In Japan, many trials and errors were repeated experiencing so called "the boy who cried wolf" issues before implementing flood forecasting and warning. Today in Japan, while the necessity of making efforts for increasing the accuracy of information is a matter of course, we seldom hear an opinion that information should not be released or used unless a forecast value completely coincide with an observed value. The majority agrees to use the information understanding the accuracy of forecast information as it is, and bearing the nature of forecasting in mind. As structural measures alone cannot deal with all the disasters, for reducing damages as much as possible, non-structural measures of information utilization including forecasting is particularly important.

5.5 Prototype

52. The prototype of flood forecasting system, which was named as "the Flood Risk Information system", was designed. Table 3 shows the outline of the information provided by the system.

53. The prototype system was to become operational early September 2012. The language of the system was English.

54. The information display system was to be operated in the process of (i) data input, (ii) schematic diagram display production, and (iii) flood area display production.

Table 3 Information Provided by the Flood Risk Information System (Prototype Design)

Time	Kinds of Information	Expressed in	Note
Past	Flow Rate	Graph	
	Water Level		
Present	Flow Rate	Pop-up figure over a schematic diagram	
		Graph	
	Water Level		
Forecast	Flow Rate	Graph	Max. and Min. expressed with two lines
	Water Level		
	Inundation Area	Color-coded Map	“High Risk” area and “Risk” area expressed with the difference of colors

5.6 Server

55. The Flood Risk Information system was to be developed using servers located in Japan. The prototype system was to be operated and improved on the servers on which the system was developed, and the information over internet originated in Japan. The servers required for operating the complete version of the system was to be procured and installed in the RID in the beginning of November 2012. For 2013 flood season, the information was to be circulated over internet originating RID.

5.7 Monitoring

56. Forecast of natural phenomena, such as rainfall, evaporation, and runoff, involves uncertainty. In delivering messages, it should be noted that proper use of the analysis output as disaster information is vital. When information, even if it is numerically accurate, is used improperly from the viewpoint of disaster prevention, it may give adverse effects in reducing flood damage.

57. Both the uncertainty involved in information and the appropriate use of the information were to be well-understood by the users. The prototype Flood Risk Information system was to be first opened to the registered users who stated that they understood the uncertainty involved in the forecast, and the use of the information was their responsibility. Monitors would be asked to provide the Study Team with suggestions, opinions, and questions on the prototype system with regard to necessary information, function, and its usability. The Study Team, in cooperation with the Government of Thailand, was to improve the system, and then get the system open to the public.

58. The system, when completed, would become the Thai Government’s system with necessary improvements and operational arrangements. Therefore, further development beyond the prototype was to be done by the Japanese and Thai experts in close collaboration. The

functions to be added to the prototype system could be:

(i) Overwrapping GISTDA images over the Flood Area map;
(ii) Forecasting the effects of dam operation;
(iii) Forecasting the effects of levee break;
(iv) Forecasting the effects of government's flood defense actions such as large-scale sandbagging and emergency pump installation; and
(v) Accuracy improvement through the utilization of LiDAR data.

VI. FLOOD DATA ANALYSIS/FLOOD FORECASTING SYSTEM

6.1 Development of Prototype

6.1.1 General

59. A prototype of flood data analysis/flood forecasting system (referred to as “the Flood Risk Information System”) was provided the information indicated in Table 3 above to the registered monitors including related Thai government organizations and Japanese firms in industrial estates during flood season (September-October) of 2012.

60. The Flood Risk Information System (prototype) was developed in two months (July-August, 2012). A prototype, by definition, is “a rudimentary working model built for demonstration purposes and as part of the development process”. Therefore limited functions for providing information given in Table 3 were programmed.

61. The chronology of activities of the system development is indicated below.

Timing	Activities
July-August, 2012	A series of interviews, meetings, and exchange of mails with relevant persons of the Thai government organizations including RID, DWR, Ministry of Natural Resources and Environment (MNRE), HAII, ONWF, and TMD, as well as researchers of Kasetsart University, Integrated Study Project on Hydro-meteorological Prediction and Adaptation to Climate Change in Thailand (IMPAC-T), and International Center for Water Hazard and Risk Management (ICHARM) were done to materialize the ideas of the system.
4 September, 2012	**Seminar for Japanese Firms (Briefing on JICA Project - Improvement of a Flood Management System and Its Operation for the Chao Phraya River Basin).** Some 200 Japanese factories located in Thailand participated in the seminar. Participants were invited to become monitors of the system. Monitors were asked to note the following issues: • Simulation of natural phenomena involves uncertainties; and • Information should be used for taking proper actions for reducing flood damage.
5 September, 2012	**Technical Group Meeting** Progress Report of Component 3 was explained, in which Urgent Action Plan was proposed. Attachment of the report described the Flood Risk Information System.
18 September, 2012	**URL of the system notified to the monitors.** The system was run and risk information updated daily, while a number of improvements, tune-ups, new functions were added, and errors corrected continually.
9 October, 2012	**Seminar for Thai Government Officials (Briefing Seminar on the Chao Phraya Flood Forecasting System)** Some 70 officials from various government agencies of Thailand including NESDB, GISTDA, DWR, SWRC, TMD, RID, Office of the Royal Development Project Board, MNRE, HAII, ONWF, and universities participated in the seminar. The participants were informed of the URL of the system.
22 October, 2012	**Submission of Urgent Activity Action Plan Report** The report describing the Flood Risk Information System was explained to the RID (Technical Working Group) on 29 October, and to the DWR on 2 November. A number of comments and suggestions were received during these meetings. In order to

	discuss these suggestions in detail and to prepare draft solutions to technical Issues, operational Issues, and utilization Issues of the Flood Risk Information System, holding small group meetings was proposed.

62. The Flood Risk Information System (prototype) was operated and improved by the Study Team using servers located in Japan. The risk information was sent from Japan via internet.

6.1.2 Observed Data Input

63. Considering the characteristics of hydrograph at Nakhon Sawan, the flow rate of which was the key figure in understanding the flood situation of the lower Chao Phraya River, runoff forecast was to be carried out daily: This required daily data of hydrological observation.

64. The Flood Risk Information system required the following input data;

- daily rainfall - as input data for the analysis model;
- water level - for displaying water level graphs;
- flow rate - as input data for the analysis model and for displaying flow rate graphs; and
- dam discharge - as input data for the analysis model.

These observed data were collected in the ways indicated below.

(i) Water level and flow rate

The stations indicated in the flow rate distribution chart in the website of RID (http://water.rid.go.th/flood/plannew_3hr/lowplan_3hr.jpg) are considered to be important ones. Data of these stations are collected from the websites of three Hydro Centers of RID, the URLs of which are http://hydro-1.net/,
http://hydro-2.com/HD-03/3-01-DOCS/3-01-2.htm, and
http://hydro-5.com/report/rain_week.php.

(ii) Dam discharge

Discharge from Bhumibol, Sirikit, and Pasak dams are expected to considerably affect flood situations. Data are collected from the website of RID
(http://water.rid.go.th/flood/flood/res_table.htm).

(iii) Daily rainfall

Stations for daily rainfall are carefully selected taking considerations both that the number of stations should be enough for the accuracy of analysis, and that the result of the analysis should be swiftly obtained for delivering information timely. The selected stations are those (50) of TMD, a list of daily observation data of which is mailed from TMD to the Study Team every day in the morning, and those (62) of RID that are listed in the websites of three Hydro Centers indicated in (i) above.

Required data were arranged and supplied to the analysis models.

65. Observed data used in the Urgent Activities during 2012 flood season are summarized in Table 4, and locations of stations are indicated in Fig. 4. These data were collected and put into the system manually. Automatic input procedures were considered in consultation with WMSC (The Water Watch and Monitoring System for Warning Center) of RID.

Table 4 Numbers and Sources of Data Used in the Analysis in Urgent Activities

Item	Numbers	Sources
Rainfall	112	Hydro Center 1, 2, 5, and TMD
Water Level	125	Hydro Center 1, 2, 5
Flow Rate	131	Hydro Center 1, 2, 5, and RID water
Dam Discharge	3	RID water

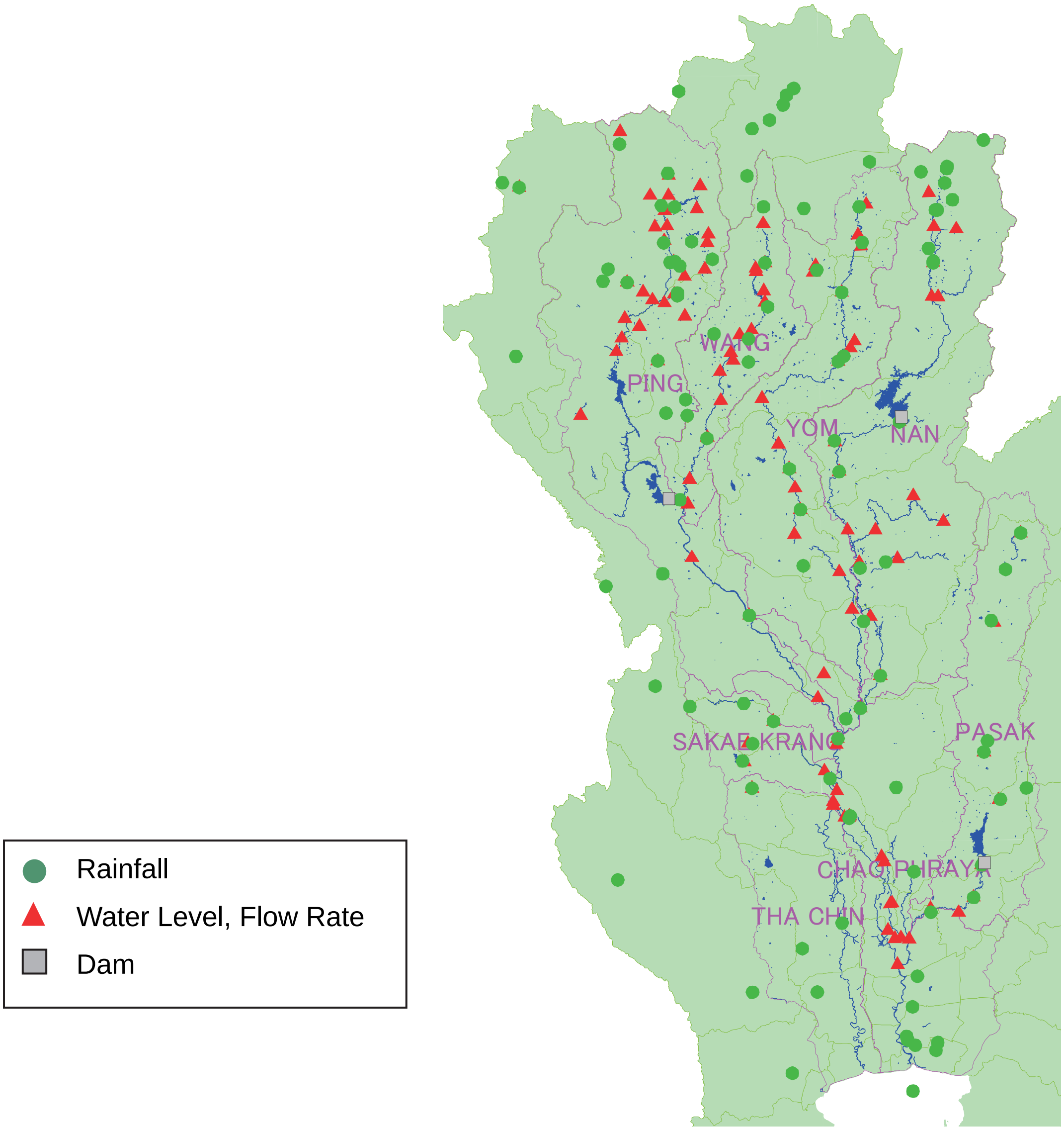


Fig. 4 Location of Observation Stations (Urgent Activities)

6.1.3 Forecast Data Input

66. In the Chao Phraya River, it normally took long time for rainfall to run into the rivers. However, past data indicated the possibilities of incidents where discharge relatively rapidly increased influenced by short-term rainfall events. Therefore, meteorological rainfall forecast was to be included in the input data of the Flood Risk Information system.

67. Forecast values included errors and uncertainties due to insufficient observation points, observation errors, limited model representation of the real world, and others. Therefore, the Flood Risk Information system was designed to present both maximum and minimum values of forecast, showing not the exact forecast value, but the range of the forecast.

68. The flow rate at Nakhon Sawan in the future consisted of the following three factors;

(i) flow rate in the upstream rivers (i.e. past rainfall already converted into river flow);
(ii) upstream rainfall of recent past (e.g. past one week); and
(iii) upstream rainfall of coming days (i.e. forecast rainfall).

Among the above, (i) and (ii) were observed. Then the uncertainty was most heavily involved in the factor (iii). A study showed that the magnitude of contribution of the factor (iii) in flow rate at Nakhon Sawan was rather small compared to the one of the factors (i) and (ii), thus making the forecast relatively stable.

69. Quantitative Precipitation Estimate (QPE) (global coverage with 0.5 degree pitch) based on the meteorological data internationally exchanged under the framework of the World Meteorological Organization (WMO) was available. In the Chao Phraya River Basin 60 grid points of QPE existed.

70. The maximum expected rainfall in coming 7 days and the minimum expected rainfall in coming 7 days were tentatively formulated as follows;

- Maximum: QPE value with past error distribution factor added; and
- Minimum: No rainfall.

Analysis was still being made on the scientific meaning of the maximum and the minimum values at the stage.

6.1.4 Runoff Forecast and Inundation Forecast Calculation

71. For managing flood risk in the Chao Phraya River using the flood forecasting model, inundation events should have been properly reproduced in real-time, based on detailed topographical data. Since the Chao Phraya River had a huge flood plain, the model should reproduce the inundation events efficiently and accurately. Considering the above, Rainfall-Runoff-Inundation Model (RRI Model) developed by the ICHARM of the Public Works Research Institute, Japan (PWRI) was selected. The RRI model was considered suitable for analyzing the Chao Phraya River basin, as it analyzed runoff into the river and inundation in the flood plain as a whole, dividing the basin into cells. The RRI model required the following input data:

- Basin geometry (ground level);
- Basin characteristics (permeability, land use, roughness, etc);
- River geometry;
- Initial states (basin, river, flood plain);
- Boundary conditions (dams, division, sea water level); and
- Rainfall (past, forecast).

72. The RRI model consisted of two-dimensional runoff analysis (runoff and inundation analyzed simultaneously) model, and one-dimensional river routing model. Both models used the momentum equation with diffusion wave approximation as a basic equation. To express the rainfall runoff process properly, vertical and lateral infiltration flows were considered underground. Exchange of water between runoff model and routing model was calculated by an overflow formula.

73. In order to meet the beginning of the flood season of 2012, the RRI model was used for both upper basin (upper Nakhon Sawan) and for lower basin (lower Nakhon Sawan) (Fig. 5).

Flow rate at Nakhon Sawan forecast by the upper basin model was handed over to the lower basin model.

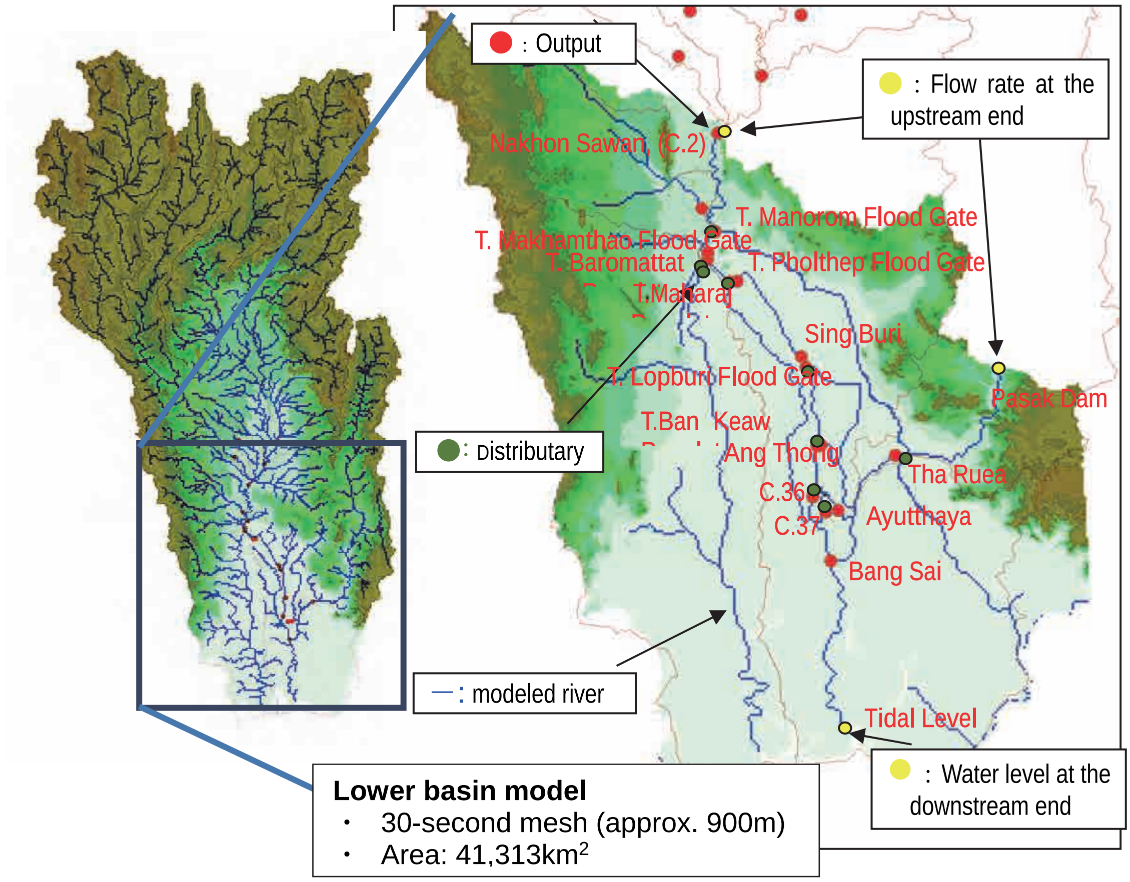


Fig. 5 Outline of the Chao Phraya River RRI Model (Lower Basin)

74. The accuracy of the RRI model was validated based on 2011 and 2006 flood data. As boundary conditions on the model, dam discharge record, observed tidal level, barrage discharge recorded (May-November, 2006, and June-December, 2012) were collected and reflected in the model. The parameters of the model were calibrated for flow rate and water level at main points including Nakhon Sawan, Chainat, and Ayutthaya, and downstream inundation situations. Typical results are shown in Fig. 6, and it is considered that the model properly reproduces the observed inundation extent, inundation depth, and flow rates.

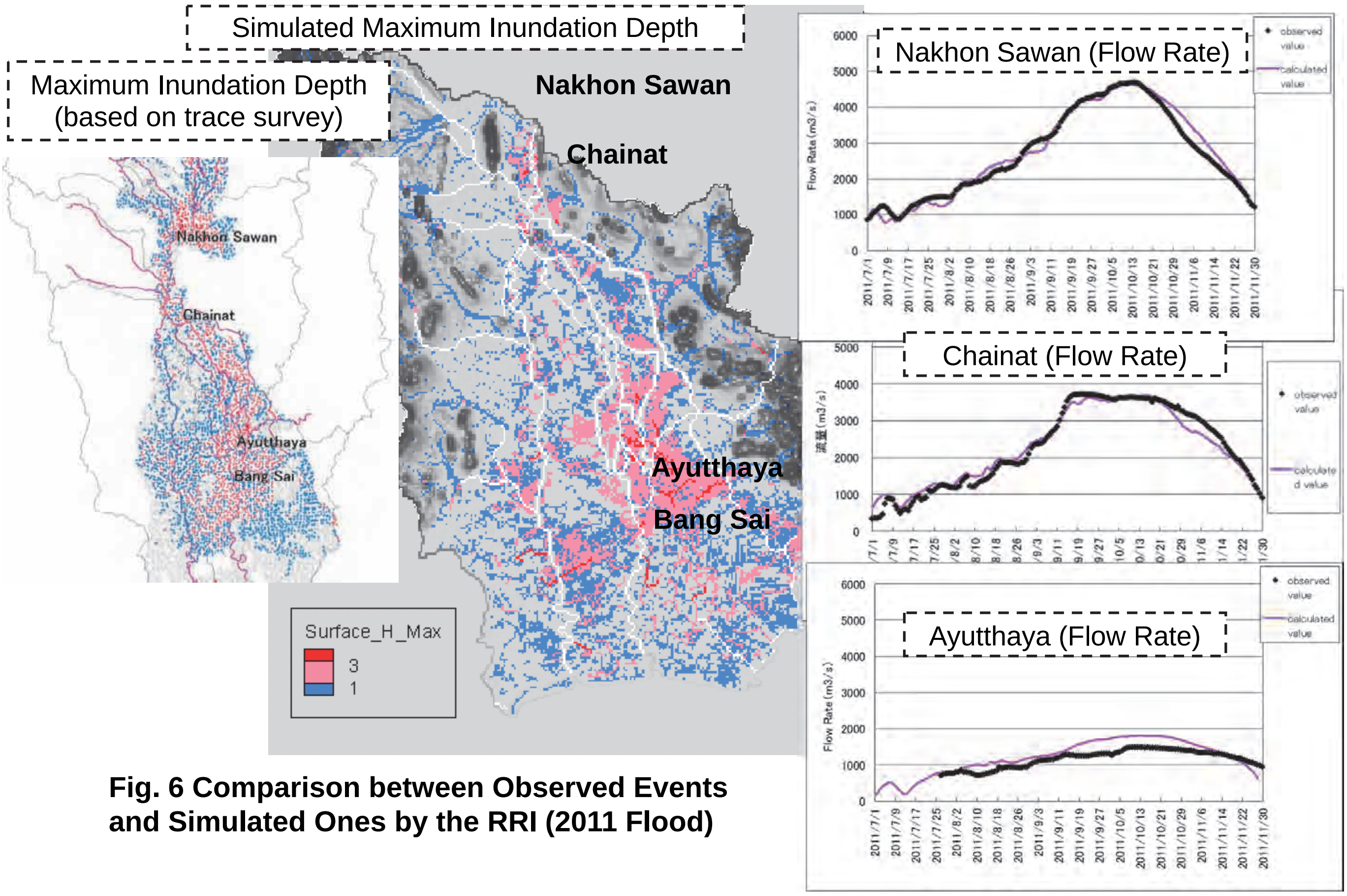


Fig. 6 Comparison between Observed Events and Simulated Ones by the RRI (2011 Flood)

75. Conditions of runoff and inundation forecast calculation by the RRI model were as follows:

(i) forecasting interval: once a day (initial time is set at 6 am, and 7-day forecast is executed);

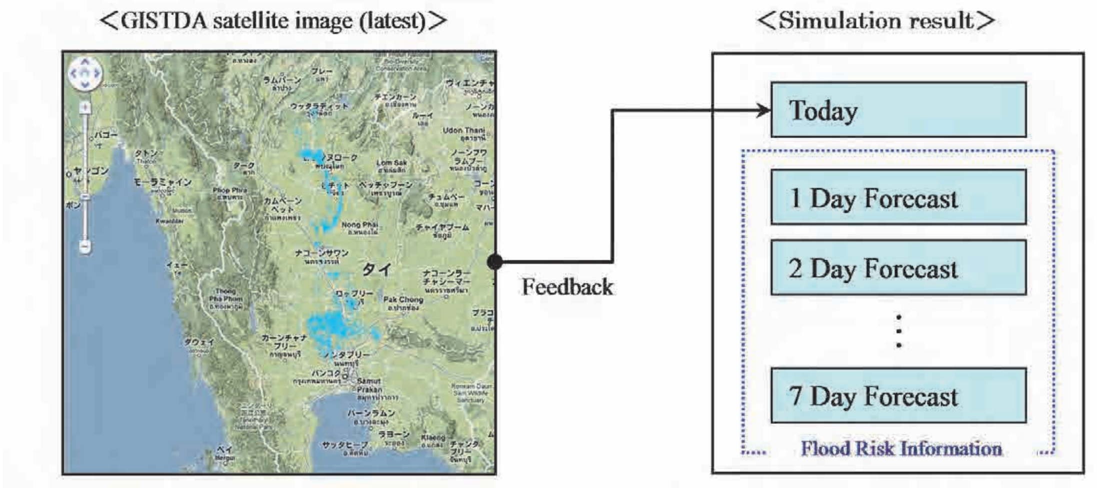
(ii) input data;
- observed rainfall: rain gauges of RID and TMD on the ground
- forecast rainfall: QPE
- dam discharge: EGAT and RID (present values assumed to continue in the future)
- distributaries discharge: RID (present values assumed to continue in the future)

(iii) output data:
- forecast flow rate and water level: for 7 days in 6-hour interval
- forecast inundation area: for 7 days in 6-hour interval

76. In order to reflect the actual flooding situation, GISTDA satellite images indicating inundation area were applied to the simulation by the RRI model as the initial condition. Satellite images were converted to numerical grid data for determining inundation area. Because the satellite images did not give information on inundation depth, the depth estimated from latest simulation on the same day were used. If results showed that there was disagreement between

satellite images and simulated inundation area, approximate water depth values[2] were given to the grid as indicated in Fig. 7. Automatic operation of data conversion and its incorporation into the RRI model was hoped for which would require a consultation with GISTDA.

[2] An appropriate method to incorporate actual inundation area into the RRI model simulation was still under consideration at the prototype stage, and figures indicated in Fig. 7 are those of the open-to-public version.



1. Correction (based on GISTDA image) made on the inundation calculation result of 7 days ago (initial condition);
   GISTDA image shows inundation (dense: 100%)
   - Inundation depth calculated to be 0.5m or more: As calculated
   - Inundation depth calculated to be less than 0.5m: Assumed to be 0.5m
   - Soil moisture set saturated

   GISTDA image shows inundation (sparse: 50-100%)
   - Inundation depth calculated to be 0.2m or more: As calculated
   - Inundation depth calculated to be less than 0.2m: Assumed to be 0.2m
   - Soil moisture to be saturated

   GISTDA image shows no inundation (less than 50%)
   - Inundation calculated: No inundation
   - Soil moisture as calculated
2. Calculation carried out for 14 days –(7 days for preliminary calculation and 7 days for forecasting);
3. Correction (based on Today's GISTDA image) made on the inundation calculation result of today;
   GISTDA image shows inundation (dense: 100%)
   - Inundation depth calculated to be 0.5m or more: As calculated
   - Inundation depth calculated to be less than 0.5m: Assumed to be 0.5m

   GISTDA image shows inundation (sparse: 50-100%)
   - Inundation depth calculated to be 0.2m or more: As calculated
   - Inundation depth calculated to be less than 0.2m: Assumed to be 0.2m

   GISTDA image shows no inundation (less than 50%)
   - Inundation calculated: No inundation

Dense/ Sparse

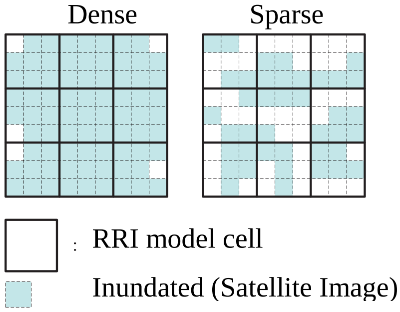


Fig. 7 Concept of Feedback Method by Applying GISTDA Satellite Images

77. Forecast inundation area was calculated for 1-7 days, and categorized into two risk areas; “High Risk” area, and “Risk” area. “High Risk” area was the area with the possibility of inundation (with the inundation depth of 20 cm or more) in case of the minimum flow rate value occurred. Considering the error in forecast rainfall, even less than expected rainfall would result in inundation; therefore the risk was higher. “Risk” area was the area with the possibility of inundation in case of the maximum flow rate value occurs. Only more than expected rainfall would result in inundation; therefore the risk was lower compared to “High Risk” area.

78. Inundation calculation heavily depends on manual operation as indicated the followings.

(i) change the format of the observed data for calculation;
(ii) execution of calculation;
(iii) change the output format for display purpose; and
(iv) transfer (FTP) to display server

6.1.5 Information Display System

79. An eye-catching, easy-to-use website of the Flood Risk Information system was constructed. The top page had two big buttons only; one for the Schematic Diagram display of flow rate and water level, and the other for Flood Area display. The system focused on the forecast status of events; flow rate, water level, and inundation extent. Present status information was limited to the one required for understanding the forecast. Numerals/data did not appear on the basic screens or on the graphs. They, when vicinities clicked, popped up from basic screens. The structure of the website was simple: Absolutely no manual was required to use the system.

80. The Schematic Diagram display (forecast flow rate and water level) had three layers of screens as indicated below.

Layer 1 - Plane view and Bird’s-eye view of the Chao Phraya River containing followings;

- symbol marks representing stations and dams
- symbol of station is color-coded for normal (green), critical (yellow), and flood (red), indicates the magnitude of water level on the current day
- information update time (right top) and guide chart indicating displayed screen (right bottom)

Layer 2 - Pop-up display of flow rate at a station selected.

Layer 3 - Additional screen of graphs of forecast flow rate and water level at the station. Comparison of forecast values with critical level and flood level helped understanding the timing of flooding. The graphs showed the followings;

- Critical level indicates the magnitude above which flooding from the river may occur;
- Flood level, defined by RID, indicates the magnitude on which attention is required;
- Center is present (updated) time, left is past and right is future;
- Two lines of forecast are indicated, one is pink for maximum (with maximum expected rainfall), and the other is green for minimum (with minimum expected rainfall)

Bird’s-eye view was expected to draw user’s interest and to help users to understand intuitively the entire picture of the Chao Phraya River basin with typical landmarks arranged in the map.

81. The Flood Area display showed forecast inundation (of 20 cm or more) extent with colored cells overwrapped on Google Map. Forecast inundation area of 1-day through 7-day could be selected with buttons on the top. The screen contained the followings:

- “High Risk” area (dark-blue), and “Risk” area (light-blue);
- Switching between “All Watershed” and “Downstream Region”;

- Scale up/down button (on iPad touch screen operation is possible as well);
- information update time (right top) and guide chart indicating displayed screen (right upper middle)

Checking daily changes in forecast “High Risk” and “Risk” areas helped understanding the inundation possibility and its timing at the locations of interest.

6.2 Development of Open-to-Public Version

82. Small group meetings proposed in the explanation of the Urgent Activity Action Plan Report were held three times to discuss outstanding issues toward preparation of the “open-to-public” version on the Flood Risk Information System. Officials of RID, DWR, HAII, and ONWF and the Study Team exchanged/shared their views on the system, and concluded draft solutions for the issues. Meetings were held as follows:

- First discussion (8 November, 2012)
  Utilization issues
- Second discussion (15 November, 2012)
  Technical issues
- Third discussion (30 November, 2012)
  Technical issues (continued) and operational issues

Outline of these discussions are described below.

6.2.1 Summary of discussions

83. The conclusions of three small group meetings are summarized below. They appropriately described the situation of development/improvement of the Flood Risk Information System (prototype) at that time. They were referred to in upgrading the prototype to the open-to-public version of the Flood Risk Information System.

(Utilization issues)	
(i)	The Flood Risk Information System will be operated for 2 groups -- General public and Administrative officers;
(ii)	Additional functions to be considered are scale locking, inundation volume data output, note display, print and save (including KML).
(Technical issues)	
(i)	Maximum and minimum data are to be presented
(ii)	Both the current inundation area and forecast inundation area are to be indicated
(iii)	Inundation area (forecast) is to be indicated with water depth of 3 levels; 0.20-0.50 m, 0.50-2 m, and above 2m
(iv)	The GISTDA images are to be compared with the actual situation
(v)	For rainfall forecast, Thai Meteorological Department's (TMD) rainfall forecast, or HAII's rainfall forecast (9 km × 9 km mesh) are to be considered
(vi)	The differences between observed and forecast values are not to be presented in the system pages. An error estimates may be presented in the explanatory pages for the users who want to know technical details
(vii)	While the model currently uses 1 km × 1 km mesh, finer mesh will be applied in case of more detailed data are required in the future.
(viii)	The system should be made easy to be improved by Thai authorities
(ix)	Displaying flood gates on main rivers (Ping River, Wang River, Yom River and Nan River) should be considered. In this regard, required system size and budget should be studied, and presented to the Technical Working Group to make decision
(x)	The possibility of estimating and presenting how much water will cause water flow through the gates should be studied
(xi)	MSL is to be used in the graphs of water level
(xii)	Displaying land profiles based on the LiDAR data on the website should be considered. It, however, should be noted that the use of LiDAR data for this purpose is to be approved by the Thai authorities
(xiii)	Inundation area in municipalities/districts is deleted from the menu
(xiv)	An application for smart phones is to be added to make the website easier to access
(Operational issues)	
(i)	Regarding implementation of automatic data input, it is required to discuss with the administrative agencies and study which data can be used for the system operation
(ii)	Agency in charge of the system and data input operation will be discussed later. In this regard, the study team will summarize the needed input data and process of the system, and present to the relevant agencies to make a decision.

6.2.2 Questionnaire Survey to the Monitors

84. Some 214 registered monitors of Japanese firms located in Thailand were asked, on 29 November, 2012, to respond to questionnaires on the Flood Risk Information System (prototype), to provide the Study Team with opinions on the system for reference in improving the system on necessary information and functions, usability before opening it to public. Questions were on:

- Inundation experienced in 2012;
- System utilization in 2012;
- Additional information expected;
- Usability of the system;
- Suggested Improvement;
- Understanding uncertainty involved in the forecast and wanted information; and
- Other opinions.

By 6 December, 2012, some 31 responses were received. Answers was studied/analyzed, and utilized in system improvement. Brief description of the results is presented in the following paragraphs.

85. While only a quarter of respondents experienced inundation in/near the factories/offices in 2012, 58% of them answered that they looked at the system almost every day when they were anxious about floods. A quarter responded that they checked the system when water level of rivers nearby increased, or there was inundation nearby, and others visited the site less frequently but regularly.

86. As for additional information expected in flow rate pages, answers included the following:

- Upstream dam situation (reservoir water level, discharge);
- Past flood situation;
- Upstream rainfall averaged over the area, accumulated rainfall;
- Photos; and
- Additional flow rate indication points.

As for additional information expected in inundation area pages, answers included the following:

- Links to pages presenting current (today's) situation;
- Landmarks;
- Text information on damages;
- Actual inundation situation;
- Past inundation situation; and
- Probability of inundation, and (expected) inundation depth.

87. Respondents were generally satisfied with the usability of the system, while some had difficulties in the speed of system. Improvement ideas included the following:

- Information on levee break;
- Overall (qualitative) comments given by experts;
- Warning mails;
- Explanation on the situations/changes, and their (conjectured) reason;
- Rainfall forecast; and
- Print function.

88. Regarding uncertainty involved in the forecast and wanted information, a majority of respondents preferred the choice that the system should deliver both (i) macro caution and warning information, as well as (ii) information describing extent of inundation (adding current situation information of specific locations nearby), to the choices either one of (i) or (ii) only.

6.2.3 Further Improvement

89. Through close collaboration of both Japanese and Thai experts, the required functions to be equipped in the Flood Risk Information System for the Chao Phraya River Basin were identified. Considering the discussions and responses of monitors, the prototype system was upgraded into the "open-to-public" version by January 2013. Table 5 describes the comparison between the prototype system and the "open-to-public" version. Important changes were:

- LiDAR data were used as topographic data;
- 2006, 2010 data were used for calibration in addition to 2011 data;
- System equipment is in installed in RID;

- Schematic display area was expanded to the whole basin;
- Past inundation area is displayed from 7 days ago;
- Risk is classified by water depth, with switching possibility mechanism;
- Correction of inundation area is made using GISTDA images automatically;
- Display languages are Thai and English; and
- Help and message display functions added.

Table 5 Features of the system

		Prototype	Open to the public version	Reference
Agent of information delivery		JICA/FRICS	Thai government (RID etc.)	
System structure	Observation data applied	RID(Hydro Center) and TMD	RID(Hydro Center, telemetering system) and TMD	Under preparation by RID (telemter)
	Dam and diversion channel data	EGAT (dam), RID (channel)		
	Forecast rainfall data	JMA (international cooperation in framework of WMO)		Under discussion for usage of TMD data
	Topographic data	USGS	LP data (JICA)	
	Simulation model	RRI model basis		
	Calibration of flow-rate and inundation area	2011 actual data	2006, 2010 and 2011 actual data	
	Update	Once a day	Once a day	Under consideration of multiple update
	System equipment	Server in Japan	RID server and RID line	
Forecast of water-level and flow-rate	Display information	Current flow-rate and warning level (plain view and bird's-eye view) Temporary change of flow-rate and water-level, and warning level (temporary transitional graph)		
	Display period	Observed: from 7 days ago to present		
		Forecast: from 1 day later to 7 days later		
	Display area	Only downstream basin	Whole basin	
	Range between maximum and minimum on forecasting	max: 2σ of error estimated from past data (whole basin average)	max: maximum error in the past data (reflecting a rainfall distribution)	
		min: no rainfall	min: minmum error in the past data	
	Correction	Correct present water-level in the model to daily observed water-level		
Forecast of inundation area	Display information	Inundation area at the forecasting (displayed on the Google Map)		
	Display period	Observed: not available	Observed: from 7 days ago to present	
		Forecast: from 1 day later to 7 days later	Forecast: from 1 day later to 7 days later	
	Risk classification	Classified by possibility	Classified by water depth	
			Switching page by possibility	
	Correction	Correction by water-level only	GISTDA image and automatic correction	
Usage environment	Web display	Operation by click, adjusted design for iPad		
	Display language	English	Thai and English	
	Auxiliary function	-	Help, message function etc.	

90. By the 2013 flood season, the function of the system was further improved on smooth communication of data among related organizations, back-up functions and operation functions.

91. Studies were made on the differences between forecast and observed rainfall in the past events, the maximum (area-averaged) rainfall of 1-7 days, and the influences of rainfall forecast errors on the flow rate at Nakhon Sawan. Based on the study results, the maximum expected rainfall in coming 7 days and the minimum expected rainfall in coming 7 days were formulated as follows;

- Maximum Expected Rainfall:
    - (i) Cumulative rainfall one to seven days later is calculated based on the present condition of rainfall (observed rainfall one day ago) using an approximate equation[3].
    - (ii) Cumulative rainfall one to seven days later is calculated based on the forecast rainfall using an approximate equation[4].
    - (iii) The smaller of the cumulative rainfall obtained in (i) and (ii) above is defined as the primary forecast.
    - (iv) The primary forecast is corrected using continuous rainfall and mean rainfall at C2. Corrections methods are:
        - a) <u>Correction using continuous rainfall</u>: Corrections are made so that one- to seven-day rainfall forecast one to seven days later (cumulative rainfall) might not exceed the maximum rainfall ever observed in each sub-basin. When the primary forecast exceeds the maximum rainfall ever observed, corrections are made to make the primary forecast equal the maximum rainfall ever observed.
        - b) <u>Correction using the mean rainfall at</u> C2: Corrections are made so that cumulative rainfall forecast one to seven days later might not exceed the maximum rainfall ever observed.
    - (v) Convert the obtained cumulative rainfall (in the future) into (forecast) daily rainfall
- Minimum Expected Rainfall:
    - (i) Cumulative rainfall one to seven days later is calculated based on the present condition of rainfall (observed rainfall one day ago) using an approximate equation[5].
    - (ii) Cumulative rainfall one to seven days later is calculated based on the forecast rainfall

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3 In relation to the mean rainfall in the sub-basins, scatter diagrams were developed that show the relationship between the present rainfall (observed rainfall one day ago) and "observed rainfall/ forecast rainfall". Approximate lines were developed that envelope the areas near the maximum "observed rainfall/forecast rainfall". The approximate line enveloping the maximum value could be used to obtain the ratio of maximum rainfall forecast one to seven days later to the observed rainfall one day ago "observed rainfall/forecast rainfall". The ratio was multiplied by the observed rainfall one day ago to create the maximum forecast rainfall.

4 In relation to the mean rainfall in the sub-basins, scatter diagrams were developed that show the relationship between the forecast rainfall and "observed rainfall/forecast rainfall". Approximate lines were developed in the figures that envelope the areas near the maximum "observed rainfall/forecast rainfall". The approximate line enveloping the maximum value could be used to obtain the ratio of the maximum possible rainfall to the forecast rainfall "observed rainfall/forecast rainfall" when the forecast was publicized. The ratio was multiplied by the forecast rainfall to create the maximum forecast rainfall.

5 In the same way as the maximum values, the minimum forecast rainfall was created using the approximate line enveloping the minimum values based on the present rainfall.

using an approximate equation[6].

(iii) The larger of the cumulative rainfall obtained in (i) and (ii) above is defined as the forecast.

92. Detailed description of setting maximum and minimum expected rainfall is found in Attachment 02 "Forecast Rainfall Configuration".

93. The daily data input to the Flood Risk Information System are presented in Table 6. In addition to these, forecast rainfall (refer to para. 69) is necessary.

[6] In the same way as the maximum values, the minimum forecast rainfall was created using the approximate line enveloping the minimum values based on the forecast rainfall.

Table 6-1 Flood Risk Information System Input Data (rainfall)

No.	Station Name	Latitude.	Longitude.	Org.
1	Amphur Viang Haeng	19.5537	98.6358	RID
2	A. Chiang Dao	19.3647	98.9667	RID
3	Mae0ngad Dam	19.1442	99.0139	RID
4	Mae Taeng Headwork	19.1544	98.9228	RID
5	Amphur Mae Rim	18.9099	98.9393	RID
6	A. Wang Nua	19.1450	99.6222	RID
7	W.16A	18.7792	99.6311	RID
8	Mae Mai forest Plantation A. Muang	18.4928	99.6486	RID
9	A. Pong	19.1422	100.2780	RID
10	Amphur Chiang Muan	18.9088	100.2966	RID
11	Lower 1R09L Canal	18.7308	99.9858	RID
12	Y.20	18.5842	100.1547	RID
13	Y.1C	18.1331	100.1275	RID
14	Amphur Chalerm Prakiat	19.5701	101.1347	RID
15	A. Thung Chang	19.3864	100.8800	RID
16	A. Chiang Klang	19.2925	100.8660	RID
17	Amphur Song Kwae	19.3667	100.7047	RID
18	A. Pua	19.1825	100.9180	RID
19	A. Tha Wang Pha	19.1178	100.8130	RID
20	Mae Kuang Dam	18.9178	99.1306	RID
21	Baan Huai Kaew	18.8031	99.2718	RID
22	Baan Rong Wua Daeng	18.7600	99.0495	RID
23	A. Wiang Pa Pao	19.3464	99.5111	RID
24	A. Mae Suai	19.6550	99.5467	RID
25	Mae Lao	19.7100	99.6661	RID
26	A. Mae Tha	18.1328	99.5167	RID
27	Thung Luang	18.7374	98.5595	RID
28	Khun Waang	18.6597	98.5243	RID
29	P.82	18.6522	98.6906	RID
30	A. Li	17.8003	98.9547	RID
31	A. Thung Hua Chang	17.8878	99.0889	RID
32	P.76	18.1397	98.8994	RID
33	R.I.D. Office Unit 1 A. Muang	18.7892	99.0169	RID
34	N.1	18.7731	100.7808	RID
35	G8	19.8091	99.7612	RID
36	Kwang Dam	19.4357	100.3514	RID
37	Sw.5A	19.2694	97.9486	RID
38	Lamphun	18.5833	99.0333	RID
39	P.7A	16.4772	99.5183	RID
40	P.47	16.3342	99.2747	RID
41	Y.6	17.4342	99.7922	RID
42	N.12A	17.7361	100.5411	RID
43	N.60	17.4139	100.1306	RID
44	N.8A	16.0792	100.4000	RID
45	Hydrology center	16.8227	100.4405	RID
46	S.33	17.0031	101.3561	RID
47	S.42	15.5764	101.0911	RID
48	Tak	15.8833	99.1167	RID
49	Uttaradit	17.6167	100.1000	RID
50	Pichit Agromet	16.4361	100.2889	RID
51	Phetchabun	16.4333	101.1500	RID
52	N.67	15.8689	100.2644	RID
53	C.2	15.6708	100.1125	RID
54	C.13	15.1658	100.1922	RID
55	C.30	15.3494	99.5342	RID
56	Ct.4	15.7858	99.6783	RID

57	Ct.5A	15.9028	99.4792	RID
58	Ct.7	15.6397	99.5389	RID
59	Ct.9	15.5272	99.4694	RID
60	Ct.2A	15.4106	100.0575	RID
61	S.9	14.6283	101.0142	RID
62	S.13	15.3392	101.3750	RID
63	S.28	14.8392	101.0689	RID
64	Mae Hong Son	19.3000	97.8333	TMD
65	Mae Sariang	18.1667	97.9333	TMD
66	Chiang Rai	19.9167	99.8333	TMD
67	Chiang Rai (agr)	19.8708	99.7828	TMD
68	Phayao	19.1333	99.9000	TMD
69	Chiang Mai	18.7833	98.9833	TMD
70	Doi Angkhlang	19.9009	99.0424	TMD
71	Nan	18.7833	100.7833	TMD
72	Nan (agr)	18.8667	100.7500	TMD
73	Tha Wang Pha (hydro)	19.1167	100.8000	TMD
74	Thung Chang (hydro)	19.4000	100.8833	TMD
75	Lamphun	18.5667	99.0333	TMD
76	Lampang	18.2833	99.5167	TMD
77	Lampang (agr)	18.3167	99.2833	TMD
78	Thoen	17.6333	99.2333	TMD
79	Phrae	18.1667	100.1667	TMD
80	Uttaradit	17.6167	100.1000	TMD
81	Sukhothai	17.7833	99.1000	TMD
82	Si Samrong (agr)	17.1667	99.8667	TMD
83	Bhumibol Dam	17.2333	99.0500	TMD
84	Tak	15.8833	99.1167	TMD
85	Mae Sot	16.6667	98.5500	TMD
86	Umphang (hydro)	16.0167	98.8833	TMD
87	Doi Muser (agr)	16.7500	98.9333	TMD
88	Phitsanulok	16.7833	100.2667	TMD
89	Lom Sak (hydro)	16.7667	101.2500	TMD
90	Phetchabun	16.4333	101.1500	TMD
91	Wichian Buri (hydro)	15.6500	101.1167	TMD
92	Kamphaeng Phet	16.8000	99.8833	TMD
93	Phichit (agr)	16.4361	100.2889	TMD
94	Nakhon Sawan	15.8000	100.1667	TMD
95	Takfa (agr)	15.3500	100.5000	TMD
96	Chai Nat	15.1500	100.1833	TMD
97	Ayutthaya (agr)	14.5333	100.7278	TMD
98	Bua Chum (hydro)	15.2667	101.2000	TMD
99	Lop Buri	14.8000	100.6167	TMD
100	Suphan Buri	14.4667	100.1333	TMD
101	Uthong (agr)	14.3000	99.8667	TMD
102	Thong Pha Phum	14.7500	98.6333	TMD
103	Kanchanaburi	14.0167	99.5333	TMD
104	Ratcha Buri (agr)	13.4872	99.7975	TMD
105	Kampheang Saen (agr)	14.0167	99.9667	TMD
106	Pathum Thani (agr)	14.1167	100.6333	TMD
107	Samut Prakan	13.6336	100.7549	TMD
108	Suvarnabhumi Airport	13.6833	100.7667	TMD
109	Don Muang Airport	13.9167	100.6000	TMD
110	Sirikit Center	13.7243	100.5590	TMD
111	Bangkok Port	13.7000	100.5667	TMD
112	Bang Na (agr)	13.6667	100.6167	TMD
113	Pilot Station	13.3667	100.6000	TMD

Table 6-2 Flood Risk Information System Input Data (water level/flow rate)

No.	Code	Station Name	Basin
1	P.1	Chiang Mai	Ping
2	P.7A	Kamphaeng Phet	
3	P.17	Banphot Phisai	
4	P.67	San Sai	
5	W.1C	Lanpang	Wang
6	W.4A	Sam Ngao	
7	W.10A	Ban Donmun	
8	Y.1C	Phrae	Yom
9	Y.3A	Sawan Khalok	
10	Y.4	Sukhothai	
11	Y.5	PhoThale	
12	Y.14	Srisatchanalai	
13	Y.16	Bang Rakam	
14	Y.17	Sam Ngam	
15	Y.20	Song	
16	N.1	Nan	Nan
17	N.5A	Phitsanulok	
18	N.7A	Phichit	
19	N.8A	Bang Mun Nak	
20	N.12A	Tha Pla	
21	N.22	Wat Bot	
22	N.27A	Phrompiram	
23	N.60	Tron	
24	N.64	Tha Wang Pha	
25	N.67	Chum Saeng	
26	C.2	Nakhon Sawan	Chao Phraya
27	C.3	Sing Buri	
28	C.7A	Ang Thong	
29	C.13	Chainat	
30	C.29A	Bang Sai	
31	C.35	Ayutthaya	
32	C.36	Phong Pheng Canal	
33	C.37	Bang Ban Canal	
34	Ct.19	Uthai Thani	
35	S.5	Ayutthaya	Pa Sak
36	S.26	Tha Ruea	

Table 6-3 Flood Risk Information System Input Data (water gate)

No.	Water Gate Name
1	Makham Thao-U Thong Water Gate
2	Manorom Water Gate
3	Ponthep Water Gate
4	Maharat Water Gate
5	Bharomthat Water Gate
6	Bang Kaew Canal Water Gate
7	Lopburi Canal Water Gate

Table 6-4 Flood Risk Information System Input Data (water gate)

No.	Dam Name
1	Bhumibol Dam (inflow, outflow)
2	KiewLom Dam (inflow, outflow)
3	Sirikit Dam (inflow, outflow)
4	Khwae Noi Bamrungdan Dam (inflow, outflow)
5	Pa Sak Jolasid Dam (inflow, outflow)

6.3 Water Management Simulator

6.3.1 General

94. Inundation information is useful for the public to take proper damage alleviation actions during flood time. Such information can be delivered by the Flood Risk Information System.

95. On the other hand, managers of river administration facilities and officers in charge of water disasters prevention are responsible for executing proper operation of facilities or emergency countermeasures for minimizing damages and/or preventing further expansion of disasters. This requires anticipating the influences in flooding situations associated with a certain operation of facility. For example, while the influences of dam discharge or adjustment of diversion flow rate using water gates can be known at the site of operation as the direct amount, it would be harder to get the changes in water level of downstream reaches. The influence level changes as the water travels downstream, and some transformation tools would be necessary.

96. Where the distance is relatively small, the relationships between discharge and downstream water level are used operationally, such that the discharge increase of 500 m^3/s from the Chao Phraya Dam can be interpreted as the increase in water level of 0.25 m at downstream stations. However the use of such relationships is limited in operation. Moreover, with regards to inundation, as the operation of facilities and inundation are not directly linked, the influence of operation to inundation would be hard to estimate intuitively.

97. If sandbags are placed crossing a flood plain to prevent expansion of flooding area, there would generally be places where the damage increases compared to the case without such an action. To know the places and the degree of damage increase would be indispensable in making decisions on taking emergency countermeasures. However, to estimate the negative influence of a certain emergency countermeasure is not an easy task.

98. It would be useful, in the situations of the above, to (i) Assume multiple scenarios on operation of facilities or emergency countermeasures; (ii) Conduct hypothetical calculations on computers with different scenarios; and (iii) Find out the most suitable scenario. The model used in the Flood Risk Information System can accommodate calculations with various conditions including facility operation and emergency countermeasures, and the water management simulator can be constructed using the model.

6.3.2 Simulator Design

99. The water management simulator was designed to accommodate the following conditions.

(i) Input

100. The simulator is to be equipped with proper GUIs, which enable easy checking of input data and changing calculation conditions. For example, to change the ground height, one click near the cell that requires changes displays the edit screen on which numerical values can be input. To run a model, a number of conditions must be input, including,

- Basin geometry (ground level);
- Basin characteristics (permeability, land use, roughness, etc);
- River geometry;
- Initial states (basin, river, flood plain);
- Boundary conditions (dams, division, sea water level);
- Rainfall (past, forecast); and
- Levee break.

Among the above, those other than "Levee break" are input data of the Flood Risk Information System, and given beforehand. These input data are to be altered on the monitor screen easily using GUI (refer to Fig.8).

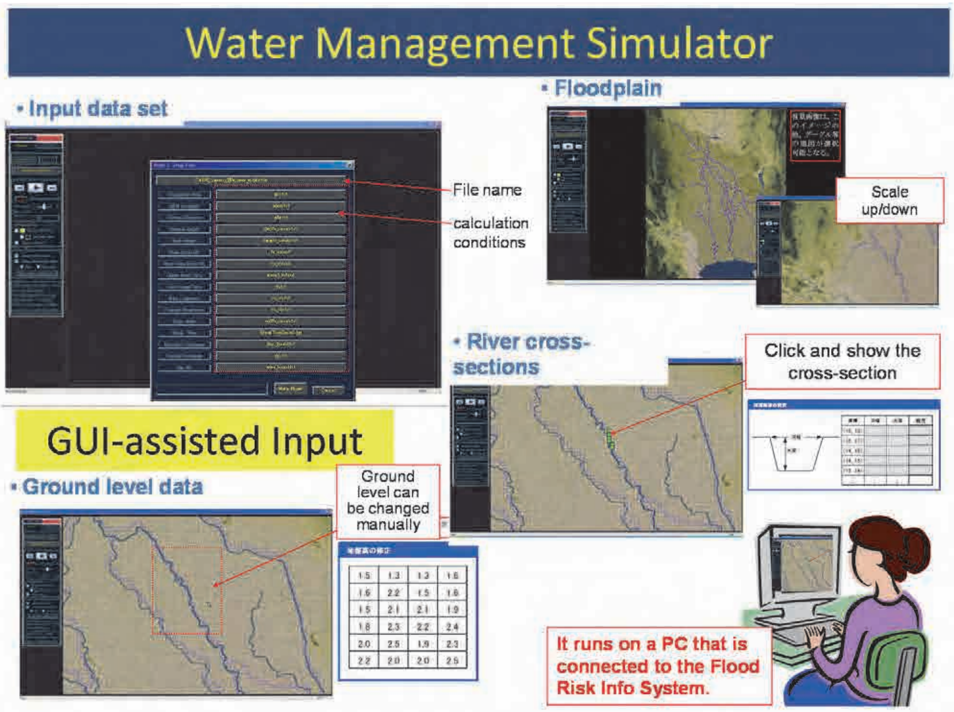

Fig. 8 GUI-assisted Input of Water Management Simulator

(ii) Output

101. The simulation results including inundation depth, river water level and flow rate are to be checked by animation images (refer to Fig. 9). In addition, a hydrograph of inundation of any selected cells is to be displayed, and longitudinal cross-section with river water depth and flow rate is to be drawn. Three dimensional display of the flood plain with inundation, river water depth, flow rate and flow direction and velocity is to be accommodated. A section of the flood plain specified on the monitor screen is to be displayed together with the inundation water level. The volume of inundation water over a specified area is to be displayed.

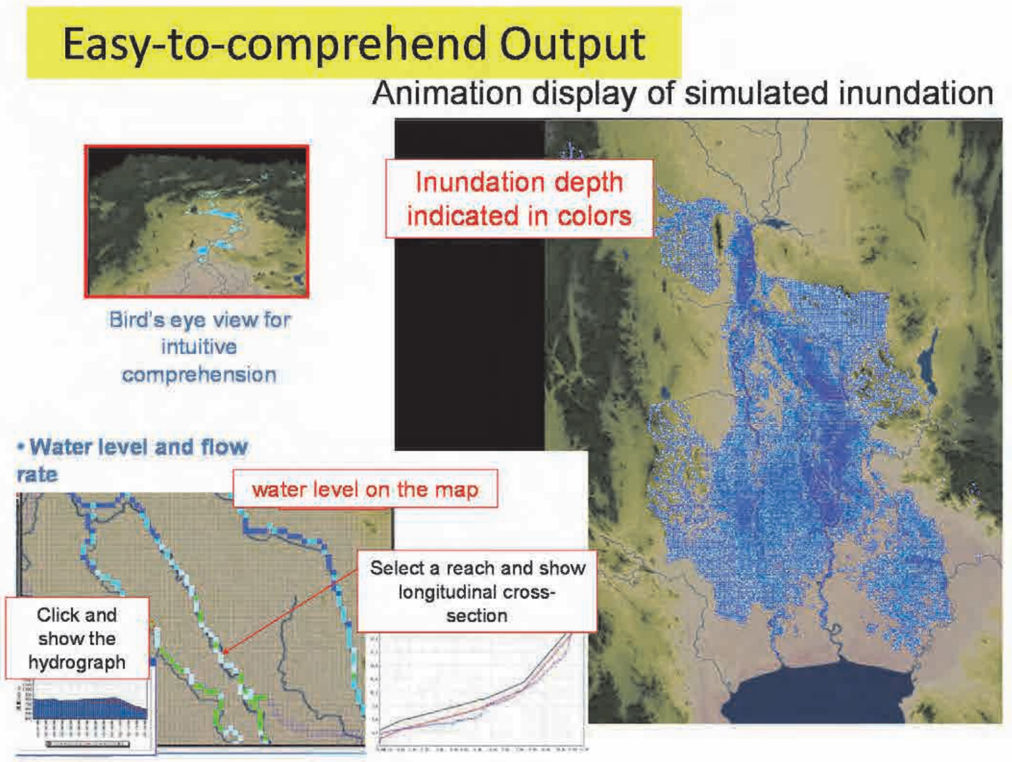

Fig. 9 Easy-to-comprehend Output of Water Management Simulator

(iii) Operation

102. For daily operation of the Flood Risk Information System, dam data, rainfall observation data and others are obtained, the Chaophraya Flood Risk Management Tool is executed, and the forecast results are to be displayed on the website. On the other hand, the calculation results, based on the calculation set downloaded from the simulation server, of the simulator are displayed on the simulator (PC monitor), and calculation conditions are changed in the simulator. The calculation set with changed calculation conditions can be uploaded on the simulation server of the System, then, if Chaophraya Flood Risk Management Tool is re-executed, the daily operation can be executed with the changed conditions and the results can be reflected on the website. If there is a levee break, the site of levee break is reflected in the model conditions using the simulator, and the daily calculation thereafter is conducted under the new conditions with the levee break.

(iv) Simulation utilization

103. The examination of dam operation and water gate operation, or evaluation of the effects of emergency pumps and sandbags can be conducted with the help of animated images of

inundation extent of the period between 7 days before and after today. Inundation depth, river water depth, flow rate and flow direction and velocity of flood water can also be displayed. The simulator program may run stand alone, if necessary data and calculation set are stored in the same folder as the program.

104. The utilization items of the Water Management Simulator are summarized in Table 7, the location of facilities (dam, water gate) that can be manipulated in the Water Management Simulator is indicated in Fig. 10, and the scenario development is schematized in Fig. 11.

Table 7 Simulator Utilization for Flood Defense Simulation

<table>
<tr><th>Scenario</th><th>Facilities</th><th>Input</th><th>Model</th><th>Remarks</th></tr>
<tr><td rowspan="7">Dam operation</td><td>Bhumibol</td><td rowspan="7">Average discharge after today (daily)</td><td rowspan="5">Upstream model</td><td rowspan="7">Study the optimum operation (daily average discharge) of dams</td></tr>
<tr><td>Sirikit</td></tr>
<tr><td>Kiew Ko Ma</td></tr>
<tr><td>Kiew Lom</td></tr>
<tr><td>Khwae Noi</td></tr>
<tr><td>Chao Phraya</td><td rowspan="2">Downstream model</td></tr>
<tr><td>Pa Sak Jolasid</td></tr>
<tr><td rowspan="10">Water gate operation (Separation)</td><td>Manorom</td><td rowspan="8">Average separation (m^3/s) or rate of separation (%) after today (daily)</td><td rowspan="10">Downstream model</td><td rowspan="8">Study the optimum operation (daily average separation) of water gates</td></tr>
<tr><td>Ponthep</td></tr>
<tr><td>Borommathat</td></tr>
<tr><td>Lop Buri</td></tr>
<tr><td>Phra Narai</td></tr>
<tr><td>Bang Kaew</td></tr>
<tr><td>Makham Thao-U Thong</td></tr>
<tr><td>Rama 6</td></tr>
<tr><td>Phong Pheng Canal</td><td rowspan="2">Rate of separation after today (daily)</td><td rowspan="2">Assume proper rate of separation</td></tr>
<tr><td>Bang Ban Canal</td></tr>
<tr><td>Drainage Pump</td><td>Drainage Area</td><td>Location (Drainage area) Capacity (mm/h)</td><td>Upstream/ Downstream model</td><td>Drainage provided in entire drainage area</td></tr>
<tr><td>Large-Scale Sand-bagging</td><td>Arbitrary Point of Flood Plain</td><td>Location(mesh) Height(m)</td><td>Upstream/ Downstream model</td><td>Study the influence of sandbagging</td></tr>
<tr><td>Levee Break</td><td>River Dyke, Road Embankment</td><td>Break point (grid) Time</td><td>Upstream/ Downstream model</td><td>Multiple levee break points accommodated</td></tr>
</table>

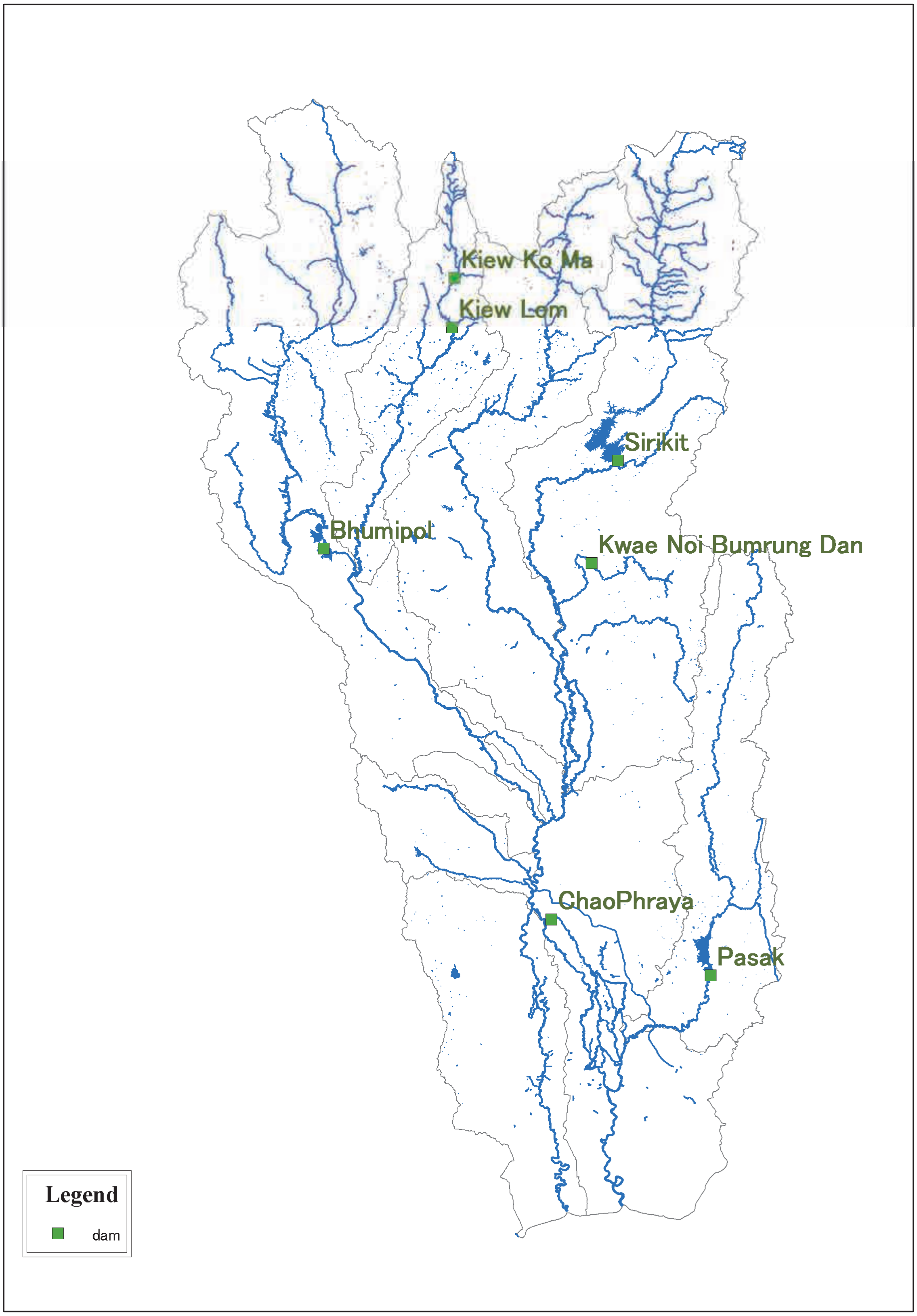

Fig. 10-1 Location of Dams Manipulated in the Water Management Simulator

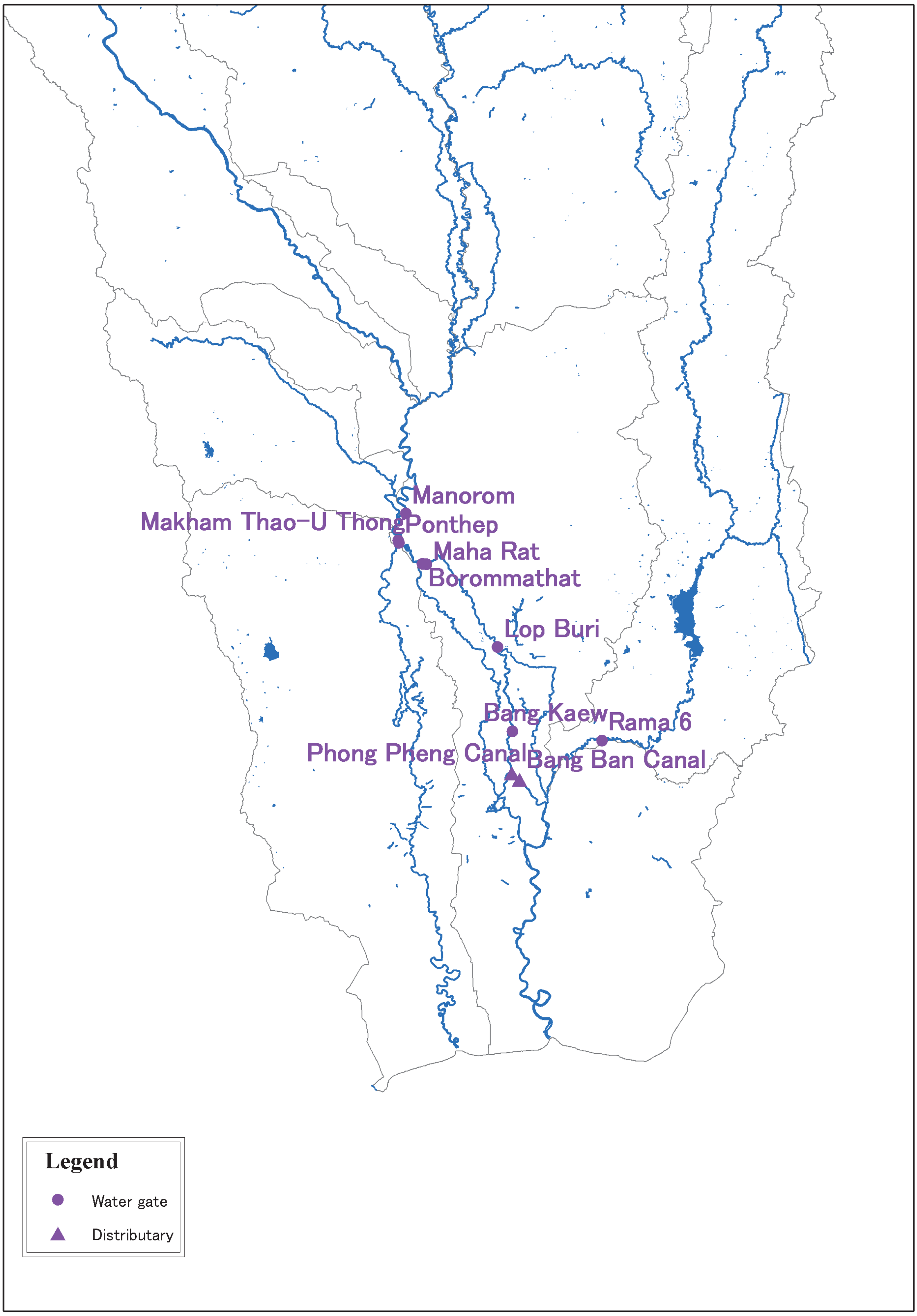

Fig. 10-2 Location of Water Gates Manipulated in the Water Management Simulator

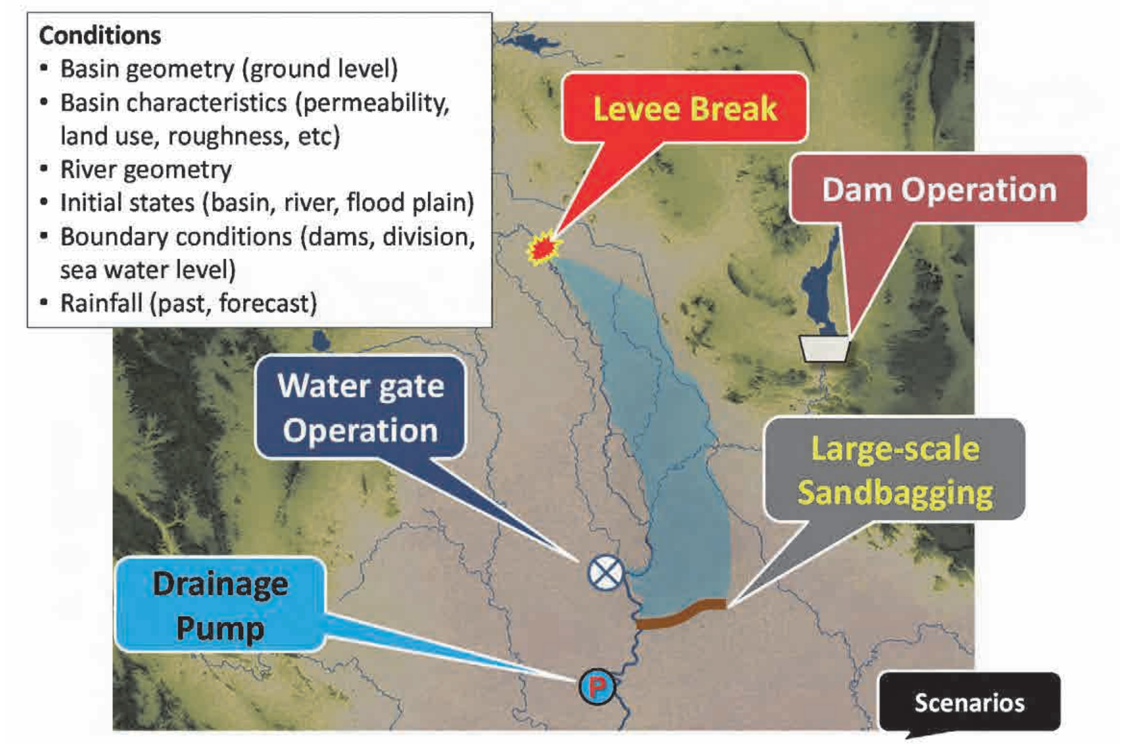

Fig. 11 Scenario Development with Water Management Simulator

6.4 System Transfer

105. The improved system was to be open to the general public and operated by RID, the system was to be properly transferred to GOT. In this connection, the following items were considered.

(i) Timing of the opening for information delivery

Information delivery for the general public by the system shall be commenced in early September 2013 by taking into consideration the beginning of flood season. For governmental officials, the system and also the water management simulator shall be started at the same timing.

(ii) Installation of system equipment

As the information has importance for residents during a flood, preparation of system equipment enabling a stable operation is required. The procurement would be started in June 2013, and installation and adjustment of the system would be completed by end-August 2013.

(iii) Technical transfer

Necessary training on system structure, operation and information utilization would be held before system management transfer in order to enable correct operation of the system by Thai Government. The training course would be held under Thai Government manner and JICA/FRICS would prepare program, textbooks and instructors.

(iv) Publicity

Necessary publicity activities would be carried out to make residents (recipient of information) utilize the information delivered by the system for disaster measures effectively. Strategic publicity would be implemented comprehensively, such as press release, seminar, explanatory meeting, website and disaster prevention learning in local municipality. Publicity strategic meeting should be held among related officials for publicity planning and implementation.

106. Training on the Flood Risk Information System was organized from 5 to 9 August, 2013 at RID. Some 76 government officials from RID, DWR, ONWF, HAII, NESDB attended the training sessions. Objectives of training were to acquire necessary human resources for accurate system operation and for technological development of Thailand. Specifically,

(i) To acquire the abilities to do the items below for accurate system operation

- Daily data management and data input;
- Checking a correctness of the contents displayed;
- Simulator operation for facility control and urgent countermeasures;
- Checking an operation of equipment and operating the system;
- Rough understanding of forecasting model and method of calibration;
- Finding abnormal action or value, simple response, and contact to appropriate address on the occasion of serious trouble;
- Periodic modification (updating rating curves, replacement of observation station, modification of threshold water-level, and etc.); and
- Any other necessary items for the smooth operation.

(ii) To acquire the abilities to do planning and implementing necessary for applying and delivering forecast information including,

- Delivering method to the general public on the utilization of information;
- Effective utilization of information forecast with uncertainty; and
- Local disaster prevention ability enhancement by utilizing the information and putting it into practical use.

107. The contents of the training were as follows.

- Development goals and effect on society of Flood Forecasting System
- Structure of flood forecast analysis
- Structure and role of system equipment
- Information utilization and accuracy in the field of disaster prevention
- Necessary data for forecasting system
- Runoff and inundation simulation and validation of forecast accuracy
- Water management simulator and its operating instruction
- Daily operation of the system
- System maintenance and response to system failure
- Accuracy of and responsibility for disaster prevention information
- Information display and utilization of forecasting information on the system
- New technologies of flood forecasting and flood runoff analysis
- Current status and future possibilities of ICT utilization in the field of disaster prevention
- Comprehensive exercise and discussion

Textbooks were prepared in Thai as attached in Attachment 03 "Textbooks of Training on the Flood Risk Information System". While the detailed descriptions of the system can be found in these textbooks, the outline of the system transferred is indicated in Fig. 12.

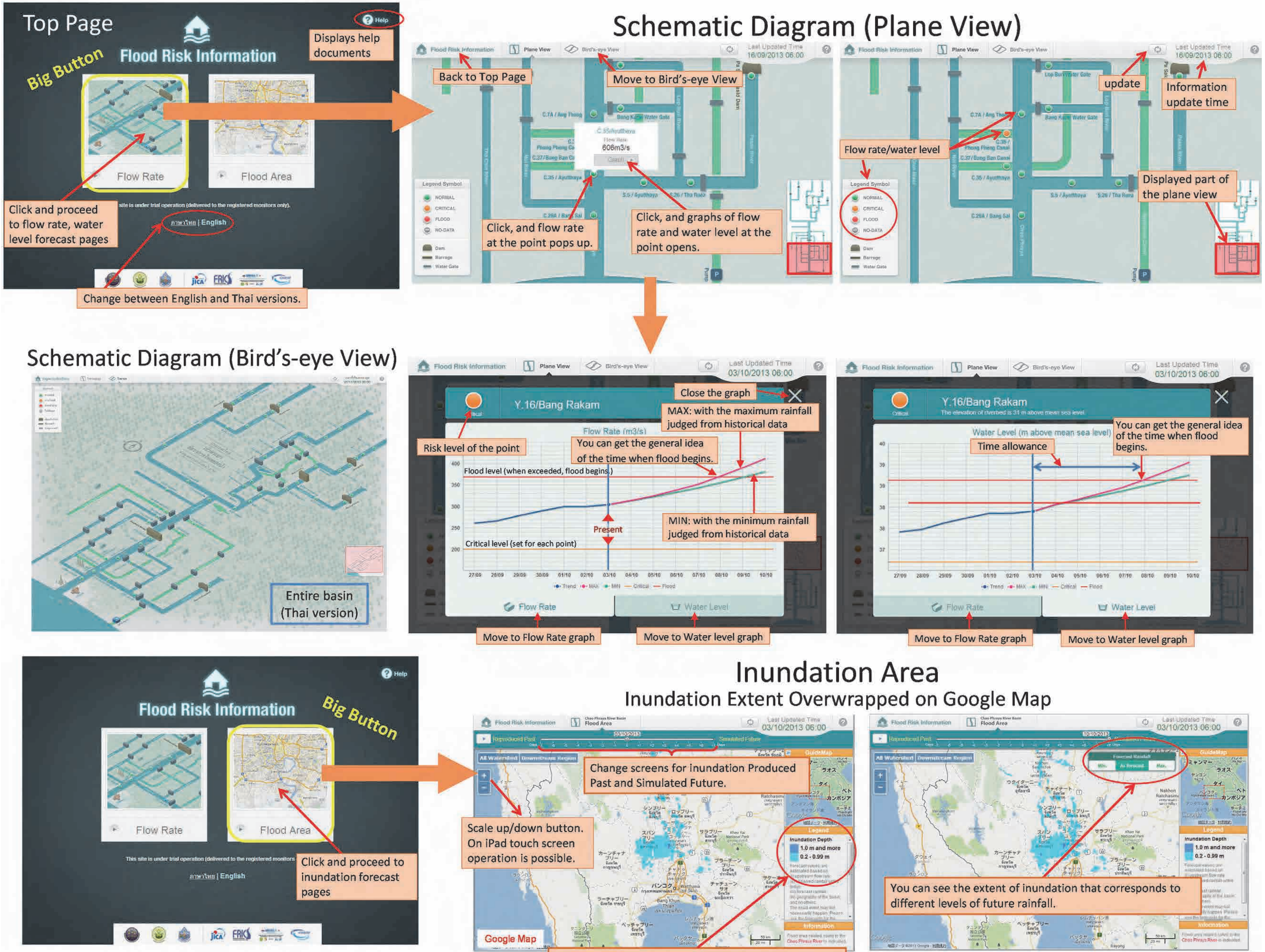

Fig. 12 Outline of Flood Risk Information System

6.5 Operation Manual

108. For smooth operation of the System by GOT, the Operation Manual of the System was prepared in Thai as found in Attachment 04 "Operation Manual of the Flood Risk Information System". Operation procedures in detail were explained to the officers in charge of operation of the system on 10 and 11 September, 2013 at RID.

6.6 Publicity

109. A series of seminars were held on 19 September (for Japanese companies) and 20 September (for GOT organizations, local administrative organizations, water management-related academics, business sectors, and mass media), 2013 in Bangkok, for introducing the commencement of the Flood Forecasting Information Delivery Service. The total attendees were nearly 300 in two days. On the second day, the presentations of outline and use of information delivered by Flood Risk Information System were by RID officials as the system was operated by RID starting September 2013. The government officials questioned on the integration of Flood Risk Information System and existing system of Thai government and evaluation of the system's accuracy. The responses from mass media were about new technology of flood forecasting information (7-day forecast) with water management mission of RID and benefits of flood-related information for the general public. These seminars were reported by different mass media (TV, newspaper, and Internet) of both in Japan and Thailand.

110. Among others, Thai PBS introduced the Flood Risk Information System in detail on its TV program called "Rusupaipibat", which broadcast nationwide disaster news and method of disaster prevention every Saturday. On 29 September 2013 the schematic diagram of the Chao Phraya River Basin was displayed during the program to explain how to monitor water situation by the system. On 6 October, the program also broadcast an interview program of DG of RID together with university professors of Thailand and Japan, in which the DG indicated that the Water Management Simulator developed by JICA would be applied for facility operation, and 7-day forecast flow rate and inundation area would be available on RID's website for the general public.

6.7 Solutions to Technical Issues

111. The Steering Committee Meeting held on 11 October, 2013 pointed out outstanding issues on the Flood Risk Information System, which included the followings:

1) The area west Prachin Buri (outside the Chao Phraya River) is colored. The extent of the model display should be clarified.
2) On the graphs of flow rate at C.2 or N67 and others, it is observed that the value of a day after decreases once then increases afterward. As the upstream flow rate does not decrease, the value at C.2 should not decrease.
3) Discharge from the Chao Phraya Dam is forecast to be constant, which is not the actual situation.

The Chairman suggested holding a small meeting in which proper solutions to the above technical issues were to be discussed.

112. The Study Team and relevant persons of RID discussed the possible solutions to the above issues on 22 and 24 October, 2013 at RID. They reached the following conclusions.

1) The System simulation includes the area where flood water of the Chao Phraya River may expand, such as west Bang Pakong River. While the model covers such area, the display of the results is to be limited to the Chao Phraya River Basin only in order to avoid misunderstanding.
2) Flow rate of a observation point is adjusted using the difference between observed and simulated (difference itself or ratio) during 2013 flood season. In parallel, study is to be conducted on the method that adjusts soil moisture of the basin to make the simulated values agree to the observed values. The model is to be calibrated again, if necessary, judging from the performance of the System in 2013.
3) Discharge from the Chao Phraya Dam is to be assumed “outflow = inflow” as default. If different outflow from inflow is to be employed at the Chao Phraya Dam, the Water Management Simulator is used for inputting (future) discharge values.

VII. BASIC PLAN OF FLOOD MANAGEMENT SYSTEM

7.1 General

113. Against floods, which are caused by natural phenomena of rainfall, important are not only structural measures such as levees, floodways, retarding basins, and dams, but also non-structural measures of appropriate actions of residents and administrative organizations based on accurate information delivered and shared. For further and sustainable development of Thai society and economy, it would be indispensable that these measures are carried out comprehensively. In order to reduce damages as much as possible in the event of floods of magnitude of the 2011 flood in the Chao Phraya River or of even larger scale, desirable flood management system in the Chao Phraya River is to be proposed under this Component.

114. In the Component, based on the current set-up of observation, collection, analysis, information delivery on the Chao Phraya River and other rivers in Thailand, aiming at more effective flood management, studies were made for preparing the Basic Plan summarizing basic forms of future flood management system.

7.2 Contents of Basic Plan of Flood Management System

115. The Basic Plan, to reduce the flood damages in Thailand as much as possible, would be proposed considering the following.

- The proposal was to be made by summarizing ideas on information systems to be constructed and operated for residents and the government to effectively take actions immediately before and during disasters, and in the reconstruction stage.
- To understand information and take actions at disasters properly, it would be important to understand related information during normal time as well.

116. Because more than one organizations of the Government were coping with flood, flood management system with information set-up in its heart as well should be materialized in the collaboration of related organizations under a solid plan such as “Master Plan of Flood Management System of Thailand” agreed upon by the entire Government. The proposed Basic Plan was expected to be utilized in actual system development and operation in Thailand as much as possible: The Basic Plan was formulated considering the follows:

- Attach most importance not to the sender of information, but to the receiver of information such as residents and related government officials, and how well they utilize the information;
- Understanding the actual situation of Thailand appropriately, and in comparison with the experiences and devices of Japan, which is one of the countries with most frequent natural disasters, formulate an effective plan;
- Utilizing existing facilities in Thailand including observation facility, information collection/transfer facility, analyzing system of various organizations, and forecasting/warning systems, introduce effective new technologies;
- Present specific proposals rather than abstract ones, so that the Thai Government could practically utilize; and
- Formulate plans utilized in various considerations in the future by the Thai Government.

117. The outline of Basic Plan is as follows. The full text of the Basic Plan is found in Attachment 05 “Basic Plan of Flood Management Information System of Thailand”.

7.3 Current Status and Issues

118. A number of information-related problems surfaced during and after 2011 flood, and a number of issues were pointed out. To understand such issues accurately, questionnaire surveys and interviews to city residents, farmers, factories, mass media, administrative organizations were conducted on actions taken at disasters and information needs required for the actions (Attachment 06 “Questionnaire Survey on Flood Information Needs”). Considering global climate changes, study was carried out on damage situations in case of a flood exceeding 2011 flood scale (even with various proposed structures completed) (Attachment 07 “Damage Estimation of Large Floods”), and necessary actions and information there. Distribution of observation data was also analyzed (Attachment 01 “Hydrological Observation Stations in the Chao Phraya River Basin”).

119. Issues of information for damage alleviation actions are summarized as follows from the viewpoint of its needs, creation, and utilization.

(1) Information Needs

i) Required information should reach users to reduce damages

To reduce damage, information on how the risk is approaching is effective. Different users require different kinds of information.

ii) Arranging/sharing information set-up should be established in the Government to make prompt and appropriate decisions

The Government’s Master Plan (SCWRM, 2012) pointed out the unsystematic and outdated database as one of the main weakness and problems. As not enough information was provided during the 2011 flood, many people had troubles in making proper judgment and taking proper actions.

iii) Monitoring present situation change and forecast information set-up should be established for coping with changing situation appropriately

To a question what kind of information did one want but actually did not get, many people selected forecast information and warning, as well as accurate status quo.

iv) Coping with localized information needs is required for appropriate actions of individuals

Individuals, while they themselves are not facing at risks, show interests to a live report of distant areas. When the risk becomes imminent to them, their interests change to when and how badly their lots are inundated, and after the inundation, when the water recedes. Individuals need local information that is useful in deciding their actions.

v) Not only water-related information, but information on actions to be taken, and traffic situations is necessary

Due to blackout, TV would go off and information cut, then other life would also be undermined. Due to inundation over roads, they would become impassable, and the life and operation of factories would be severely undermined. Therefore, not only inundation information, but also lifeline situation information would be highly wanted.

(2) Information Creation

i) Mutual coordination on observed data is important to monitor situations of rainfall accurately and efficiently

Rainfall is the most fundamental information. Distribution of rainfall and its changes should be monitored for proper disaster countermeasures. The density of rainfall observation stations in Thailand is considered not sufficient. Since stations of one organization are not evenly distributed in the basin (e.g. RID along rivers and DWR in the mountains), combining them would have considerable effects. They should be mutually used.

ii) Area-wide information monitoring set-up is important for managing vast river basin

Structural measures increase not only safety level, but also the necessity of information on water situation as a whole, facility operation status, and flood forecasting. This is because, (a) flow controlling facilities require secured operation, and (b) in case where the capacity of facilities is exceeded or levee break, rapid expansion of inundation area is anticipated.

iii) Monitoring present situation change and forecast information set-up should be established for coping with changing situation appropriately

Quite a many people and factories demanded accurate information. This mainly arose from the fact that information given by the government was inconsistent depending on organizations and persons. Rather than information of high accuracy, consistent and unified interpretation of situation by the government was wanted.

To cope with disasters, it is important to visualize the future situations. Forecast information, even with uncertainty, should be widely introduced in Thailand, with how to treat the uncertainty being examined.

(3) Information Utilization

i) Coordination with mass media and NGOs should be promoted

While residents often receive information through mass media, TV in particular, there seldom is coordination between the governments and mass media, rather they are mutually critical. In Japan, mass media, which are critical against administration in normal time, are coordinated on information delivery during disasters.

During 2011 flood, NGOs played important role in providing information to the damaged people.

ii) Raising awareness and enhancing knowledge among residents (recipient of information) is important to utilize provided information

Survey showed cases where, before the flood water reached their farmland, some respondents did not take any action because they thought their farmland would not be inundated. When the inundation approached, many of them did not do any action since they did not know what to do. After the flood water spread over the farmlands, most of them did not do anything since there was no effective measure. If actions were taken beforehand, the situation would have been quite different

iii) Set-up for comprehensive information and remote operations is necessary for coordinated and effective operation of water gates

In the Chao Phraya River, water use facilities such as water gates and canals are intertwined in a complicated fashion, which play important roles in flood control as well. As they are located on the extremely flat ground, the operation of gates changes not only the flow rate in the canals, but also the flow direction. Thus the local optimum operation may not necessarily be appropriate in the whole basin. To operate them as a whole and efficiently, monitoring the status quo of the whole basin based on the comprehensive information, and central operation are required.

iv) Basic network with sufficient capacity should be developed for swift and smooth transfer of information and data

Currently many of data and information in Thailand are not linked online. For supporting the Flood Management Information System in Thailand, collection of data and information from local sites, processing into comprehensive information, smooth delivery of prepared information, and utilization of image information require sufficient data transmit capacity.

7.4 Flood Management Basic Policy of Thailand in the Future

(Society to be achieved)

120. Thai people mildly get along with nature, which gives many blessings as well as disasters sometimes. They, with tender heart, help each other. These characteristics are appreciated in designing the Thai-way flood management for achieving the society pictured here.

121. Not only achieving safe society for Thai people and industries, but securing international reliability on safety, as well as aiming at long lasting growth of the Thai-way flood management, which would be a model of neighboring countries, should be sought.

(1) Reduce damages through self-help mutual-help and public-help

- In actions for damage reduction, administration, society, and individuals should play their roles.
- Self-help is to protect oneself by preparing against disasters and evacuating. Mutual-help is to help each other or to cooperate with people. Public-help is a support provided by administration organizations, including construction of structural measures. Combination of self-help, mutual-help, and public-help can minimize damages and enable prompt recovery.
- The administration should not play all the roles, rather support local societies and individuals to play their roles. This allows disaster-resilient society be achieved with low-cost.

(2) Effects to be generated with facilities against flood damages (structural) and information set-up (non-structural)

- Basic principles of disaster prevention/mitigation are, (i) not to live in dangerous place (no damages even if one gets across with phenomena); (ii) to defend the phenomena with disaster prevention facilities (adjust phenomena); and (iii) to escape from risks (rescue from dangerous situation). These three supplement each other. Integration of structural and non-structural measures selecting the best mix of them is the principle.

- Flood control structures are constructed on the premise that they will be operated properly in emergency. Dams and water gates, if operated wrongly, would not provide good effects, but might increase damages. Especially the use of retarding basin generates damages on the condition that they would be compensated later. With appropriate information set-up, these facilities should be effectively operated.

(3) Sustainable flood management

- Due to global-scale climate change, rainfall from June to October is expected to increase by about 6-10% in Thailand (IPCC4th report). To cope with such increase flexible flood management is required. The government's risk management and cares for residents during 2011 flood were not appropriate from various aspects. The situation might be attributed to the actions solely based on the experiences of past floods. To avoid falling into the same situations of 2011 flood, not only constructing flood damage alleviation structures against the scale of 2011 flood, but a study should be carried out on the actions of residents and the government and required information in the case of a flood exceeding the scale of 2011 flood. Required measures thus identified should be materialized.
- By securing safety against floods, risks in agriculture industries and commerce are expected to be lower. Thus business attraction and industry promotion would be possible, and sustainable development of Thailand could be possible.

(4) Flood management to grow further through Industry-academia-government collaboration and international cooperation

- The responsibility of flood management should rest with the government organizations. With respect to researches on flood management and peripheral technology development, collaborations should be made with academia and private firms, so that the level of knowledge technology and human resources of the country would be enhanced. Through international cooperation good examples of other countries can be introduced for further developing the Thai-way flood management, which should be the appropriate model of neighboring countries.

7.5 Basic Strategies of Flood Management Information System Construction
(Things to be done holistically)

122. In this period after the 2011 flood, drastic measures against flood disasters are to be taken, for raising the standard of the coping ability with flood disasters of Thailand as a whole. Unimportant details of individual information system should not be concerned, but the fundamental information basis of the flood management is to be developed. Such a fundamental information basis would be utilized in various flood disaster countermeasures, water use, and environmental management for a long time to come.

123. Based on (i) Current Status and Issues, and (ii) Flood Management Basic Policy of Thailand in the Future, the following strategies are to be taken. They were derived by verifying all kinds of information from the viewpoint of appropriate damage alleviation actions of residents and administrative organizations (information users), and necessary information for the actions, with their priorities and importance in mind. They consist of contents that can be materialized and employed within 3-5 years, if executed steadily with maximum use of existing assets and wisdom of Thailand, and with their feasibility being well taken into consideration.

124. While various proposals are made as part of the comprehensive flood countermeasures as of February 2013, this plan summarizes universally required items of the flood management information system of Thailand in the future, which all the proposing parties should consider: It does not have a prejudice in favor of any of such proposals.

(1) Understand flood situation and damage situation completely, eliminating present situation information (source) vacancy
- The holistic picture of movement of water in the basin, as well as localized situations of water, to be monitored
- Not to mention floods in main rivers, situations of branch rivers and the mountainous areas (such as flash floods) should be monitored
- The holistic picture and individual situations of damages, emergency measures, and restoration works to be monitored

(2) Improve the accuracy of information, promote information sharing among government organizations, and take effective measures based on reliable information provision

(3) Establish flood forecasting set-up of water-level/flow-rate and inundation area
- Use the forecasting system, forecast water-levels/flow-rates of rivers, review the caution/warning water levels from the viewpoint of necessary actions, and issue effective forecast and warning
- Use the forecasting system, provide highly demanded forecast information of inundation areas, and issue appropriate forecast and warning to the areas where preparations are required
- Evaluate the effects/influences of operation of dams, water gates, and pumps, and select the effective operations
- Obtain forecast information on inundation area expansion in individual areas due to flood: The characteristics of downstream flood plain, mountainous areas, and tributaries are to be taken into consideration.

(4) Eliminate information (provision) vacancy in delivering to residents, and establish information sharing society
- Make information delivered to residents through traditional means and making full use of multiple every possible measures
- Collaborate with mass media and NGOs
- Raise awareness and enhance knowledge through disaster education during normal time for information to be utilized effectively

(5) Establish the Comprehensive Information System to achieve (1) - (4) above
- Improve set-up of each organization on observation, analysis, and information utilization, as well as integrate fundamental information in the Comprehensive Information System
- Use different organizations' correlated information, not just collecting and displaying data of different organizations
- Use the System for sharing information among government organizations and decision making, and be the center of totalized direction of countermeasures, and information delivery

(6) Develop Information and Communication Trunk Network

- Construct large capacity and high speed trunk lines along the Chao Phraya River, so that swift and reliable collection and transmission of data from local areas, transmission and delivery of generated information to local areas, and utilization of image information would be possible
- The north-south axis indicated above goes through the Route 1, major cities and industrial zones, constituting the economic axis of Thailand. The trunk network would be not only measures against disaster but also the key to further economic development.
- As there are complex water ways networks in the vicinity, when the related information functions smoothly, rational water use and new agriculture utilizing IT would also be expected.

7.6 Specific Measures Development Plan of Flood Management Information System

125. According to the basic policy and strategies described above, following specific measures of information system were presented as to be urgently developed for the flood management of Thailand.

(1) Present Situation Monitoring
  i) Rainfall (observation station on the ground)
  ii) Radar rainfall data
  iii) Monitoring water-level and flow rate
  iv) Understanding inundation area
  v) Present Situation Monitoring by CCTV Camera Images

(2) Forecasting, warning
  i) Improve the accuracy of meteorological forecast
  ii) Water-level/flow-rate forecast and warning
  iii) Inundation area forecast and warning

(3) Facility Operation and Emergency Countermeasures
  i) Judgment on optimum operations of facilities based on simulation on effects of operations
  ii) Optimum urgent flood defense measures based on simulation on effects of countermeasures

(4) Comprehensive Information

(5) Delivery System

(6) Communication Network

(7) Information Management Set-up

126. The Basic Plan was explained and discussed in seminars held on 25 January and 20 February, 2013. Copies of booklet containing the Basic Plan (Thai and English) were widely distributed among government officials, researchers, students and the public taking opportunities of seminars and meetings including Asia Pacific Water Summit (Chaing Mai, June 2013) in which a number of top executives of the Government participated.

VIII. Additional Study for Realizing Basic Plan

127. For realizing the Basic Plan of Flood Management System, some additional studies were conducted. The following items were considered.

(1) Forecasting/Warning on landslide disasters (flash flood, steep slope failure)
(2) Water level standards for warning information (evaluation of water levels as warning information)
(3) Forecasting/Warning for disaster alleviation actions (set-up of issuing forecast and warning)
(4) Benefit analysis of non-structural countermeasures (economic evaluation of flood forecasting system)

8.1 Landslide disasters

8.1.1 General

128. The heavy rain disasters in mountainous areas of Thailand are categorized into two:

(1) Localized disasters that occur relatively frequently

In the village communities of mountainous areas in Thailand, when it rains relatively heavily, small and medium rivers in the community overflow, causing damage to humans and inundation damage to houses, household goods, and farmlands in parts of the community.

(2) Disasters that occur with less frequency but cause severe damage

In the mountainous areas of Thailand, when heavy rains continue for several hours, it will trigger flooding that accompanies sediment-related disasters (debris or mud flow ("Nam Paa" containing a large volume of sediment) or large-scale multiple landslides ("Pan Din Talom"), causing a number of deaths and severe damage in a wide area affecting a large part of the community or multiple communities).

129. Flooding disasters that accompany sediment-related disasters tend to occur more often in the northern and southern regions (due to rainfall and geological conditions).

130. The early warning system of DWR is designed as follows.

(1) The rain alarm station (mountainous area type) consists of an automatic rain gauge, manual rain gauge, transmission device, warning signal and speaker, thermometer, and soil moisture gauge.
(2) The rainfall measured by the automatic rain gauge is recorded in the data logger as a 15-minute rainfall. The recorded data is then transmitted in real-time to the main station at DWR headquarters.
(3) If the measured rainfall exceeds a warning criterion (three tier: green, yellow, red), a warning signal and speaker will be activated.
(4) If a warning criterion is met, and a warning signal and speaker are activated, village volunteers in charge will start monitoring factors, such as river conditions, and will instruct villagers on whether to evacuate.

    Green: Start to monitor rainfall amounts and river conditions (Alert)
    Yellow: Intensify monitoring activities and prepare for evacuation (Alarm)
    Red: Decide to evacuate (Action)

(5) If green warning criteria are met, DWR regional officials in charge of the Early Warning

System in the region will start monitoring conditions by communicating with the village volunteers.

(6) When installing a rain alarm station, a volunteer leader is appointed and a volunteer network will be established to assist him.

(7) A 24-hour communication system is set up between them and the DWR officials in charge.

(8) A training session is held when a rain alarm station is installed and once a year thereafter.

8.1.2 Advantages and Issues

131. The early warning system was evaluated as follows.

(1) Advantages

- i) The Early Warning System can promptly provide information to local people through real time rainfall gauging and the issuance of automatic alerts.
- ii) Telemetric rain alarm stations have been installed in locales where rainfall gauging has not been carried out, such as mountainous regions, and locations where only daily rainfall was monitored previously. This made it possible to continuously accumulate 15-minute rainfall data.
- iii) Since its warning criterion is based on the rainfall index, which is easy to understand and measure, it is a system that allows for the active participation of local people.
- iv) A risk communication and mutual reporting system has been established between the local people and the government.

(2) Issues

- i) Warning criteria accuracy
- ii) Alert issuance based on terrestrial phenomena
- iii) Rainfall measuring site with respect to susceptible areas

8.1.3 Proposals

132. The following proposals were presented for further improving the early warning system of DWR.

(1) Improvement of warning criteria accuracy

- Study should be conducted on the implementation of more accurate warning criterion that focuses on sediment-related disaster-criterion as an equivalent to Red warning, and put it into test operation in order to establish a mechanism that can convey the urgency of large-scale disasters without failure.
- For the new warning criterion, the rainfall amounts measured by telemetric rain gauges should be plotted as a curved line (snake line of real rainfall) on the graph that shows the long and short-term rainfall indices on the abscissa and ordinate axes, respectively. Monitoring should be continued by watching for whether the snake line crosses the criterion value (critical line).

(2) Issuance of an alert based on terrestrial phenomena

- Terrestrial phenomena and other events at the site, such as river overflow, sediment movements (landslides, debris flows, mudflows, etc.), the start of evacuation, and the occurrence of damage, are important information indicating that a large scale disaster is imminent.
- The Early Warning System should possess a mechanism that enables village volunteers to report terrestrial phenomena and other information to DWR (DWR headquarters and the regional officials in charge of the Early Warning System in the region) quickly, and allowing for the prompt sharing of information with other village volunteers.

(3) Measuring rainfall at upper reach of the watershed and in the mountain

- A rain alarm station (telemetric rain gauge) should be installed in the village communities in the upper mountain in addition to ordinary installation locations, such as communities that have a disaster history and communities where rain gauges can be installed easily.

(4) Actions for the practical use of radar-analyzed rainfall

- It is impossible to cover all source areas of sediment-related disasters using only the ground level rain gauges. Therefore, practical use of radar rain gauges should be promoted in collaboration with related organizations.
- In addition, the use of ground level rain gauges should be continued steadily because the telemetric ground rain gauge network is indispensable to the calibration and accuracy improvement of radar-analyzed rainfall.

(5) Survey of the flooding and deposition areas of debris and mud flow

- Surveys of flooding and deposition areas should be conducted at the sites of debris and mud flows in order to use the obtained data for purposes such as identifying the occurrence mechanism of sediment-related disasters, verifying hazard maps and improving their accuracy, and evaluating the importance (effect) of policies regarding sediment-related disasters.

133. Detailed report is attached in Attachment 08 "Technical Proposal for DWR Early Warning System".

8.2 Water level standards

8.2.1 General

134. Current water level standards of the Chao Phraya River basin are two kinds according to the different warning target. One is for warning the area nearby station, and another is for warning the downstream basin. Standards are based on the flow capacity at each station.

(1) Water level standard for warning to the area nearby each station

- Water level of river is divided into three zones, as colored by green, yellow and red. Threshold between these zones are defined as "Warning level" and "Critical level", respectively.
- "Critical level" is determined as the water level of overflow from the river. It is equal to the lower side of bank level or the bank level at the point with highest risk surrounding the observation station.
- "Warning level" is defined as the water level for warning issuance. Actual value of warning level is based on critical level of each station, considering various conditions on land use or economic situation of the surrounding area, and so forth.
- The early warning method based on correlation between two adjacent stations was established..
- The severity of a flood was defined as flood start, medium flood, heavy flood and severe flood. The water level corresponding to and indicating the severity of a flood was determined. Flood arrival time was determined according to hydrograph during a past flood event.
- Residents are notified with water level at upstream station and estimated arrival time when a flood would occur and how a flood would extend.
- For some cities, possible inundation area maps were created based on the past flood event.

- At the area of downstream of the Chao Phraya Dam, a flood risk in near future could be judged by comparing with dam discharge and flow rate standard at each station.

(2) Water level standard for warning to the downstream basin

- Main stations in the Chao Phraya River basin, including branch rivers, have the water level that indicates the risk of flooding at the downstream area. This water level is defined as "Critical level" and designated to indicate the risk as a kind of alert system after the 2011 flood occurrence.
- "Critical level" for this alert system is applied for only 38 stations in the Chao Phraya River basin.
- "Flood level" is defined as the water level at starting overflow from the river or flow capacity of the river. The value of "Flood level" is exactly equal to that of "Critical level" for the warning to the area nearby each station.
- "Critical level" is also designated by flow rate of river as well as water level.
- "Critical level" is used as the alert indicator for flood management officials. "Critical level" defined here isn't determined based on "Flood level" at that station. This "Critical level" indicates not the risk at the station but the risk at downstream basin. When the water level at one of upstream station exceed "Critical level", flood management officials start to monitor the upstream flow continuously and to consider a preparation of flood measures at downstream basin, such as central plain.
- In order to judge actual risk at downstream basin, not only flow rate exceeding "Critical level" but also increasing trend of water level or flow rate is verified.
- In case of excess of "Critical level", Single Command Center (SCC) is sole authority to command a facility operation.
- In the downstream area of the Chao Phraya Dam, there is less importance on "Critical level" as alert information, than upstream area.
- This standard is the system to know future trend of river flow and coming flood basically, thus it isn't established as warning system.

8.2.2 Observation station

135. Current telemetering stations in the Chao Phraya River basin had been evaluated in the Basic Plan. Based on the analysis of rainfall data density, necessary density was estimated at less than 500km^2 of catchment area per one telemetering station. Furthermore, from the viewpoint of operation of the Flood Risk Information System, the sub basin which would require allocating more rainfall telemeter station are narrowed down and prioritized. For a flood forecasting at the downstream of Chao Phraya River basin, catchment area of dam has relatively less importance as rainfall input, since dam discharge are used as model input to simulate runoff and inundation. Rainfall in the lower basin also relatively less importance, since there is not so large influence on the future flow rate in the downstream. Table 8 shows that deficiency of telemetering station in sub basins (only RID, and RID with TMD). The upper basin of C.2 and the lower basin of several dams should be focused as vacant data area to be improved a telemetering system.

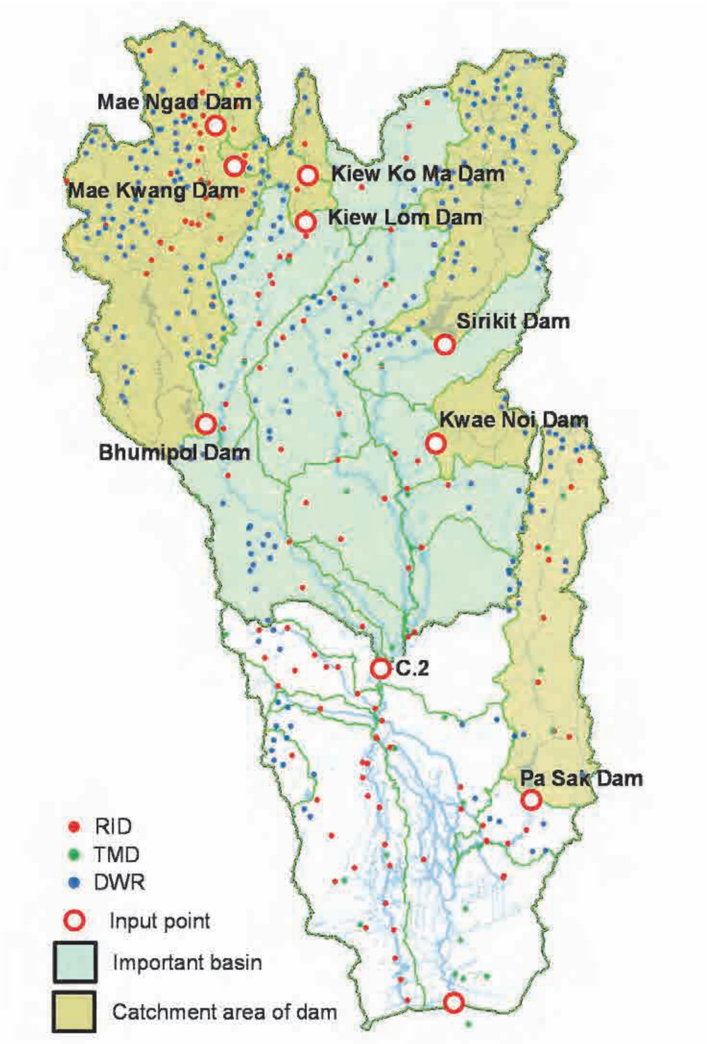

Fig. 13 Location of rainfall telemeter station and data vacant area in sub-basins in the Chao Phraya River basin

Table 8 Deficiency of telemeter station in sub basins

Sub basin	Catchment area (Km^2)	RID			RID+TMD		
		Number of telemeters	Catchment area per one telemeter (Km^2)	Deficiency	Number of telemeters	Catchment area per one telemeter (Km^2)	Deficiency
Bhumipol dam	26,315	39	675	14	42	627	11
Kiew Lom dam	3,975	7	568	1	7	568	1
Wang downstream	6,885	12	574	2	15	459	0
Ping downstream	8,436	4	2,109	13	7	1,205	10
Yom upstream	5,612	5	1,122	7	5	1,122	7
Yom middle stream	12,194	13	938	12	15	813	10
Yom downstream	8,114	7	1,159	10	9	902	8
Srikit dam	13,119	0	-	27	4	3,280	23
Kwae Noi dam	4,254	0	-	9	0	-	9
Nan middle stream	7,580	4	1,895	12	5	1,516	11
Nan downstream	8,111	4	2,028	13	5	1,622	12
Pasak dam	12,929	14	924	12	18	718	8
Lower (ex. Pasak)	45,672	41	1,114	51	55	830	37

8.2.3 Issues

136. Water level standards and related matters were evaluated as follows.

(1) Definition of water level standard

Water level at which a flood starts (threshold between red and yellow zone) and water level for making warning (threshold between yellow and green zone) have two names, respectively. It would lead to confusion if the same water level as standard was defined and named differently.

(2) Early warning method was applied to the limited area

Only 8 stations are applying to the early warning method using water level correlation with upper adjacent station. Most of other stations haven't introduced such a warning method.

(3) Public announcement of possible inundation area is not enough

Possible inundation area wasn't examined or announced to the public, in most of cities. As the flood alert information, extent of flood and river water level should be correlated to possible inundation area. Water level standards might be reviewed after examining possible inundation area.

(4) Relationships between a certain water level and actions to be taken by residents or officials are not indicated

There is no indication of associations between water level standards and concrete actions to be taken by residents, local officials or flood defense. Moreover, water level standard doesn't indicate the time to take any action. It would be possible to mitigate flood damages by defining the actions to be taken associated with water level standards.

(5) Distance to station to be monitored in the early warning method

As illustrated in Table x-x, distance to upstream station to be monitored in the existing method vary considerably, flood arrival time has also wide variability, such as 4 – 24 hours. It would be required to find optimum distance by examining the actions necessary for residents, farmers, factories and flood defense agencies, and the time for taking and completing their actions.

(6) River flow status indicates just on a point of the station

It is not clear how far a river reach represented by an observation station is. People living in local area along a river, not in a city area nearby the station, cannot understand flow status correctly from color indication on a point.

(7) Vacancy of rainfall telemetering station

Based on the analysis for necessary density of rainfall telemetering station, there is still some data vacant area in the Chao Phraya River basin. To develop a flood forecasting system with high accuracy and high reliability for simulating flood and inundation, replacing the existing early warning method, the number of rainfall station is not enough at all.

(8) Information on the water level standard is much disorganized

At least, water level information on the web site is not organized well. Some old information can also be available for browsing on the web site, and user may not understand which would be the latest information.

8.2.4 Proposal

137. The following proposals were presented for further improving the water level standards and its setting used for a flood warning in Thailand.

(1) Redefinition and notification of warning level standard

- Water level standard indicating the start of a flood is called either Flood level or Critical level, and that for warning is called either Critical level or Warning level. To avoid confusion and to make them more understandable, water level standards should be redefined reflecting exact meaning and renamed corresponding to the definition. For example, the standard indicating the start of a flood could be Critical level as it represents the threshold of not flooding and flooding, and the standard for warning people could be literally Warning level.

- Warning level of each station has been determined according to minimum flow capacity of downstream of the Chao Phraya River. In some station, therefore, it doesn't represent the warning to the residents at that station. Correct meaning of Warning level should be explained to the general public, since it would resolve confusion which hinders people's understanding of the actual river flow situation.
- Warning level of each station should be related to the action to be taken by the residents and officials. In case the river flow reaches to the warning level, people may get alert for their preparation for measures to prevent damages.
- Correct installation of water gauge is required to notify flood warning to the general public. In some stations, paint on the gauge indicating normal, warning and critical (green, yellow and red) are not properly updated, in spite of the changes in standards.
- The most vulnerable point should be selected as the setting point for Critical level and Warning level. To cover all area along the river, color indication (green, yellow and red) of flow status in a river reach, not on a point, would be desirable.

(2) Utilization and extension of the existing early warning method indicated by the severity of a flood

- The existing early warning method based on correlation between two adjacent stations should be introduced for necessary stations according to their importance. At present, only 8 stations in upper basin use the method. Upstream station to be monitored should be selected according to the required time for flood measures and its preparation.
- Utilization of the early warning method should be informed widely to the general public. They need to know clearly which station is to be monitored and what level corresponds to the severity of flood at their area.
- In order to inform the relationship between inundation depth at specific places and the severity of a flood to the general public, inundation forecast map should be created and distributed. The map would be based on the past flood events or inundation simulation results. Moreover, signage or scale to indicate the past or expected inundation depth based on the map should be installed to notify throughout the city. Water Management Simulator will be useful to study inundation area and create such a map.

(3) Observation station upgrading

- The existing early warning method will be replaced by a flood forecasting system with high accuracy and reliability for simulating flood and inundation. In order to establish high performance forecasting system, rainfall telemetering station should be installed more at the necessary density.
- In the simulation of the Flood Risk Information System to forecast inundation risk in the central plain of Thailand, additional rainfall telemeter stations would be effective and given priority to the Yom river basin, Ping river downstream basin, Wang river downstream basin, and Nan river middle and downstream basin.
- In order to reduce data vacant area, integration of telemeter station among organizations (e.g., RID and TMD) would be effective.

138. Detailed report is attached in Attachment 09 "Water Level Standards".

8.3 Forecasting/Warning Issuance for Disaster Alleviation Actions

8.3.1 General

139. The flood forecasting and early warning system is one of the effective measures that would be helpful for the communities under flood risk. However, in order to improve and/or establish the effective flood forecasting and warning system, the problem and obstacle dealing with the flood forecasting and warning issuance during 2011 inundation should be examined. The actual situation of 2011 flood forecasting and warning processes was investigated, including the roles of various government authorities and local agencies. In addition, the expectation of community and factory in industrial estates was also summarized.

8.3.2 City Residents, Farmers, and Factories

140. It was found that before the flood reached the central part of the lower reach of the Chao Phraya River Basin most of the local agencies received the flood information from the national agencies, and they had made the warning to residents under their responsibility. Thus, most of the residents, both the farmers and city residents received the warning at least 1-2 days before the water reached their places. It seems that the local network, which included local agency and local people, played the main roles in flood information distribution and warning. While the communication between the upper and lower levels of local agencies had to be official format, among the local agencies and residents, the warning was in the pattern of verbal messages, by word of mouth or making a phone call. Moreover, the mass media had played the important roles in information distribution as well since TVs and radios are the appliance that widely used in almost every household.

141. While all of the factories from 7 industrial estate investigated got the verbal information from local entrepreneur network, they also received the warning from Industrial Estate Authority of Thailand (IEAT) and central authorities as well. It indicated the importance of this sector and how much the national authority paid attention to the investors. However, some of the respondents were confused with too much information from various sources. Thus, instead of taking alleviation action, some could not make decision how to deal with the situation.

142. Before the water reached their place, all target groups received the information of water level, the rain upstream and within their area, and some of the factories got the warning with the information of the expected time that they would be able to return to the factory. The residents seemed mostly satisfied with the information they received mentioning that the information was sufficient for making decision, but the respondents from factories seemed to expect more. While the farmers and city residents felt that the information was reliable and much useful, the factories mentioned that the reliability of the information was too low, less useful, and more than 60% of them felt not satisfy at all on the information they received.

143. The similar trend could be seen during the period that the flood was approaching their areas as well. Most of the farmers and city residents received the information from local authorities and the local people network, but there seemed to be some confusion and panic among the factories since some of the respondents from factory did not receive the inundation information. However, it might be caused by the unsatisfactory communication processes and the warning system.

144. Most of the factories indicated that the information was less reliable, less useful and not satisfactory. They expected much more accuracy of the warning system. Besides, they want to receive the suggestion of how to deal with the emergency situation as well.

145. After the inundation water level had been standing and no additional rainfall, the rainfall data became not so necessary; the factories wished to have the name list of contact persons or agencies to contact for assistance, which some of them did not get during the recovery period of 2011 inundation. However, during this period, the factories seemed more satisfied with the information they received than the other period of inundation. More than 88% of the respondents said that the information was sufficient; more than 50% mentioned that it was average to very reliable, and average to very useful. Actually, the increasing of satisfaction among the respondents from factories might be due to the relief of them after the worst situation had been passed and they did not expect any more assistance from any agencies.

146. According to the questionnaire survey result, the respondents felt that the flood forecasting and warning system was not very good, but the farmers and city residents felt that it was better than having nothing, and still useful when combined with other information they got from TVs, from friends or relatives who live in the upstream, and from the website such as Thai fight flood's website; https://www.facebook.com/ThaiFightFlood, etc. On the other hand, the factory respondents complained a lot on the flood forecasting and warning system. More than a half of them felt that the system is not god, not reliable and never been useful.

147. Respondents suggested improving the existing flood forecasting and warning system by increasing its accuracy, more advance notification before the water reaches, more frequency of information updating; i.e. more often than once a day, and changing the pattern of information into the graphs, animation and narration that can be easier to understand. Besides, they requested additional information such as the name list of the persons or agencies that they could ask for assistance, the amount and location of evacuation points, including the evacuation routes in case of emergency.

8.3.3 Local Agency and National Flood Defense Agency

148. Based on the questionnaire survey result and interviews, it seemed that the situation of 2011 inundation management was so confused. Various data came from various national agencies and most of them had been transferred to the provincial and district level organizations. It caused information duplication and sometimes caused the difficulty for local agencies in making instant decision as well.

149. The sequences of information transferring and flood monitoring could be summarized as shown in Fig. 14.

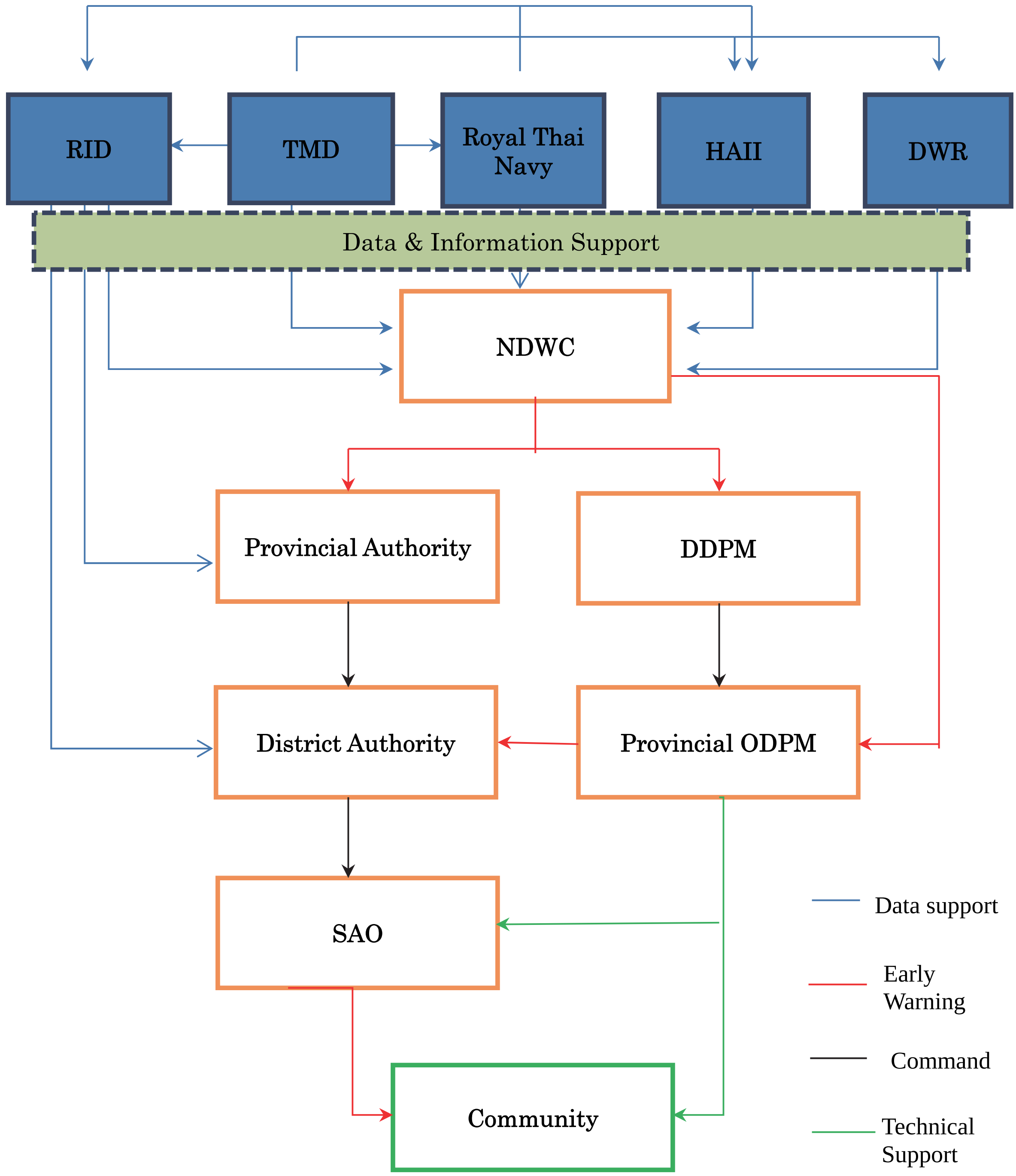

Fig. 14 Sequences of data transferring and flood monitoring, before the water approaches

150. After the situation became worse, the Emergency Operation Center had been established and later became to be a Flood Relief Operations Center (FROC), all water resources related organizations had to provide information, both the measured data and the forecast information, to FROC. Then the FROC committee made the decision of flood alleviation actions, including flood management measures. The sequences of information transferring and flood warning could be summarized as shown in Fig. 15.

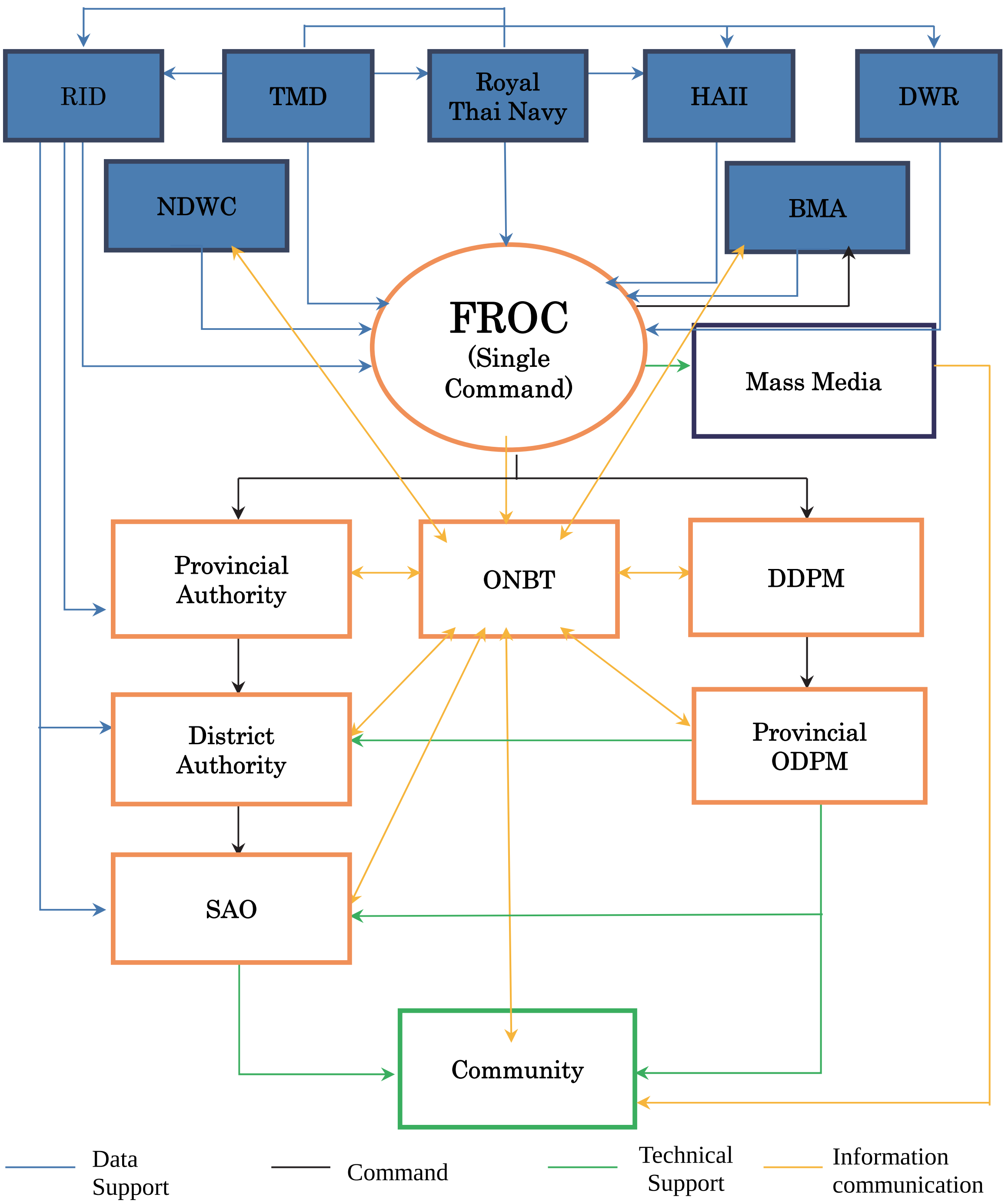

Fig. 15 Sequences of data transferring and flood warning, during the flood approaching

151. During the 2011 flood, there were several problems dealing with flood forecasting and warning issuance, and flood management, as follows:

- Flood management was intervened by many actors. It caused the miscarriage in flood management. DDPM administrator could not take the disaster handling action plan that was previously set up, thus it caused the confusion in making command. Moreover, since the Government did not accepted that the 2011 inundation was over level 3-crisis, but she announced that it was just level 2-crisis. Thus, level 2 –crisis's responsible agencies had to take their missions as designated in level 2-crisis handling action plan. It caused the delay in flood management and the international agency could not support or assist.
- The political considerations caused the distortion of flood situation information report. The people and flood victims did not get the real-situation information, thus they could not take any alleviation actions properly.
- At the beginning of flood, there was too much information from various agencies and from the people in the inundation area. Everyone who had smart phone became a situation reporter. It caused the confusion.
- Most of the water resources related national agencies, such as RID, NDWC, Royal Thai Navy, HAII had their telemetering stations and their own mathematical model for flood forecasting, thus different modeling result caused conflict and confusion.
- There were not well-organized database or integrated data archives historical data of flow and water level during the past big floods, thus the calibration and verification of the mathematical models could not be done. It caused errors in flood forecasting.
- National agency needed high accuracy mathematical model that could be used to predict the movement of water, both the water in waterways and the land overflow.
- Several agencies found the difficulty in making public understand the scientific numbers. It caused public ignorance of flood forecasting and warning messages.
- The difficulty in making official commands during the flood period caused the delay of local authority in taking actions and assisting the victims.
- The local authorities did not have "flood handling manual", which they could find how to deal with the inundation situations. Thus, it was rather hard for them, especially the area that never had flood experience, to make decision and take alleviation actions properly.
- During the 2011 flood crisis, various agencies were not promptly ready to handle the situation since it was lacking of equipment, budget and human resources.

8.3.4 Recommendations

152. The actual situation of 2011 flood forecasting and warning processes was investigated, including the roles of various government authorities and local agencies. There is possibility that the following issues may hamper proper execution of flood forecasting and warning in the future.

(1) Political consideration

(2) Apparatus problems, including the low accuracy of flood forecasting system due to:-
  - The lacking of historical data for mathematical model calibration,
  - The lacking of mathematical model for the prediction of water movement, both the water in waterways and the land overflow.
  - There were too many mathematical models that belong to various organizations such as RID, Royal Thai Navy, NDWC, HAII, etc. In the case that there were differences among results from agencies, it would cause conflict and much of confusion.

(3) Lack of personnel who can:-
   - process flood forecasting,
   - give suggestion on the emergency situation

(4) No flood handling manual and no disaster evacuation rehearsal, especially for the local authority.

(5) The people had no experience and no knowledge of how to deal with great flood.

(6) The budget problem

(7) The complexity of flood forecasting and warning authority.

153. In order to improve the existing flood forecasting and warning system, not only the accuracy of the system should be improved, but system management should also be set up properly, with the experienced personnel, without the interference from the outside actors. The experts or responsible agencies should be allowed to handle the situation and make decision.

154. Moreover, the natural disaster handling manual and the rehearsal are also necessary. It would convince the people how important is the disaster warning and evacuation process. Thus, in the future, whenever the warning is issued, the people will not be in panic, but understand how to deal with the situation appropriately.

155. Detailed report is attached in Attachment 10 "Flood Forecasting and Warning Issuance".

8.4 Benefit Analysis of Non-structural Countermeasures

8.4.1 General

156. Implementing flood forecasting and warning systems as well as other non-structural measures are vital to disaster management. In order to utilize flood forecasting and warning systems, etc., it is necessary to identify how much of an economic impact these measures will have.

157. Economic evaluation of flood forecasting system was made through the estimated amount of damage (direct) and loss (indirect such as suspended operations) incurred that would have been mitigated in the 2011 floods if flood forecasting and warning systems had been leveraged to make the most of the information disseminated.

158. Non-structural measures considered are the following:

(1) Flood forecasting and information dissemination: Flood forecasting and warning systems are used to estimate river water levels, the time rivers will start to overflow, areas prone to the risk of inundation, as well as inundation depths, and communicate all this information to government organizations and local residents.

(2) Mobile levees and sandbags: Mobile levees and sandbags are installed around various assets, based on information about estimated flood zones and inundation depths, to protect them from inundation.

(3) Waterstops: Waterstops are installed at the entrances of houses, based on information about estimated flood zones and inundation depths, to prevent them from becoming inundated.

159. The following procedure was used for estimating how non-structural measures would mitigate damage (refer to Fig. 16).

(1) Sort the amount of damage estimated by the World Bank and Thailand's Ministry of Finance by province and category (based on Thailand Flooding 2554 Rapid Assessment for Resilient Recovery and Reconstruction.)

(2) Sort information on moving of assets to a safe location during the 2011 floods.

(3) Based on the information sorted out in (2) above as well as Japanese standards and guidelines (Manual for Economic Analysis of Flood Control Measures, Guidelines for Flood Damage Index Analysis, etc.), determine the rate of damage that would be mitigated (estimated damage total divided by actual damage total) due to flood alerts that urge people to move assets to upper floors or other safe areas, and use waterstops, mobile levees and/or sandbags to prevent inundation.

(4) Obtain average maximum inundation depth for each province based on the resident survey.

(5) In provinces where the height of waterstops and mobile levees (set at 1.5 m based on case studies) was the same as or higher than the maximum inundation depth, assume that actual damage would be reduced at the damage reduction rate obtained in (3). In provinces where the height of waterstops and mobile levees was lower than the maximum inundation depth, assume that the damage to goods and assets that could be moved to upper floors or other safe areas would be zero. Also assume that damage to other assets would be the same as the actual damage (i.e. no effect).

(6) Use the steps described above to calculate the damage by category for each province. Regard the difference between the actual damage and the estimate as the amount of damage mitigation due to forecasting and warning systems.

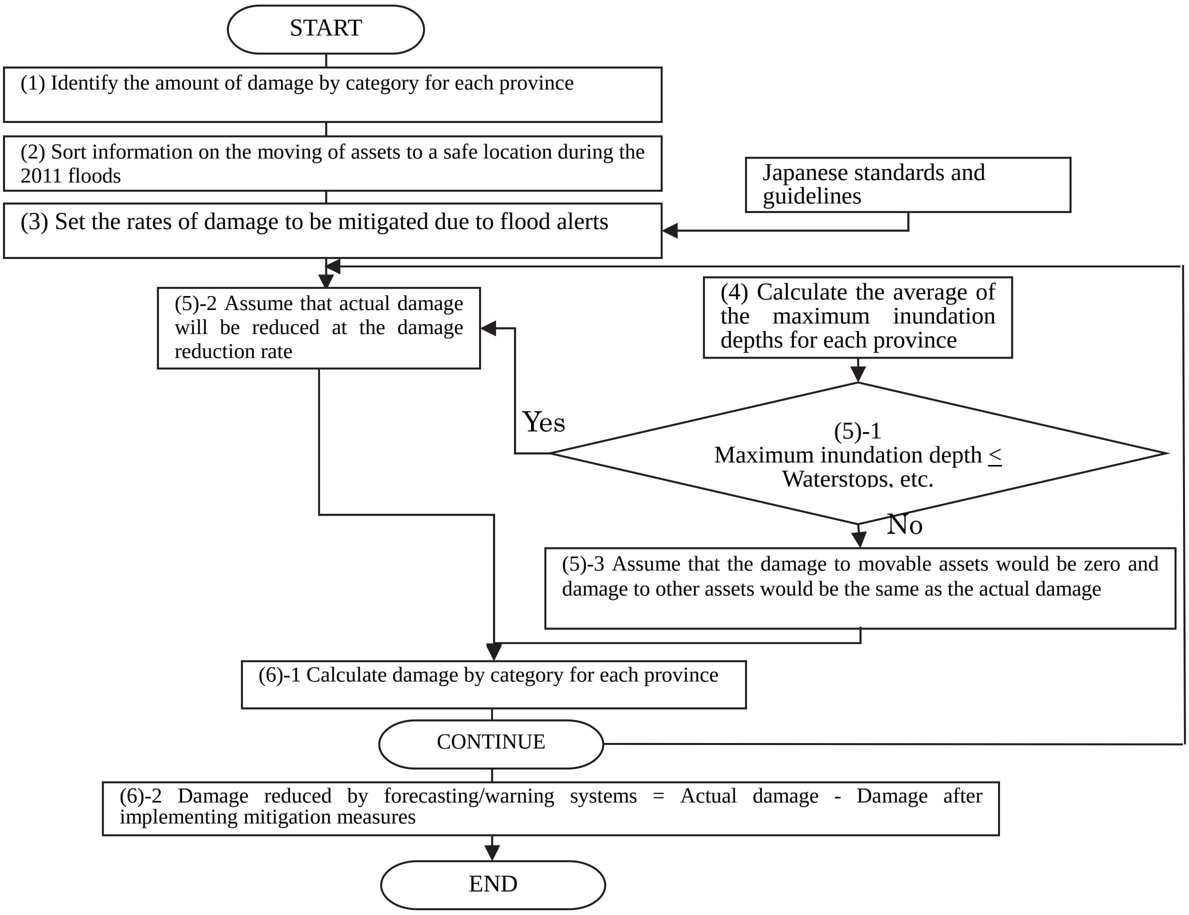

Fig. 16 Procedure of Damage Reduction Estimation

8.4.2 Comparison of Damage with and without Preventive Measures

160. Learning the estimated date and time of a flood's arrival via flood forecasting and warning systems will enable residents to protect their assets. They can prevent inundation by installing waterstops, mobile levees, and sandbags around their houses and other assets. Residents can also move their assets to upper floors or higher ground, or sell them before the flood arrives so they can prevent them from depreciating in value.

161. We regarded the difference between the estimated damage after implementing preventive measures and the actual damage as the amount of damage mitigated due to forecasting and warning systems. We estimated the amount of damage mitigated due to forecasting and warning systems for each sector as described below.

(1) Agriculture, Forestry, and Fisheries

162. In estimating damage to facilities and equipment (depreciable assets), we assumed that damage to equipment and buildings could be reduced by installing waterstops, mobile levees, and sandbags once people learned the estimated date and time of a flood's arrival via forecasting and warning systems. We assumed that it would be impossible to install mobile levees and sandbags around irrigation and drainage systems as well as plantations due to the expansive nature of these assets, so implementing such measures would not mitigate damage. The damage to facilities and

equipment (depreciable assets) is estimated to decline from 5,666 [million baht] to 4,414 [million baht].

163. When calculating losses related to products (inventory assets), we assumed that damage to products (crops, livestock, fishery products) can be reduced by moving them to upper floors or higher ground or by selling them after learning the estimated date and time of a flood's arrival via forecasting and warning systems. Whether or not products could be moved to upper floors or higher ground or sold was determined on the basis of the 2011 flood data. The losses to products (inventory assets) would decline from 34,715 [million baht] to 27,971 [million baht].

(2) Industry

164. In estimating damage to facilities and equipment (depreciable assets) and products (inventory assets), we assumed that damage to equipment and buildings could be reduced by installing waterstops, mobile levees, and sandbags after learning the estimated date and time of a flood's arrival via forecasting and warning systems. We assumed that damage to inventory assets as well as equipment and machinery could be reduced since they could be moved to upper floors or higher ground before a flood arrives. The damage to facilities and equipment (depreciable assets) and products (inventory assets) is estimated to decline from 513,881 [million baht] to 387,229 [million baht].

165. In estimating losses due to suspended operations, we assumed that losses could be reduced by installing waterstops, mobile levees, and sandbags since supplying products could be resumed once the floodwaters receded although expanding inundation would inevitably disrupt supply chains. The losses due to suspended operations can be reduced from 493,258 to 369,944 [million baht].

(3) Tourism

166. In estimating damage to depreciable assets including lodging, food services, and entertainment facilities, we assumed that damage to facilities and buildings could be reduced by installing waterstops, mobile levees, and sandbags after learning the estimated date and time of a flood's arrival via forecasting and warning systems. The damage to depreciable assets including lodging, food services, and entertainment facilities is estimated to decline from 5,134 [million baht] to 3,908 [million baht].

167. We assumed that there would be no difference in losses incurred due to suspended operations since expanding inundation would inevitably cut off supply chains and adversely affect customer traffic. The losses due to suspended operations would remain the same at 89,673 [million baht].

(4) Financial and Insurance

168. We assumed that damage to assets owned by banks, leasing companies, credit card companies, cooperatives, and insurance companies could be reduced by moving them to upper floors or installing waterstops, mobile levees, and sandbags after learning the estimated date and time of a flood's arrival via forecasting and warning systems. The damage to depreciable assets is estimated to decline from 943 [million baht] to 719 [million baht].

169. In estimating sales losses due to suspended operations, we assumed that operations could be continued by moving depreciable assets to upper floors and installing waterstops, mobile levees, and sandbags to prevent inundation. The sales losses are estimated to decline from 115,276 [million baht] to 87,922 [million baht].

(5) Flood Control, Drainage, and Irrigation

170. With regards to damage to flood control, drainage, and irrigation facilities, operators would not take preventive measures like moving assets to upper floors or installing waterstops, mobile levees, and sandbags in an attempt to maintain effective operations even after learning the estimated date and time of a flood's arrival via forecasting and warning systems. In light of this, we assumed that damage to these assets would be the same as the damage actually incurred (8,715 [million baht]).

(6) Water and Sanitation

171. Water and sanitation facilities cannot be protected by moving them to upper floors or by waterstops, mobile levees, and sandbags installed after their operators have learned the date and time of a flood's arrival via forecasting and warning systems. In light of this, we assumed that the water and sanitation sector would suffer the same damage (3,497 [million baht]) and sales losses (1,984 [million baht]) actually incurred.

(7) Roads and Transport

172. In estimating damage to the expansive infrastructure of expressways, major roads, and railroads, we assumed that no flood prevention measures would be taken even after learning the estimated date and time of a flood's arrival. It would be too difficult to install waterstops, mobile levees, and sandbags along the entire stretch of any of these structures. On the other hand, we assumed that damage to facilities with more limited boundaries, like truck terminals and airports, could be reduced by installing waterstops, mobile levees, and sandbags. The damage to the road and transport sector is estimated to decline from 23,538 [million baht] to 23,260 [million baht].

173. We assumed that losses due to suspended operations could be reduced because facilities whose boundaries were limited, such as truck terminals and airports, could continue to operate. Losses related to other infrastructure systems were estimated to be the same as the actual loss figures. The losses due to suspended operations are estimated to decline from 6,938 to 6,845 [million baht].

(8) Electricity

174. In estimating damage to expansive infrastructure systems like transmission facilities (towers and transmission lines), we assumed that no flood prevention measures would be taken even after learning the estimated date and time of a flood's arrival due to the difficulty of installing waterstops, mobile levees, and sandbags along the entire stretch of any one of these infrastructure systems. On the other hand, we assumed that damage to facilities whose boundaries were more limited, such as power generation and distribution facilities, could be reduced by installing waterstops, mobile levees, and sandbags. The damage to the electricity sector is estimated to decline from 3,186 [million baht] to 2,389 [million baht].

175. We assumed that losses due to suspended operations could be reduced because facilities whose boundaries were limited, such as power generation and distribution facilities, could

continue to operate. Losses related to other infrastructure systems were estimated to be the same as the actual loss figures. The losses due to suspended operations are estimated to decline from 5,716 to 4,810 [million baht].

(9) Telecommunications, Broadcasting, and Postal Services

176. We assumed that the landline communications sector could mitigate damage by installing waterstops, mobile levees, and sandbags to protect modular jacks and plugs used by households and businesses from inundation. We assumed that the cellular communications sector could mitigate damage by installing waterstops, mobile levees, and sandbags around base stations. We assumed that the broadcasting sector could mitigate damage by installing waterstops, mobile levees, and sandbags around base stations and relay broadcast stations. We assumed that the postal services sector could mitigate damage by installing waterstops, mobile levees, and sandbags to protect counter service facilities and buildings. The damage to the telecommunications, broadcasting, and postal services sector is estimated to decline from 1,290 [million baht] to 967 [million baht].

177. We assumed that losses due to suspended operations could be reduced since operations could be sustained by installing waterstops, mobile levees, and sandbags to protect the above-mentioned facilities and equipment from inundation. The losses due to suspended operations are estimated to decline from 2,015 to 1,511 [million baht].

(10) Health Care and Public Health (Hygiene)

178. According to the Guidelines for Flood Damage Index Analysis (draft, March 2013), floodwaters will reach floor level at a water depth of 0.5 m and power outages will occur at an inundation depth of 0.7 m due to submersion of electrical outlets. In light of this, we assumed that damage would incur the health care and public health sector 100% of the value of its assets in basements and on first floors once the inundation depth exceeded 1.0 m. The value of assets in basements and on first floors was assumed to be 0.50 of the total asset value. We also assumed that about half of the assets in basements and on first floors could be moved to upper floors. We also assumed that installing waterstops, mobile levees, and sandbags would mitigate flood damage. The damage to the health care and public health (hygiene) sector is estimated to decline from 1,684 [million baht] to 1,280 [million baht].

179. In estimating sales losses in the health care sector, we assumed that all facilities would lose power unless flood prevention measures were taken, so we set the sales loss rate at 100% even if assets in basements and on first floors were moved to upper floors. We assumed that the damage rate for health care facilities would be 50% if measures to prevent inundation were taken and power outages were avoided, so hospitalized patients would be protected. The losses due to suspended operations are estimated to decline from 2,133 to 1,600 [million baht].

(11) Housing and Household Goods

180. We used the damage rates provided in the Manual for Economic Analysis of Flood Control Measures (draft, April 2005) for the housing and household goods sector. We assumed that about half of assets in basements and on first floors could be moved to upper floors. We also assumed that installing waterstops, mobile levees, and sandbags would mitigate flood damage. The damage to the housing and household goods sector is estimated to decline from 45,908 [million baht] to 35,208 [million baht].

181. We assumed that losses in the housing and household goods sector would decline by up to 50% due to the fact that losses include evacuation and cleanup expenses and that neither evacuation nor cleanup would be necessary if inundation was prevented. The losses in the housing and household goods sector would decline from 37,892 [million baht] to 28,419 [million baht].

(12) Education

182. Damage to the education sector included buildings, equipment and supplies (textbooks, desks, chairs, blackboards, windows, doors, laboratory instruments, personal computers, etc.). We assumed that all these items, except for the buildings, could be moved to upper floors. Damage to buildings was assumed to be 0.5 of the total damage. We also assumed that installing waterstops, mobile levees, and sandbags would mitigate flood damage. The damage to the education sector is estimated to decline from 13,051 [million baht] to 6,525 [million baht].

183. The bulk of losses in the education sector arose from the interruption of operations since many schools were used as shelters for flood victims. Even if educational institutions had preventive measures in place that would successfully protect their assets from inundation, their facilities would be used as evacuation shelters anyway if the surrounding area flooded, forcing residents to evacuate. In light of this, we assumed that the damage rate would not change even if the assets were protected. The losses in the education sector would remain the same at 1,798 [million baht].

(13) Cultural and Natural Heritage

184. The only way to minimize damage to cultural heritage assets would be to use sandbags, waterstops, mobile levees, etc. that would protect historical heritage structures and sites from inundation or by moving museum exhibits to upper floors. Since not all museum exhibits can be moved to upper floors, we assumed the damage rate to be 0.5. We also assumed that installing waterstops, mobile levees, and sandbags would mitigate flood damage. As a result, damage to the cultural and natural heritage sector is estimated to decline from 4,432 [million baht] to 3,322 [million baht].

185. A large part of the cultural heritage asset losses consisted of expenses incurred for moving culturally valuable articles within the same building, and revenue losses due to temporary suspension of operations and cancellation of events. We assumed that the damage rate would not change for intangible cultural heritage assets because scheduled events would have to be canceled anyway once the surrounding area flooded regardless of whether or not performers could safely evacuate. The damage rate for natural heritage assets is also assumed to remain the same since there is no way to protect them from inundation. The losses in the cultural and natural heritage sector would decline from 3,076 [million baht] to 2,923 [million baht].

(14) Natural Environment and Waste Management

186. Damage to the natural environment and waste management sector mainly included damage to waste disposal facilities and equipment as well as destruction of biodiversity conservation-related assets (roads, offices, wildlife and plants). The only way to minimize damage to these assets would be by using sandbags, waterstops, mobile levees, etc. to protect waste disposal facilities and equipment from inundation. In light of this, we assumed that

installing waterstops, mobile levees, and sandbags would mitigate flood damage. The damage is estimated to decline from 375 [million baht] to 285 [million baht].

187. Losses in the natural environment and waste management sector came from increased expenses for transporting waste to other waste disposal facilities after flooding impaired the operational capacity of waste management facilities and damaged the waste management infrastructure. In light of this, we assumed that installing waterstops, mobile levees, and sandbags would mitigate flood damage. The losses in the natural environment and waste management sector would decline from 176 [million baht] to 148 [million baht].

188. The table below shows damage and loss estimated for 2011 flood with and without implementing preventive measures for all sectors.

Table 9 Damage and Loss with and without Implementing Preventive Measures (2011 Flood)

Sector	Damage [million baht]		Losses [million baht]	
	Without implementing measures	With implementing measures	Without implementing measures	With implementing measures
Agriculture, forestry, and fisheries	5,666	4,414	34,715	27,971
Industry	513,881	387,229	493,258	369,944
Tourism	5,134	3,908	89,673	89,673
Financial and insurance	943	719	115,276	87,922
Flood control, drainage, and irrigation	8,715	8,715	N/A	N/A
Water and sanitation	3,497	3,497	1,984	1,984
Roads and transport	23,538	23,260	6,938	6,845
Electricity	3,186	2,389	5,716	4,810
Telecomm., broadcasting, and postal services	1,290	967	2,015	1,511
Health care and public health (hygiene)	1,684	1,280	2,133	1,600
Housing and household goods	45,908	35,208	37,892	28,419
Education	13,051	6,525	1,798	1,799
Cultural and natural heritage	4,432	3,322	3,076	2,923
Natural environment and waste management	375	285	176	148
Total	631,299	481,717	794,650	625,550
Damage mitigation rate	100%	76%	100%	79%

189. Mobilization on mobile levees, sand bags, and water stop based on flood forecast is

assumed as non-structural measures.

- The damage of the 2011 flood is estimated to be 631 billion Baht. The damage could be reduced to be 482 billion Baht with non-structural measures.
- The loss of the 2011 flood is estimated to be 795 billion Baht. The loss could be reduced to be 626 billion Baht with non-structural measures.

190. Detailed report is attached in Attachment 11 “Benefit Analysis of Non-structural Countermeasures”.

IX. TRAINING

191. Training in Japan was conducted in December 2012 as one of the project activities with the following major objectives:

(1) To acquire extensive knowledge on disaster management through watching, hearing and experiencing the efforts in Japan and to compare with and consider the disaster management in Thailand for improvement of disaster management activities in Thailand.
(2) To exchange knowledge with the people in charge of disaster management in Japan.
(3) To enhance information sharing and strengthen human network among participants.
(4) To prepare action plans to improve disaster management activities by employing the knowledge acquired through the training.

192. Trainees were from RID (5), DWR (4), and HAII (1). The schedule of the training is indicated below.

	Date	**Main Program**
1	Dec. 3 (Mon)	Leave Bangkok to Narita International Airport
2	Dec. 4 (Tue).	Briefing Session by JICA
3	Dec. 5 (Wed)	Orientation
4	Dec. 6 (Thu)	Courtesy call to DG, Water and Disaster Management Bureau Flood control in Japan (overview), Provision of river information How to provide river information(FRICS)
5	Dec. 7 (Fri)	Weather observation (JMA) River information and action (FRICS)
6	Dec. 8 (Sat)	Self study
7	Dec. 9 (Sun)	Self study
8	Dec. 10 (Mon)	Information collection & delivery at the Tsunami-stricken area (Ishinomaki City)
9	Dec. 11 (Tue)	Information collection & delivery at the Tsunami-stricken area (Tohoku RCB)
10	Dec. 12 (Wed)	Visit experiment laboratories (PWRI, NILIM) Flood Risk Management (ICHARM)
11	Dec. 13 (Thu)	Remote Sensing (Geospatial Information Authority of Japan)
12	Dec. 14(Fri)	Flood control facility in urban area (Edogawa River Office) Disaster prevention system of the Kanto Regional Development Bureau
13	Dec. 15 (Sat)	Self study
14	Dec. 16 (Sun)	Self study
15	Dec. 17 (Mon)	Use of river information (river administrator) (Koto, Tokyo) Remote sensing (JAXA)
16	Dec. 18 (Tue)	Use of river information (public bodies) (Edogawa City Office) Use of river information (river administrator) (Arakawa -Karyu River Office)
17	Dec. 19 (Wed)	Use of river information (telecommunications carrier) (NTT) Use of river information (mass media) (NHK) Summary of the training (FRICS)
18	Dec. 20 (Tue)	Preparation for the reporting session Reporting session
19	Dec. 21 (Fri)	Departure

193. The list of trainees, hand-outs and other materials used in the training is attached as Attachment 12 “Training in Japan”.

X. REPORTING

194. Following reports were prepared and submitted:

Reports	Time of Submission	Remarks
Inception Report	July 2012	
Progress Report 1	August 2012	
Urgent Activities Action Plan Report	October 2012	
Progress Report 2	December 2012	
Basic Plan Report	January 2013	Thai, English
Flood Data Analysis System Report	August 2013	Thai
Draft Final Report	October 2013	
Final Report	October 2013	