Risk management and emergency response for a 300 km^2 sub-sea level area with a million citizens against extreme storm surge and flood due to the "Super Ise-Bay Typhoon"

T. Tsujimoto[1], M. Igarashi[2] & K. Kobayashi[2]
[1]*Department of Civil Engineering, Nagoya University, Japan*
[2]*Chubu Regional Bureau,*
Ministry of Land, Infrastructure, Transport and Tourism, Japan

Abstract

There is a land of 300 km^2 lower than sea level with a million citizens facing Ise-bay in the central part of Japan, which is located on a possible route of typhoons and is exposed to a risk of serious storm surge and flood. This area was attacked by storm surge by "Ise-bay Typhoon" in 1959 and more than 5,000 people were killed. In spite of a protection infrastructure constructed in this half decade after the event, recent climate change may cause extreme typhoons exceeding the level of protection and response, and resilience against such an enormous disaster has not yet been prepared. We have made efforts to prepare an action plan of risk management and emergency response since 2005. Once an extreme storm surge breaks the protection infrastructure, a wide area will be inundated with various risks and drainage from there will take a long time. Meanwhile, with recent progress in weather forecasting of magnitude and course of big typhoons, we may have a lead time of 36 hrs. We introduce 4 phases: Risk management before typhoon arrival (Phase 0), emergency response within 0–72 hrs (Phase I) and successive stages (Phases II and III). In particular, we study how to make a wide preliminary evacuation possible with proper operation in Phase 0. We have organized a working group to support the authority including all the stakeholders related to disaster mitigation to make an action plan of risk management and emergency response.
Keywords: typhoon, storm surge, catastrophe management, risk management, emergency response.

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1 Introduction

There is a land of 300 km^2 lower than sea level facing the Ise-bay in central Japan. This area includes a part of Nagoya Metropolis whose population is more than 2 million, and has developed as an industrial centre with high economic activity. On the other hand, this area is located on a possible route of typhoons and major rivers neighbouring this area cause huge flooding from mountain areas.

This area was attacked by a serious storm surge due to a typhoon (Ise-bay typhoon, “Vera”) in 1959, and 500 km^2 was flooded for a few months. More than 5,000 people were killed and the daily lives of a large number of citizens were affected for a long time [1, 2]. Within around a half decade after this event, we have completed protection infrastructures against that level of storm surge and floods due to typhoons.

However, the level of typhoon may exceed the protection level because of probabilistic phenomena, and recent climate change may cause such a super-class typhoon. At the news of serious flooding of New Orleans by Hurricane Katrina in 2005 [3], we learned of the emergency response there [4] and we started to discuss risk and emergency management for the Ise-bay area. The situation of this area such as the route of a typhoon and geographical characteristics can cause high storm surge. There is a wide land below sea level with a million citizens, and the large number of human activities is very similar to New Orleans. Moreover, not only the area facing Ise-bay but areas facing Tokyo-bay and Osaka-bay are in the same situation. In other words, 3 major metropolises, Tokyo, Osaka and Nagoya, have similar risks of wide and long term flooding due to storm surge to threaten a large number of lives and human activities. Certainly the protection infrastructure has been accomplished during this half decades, but catastrophic disaster may be estimated once a super typhoon exceeding the level of our present protection level attacks those areas. We have not prepared an appropriate risk management and emergency response plan.

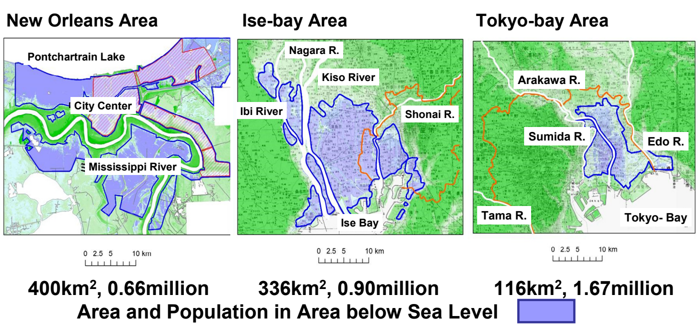

Figure 1: Comparisons of some bay areas below sea level.

Just after the event of Hurricane Katrina in 2005, we started to prepare a response plan against a super typhoon. We postulated “super Ise-bay typhoon” as a possible maximum typhoon to case the worst storm surge in the Ise-bay, and based on a scenario of this “super Ise-bay typhoon”, we started to discuss an action plan against it. At first, we organized an authority named “Tokai Nederland Regional Authority against Storm Surge and Flood” [5]. Various stakeholders related to disaster mitigation of this area such as regional and local governments, police, self-defence forces, Red Cross, water supply and sewage, telecommunications, energy (electric and gas services) public transport, mass media, and so on have joined as members of this “TNT authority”. We have a system that heads of the respective organizations agree to the output of this system [5]. In the process of making up an action plan (risk management and emergency response), a working group was organized, and a plan has been made and revised through extensive discussions and desktop exercises (DIG). In the working group, parallel sessions for different functions for disaster mitigation or different viewpoints have been prepared and driven by facilitators from academia for each session, and a plenary session discusses the output from parallel sessions to reach a tentative conclusion [6].

The case of a super-typhoon, which will attack this area with a very intensive magnitude, can be predicted 36 hrs before its arrival. So, we postulate a response of the action against the super typhoon at that time, and we divide phases as follows [5–7]:

Phase 0 = 36 hrs before typhoon arrival;
Phase I = 72 hrs after typhoon arrival;
Phase II = 4th day–2nd week,
Phase III = ~1 month.

The main functions for disaster mitigation required for the respective phases are: wide-area preliminary evacuation in Phase 0; rescue in Phase I; closure of levee or dike, drainage from flooded area and elimination of obstacles on routes of rescue and repair in Phase I–II; providing shelters, urgent recovery of life lines (water, energy, access, telecom) in Phase II–III. Then, various restoration programs will continue. Among some phases, Phase 0, risk management before a disaster happens is characteristic in a storm surge and flood disaster due to a super typhoon. In this phase we have no disaster-control headquarters though we officially have “emergency response headquarters” after a serious disaster happens. Most of the emergency responses after a disaster happens are common among various types of disasters, though urgent closure of levees and drainage operations are important in the case of flood disasters. Other emergency support functions cannot be realized after Phase I without the closure of levees and drainage.

2 Postulated wide area inundation due to super Ise-bay typhoon

We postulated about a “super Ise-bay typhoon”, which is assumed to be 910 HP in magnitude (the same as the Muroto typhoon in 1934 and the most intensive record in Japan) and travels on a route that will cause the severest storm surge on the Ise-bay. The time path of this typhoon is shown in Figure 2 [5].

Because risky points of coastal levee breach can be estimated based on the numerical calculation of storm surge (rising of sea level due to astronomic tide, lift up by pressure drop and waves), levee breaches are assumed there. In addition, heavy rainfall with return period of 1,000 years is postulated. Then, we assumed river levee breaches at several places along class A rivers. Such assumptions are practically familiar in making a “flood hazard map” [5]. Figure 3 shows the flooded area [5] which is around 500 km^2 (520 km^2 with only 202 km^2 caused by storm surge), and almost equal to the actual flooded area on

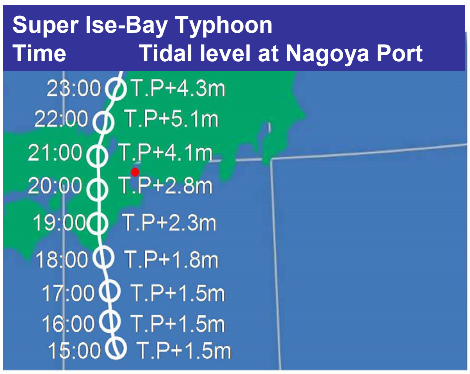

Figure 2: Time path of “super Ise-bay typhoon”.

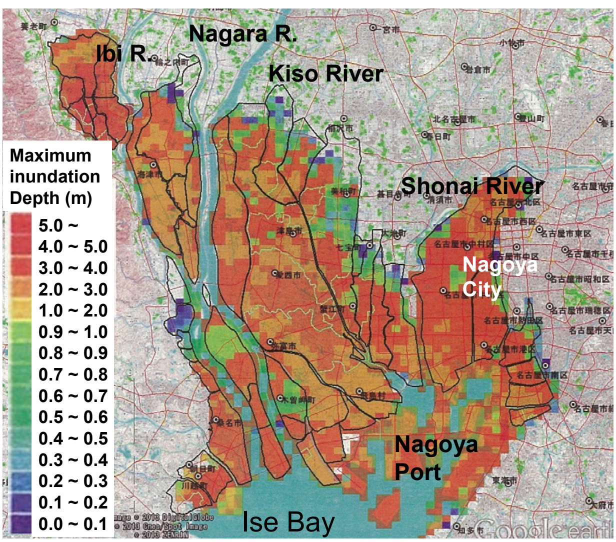

Figure 3: Inundation due to “super Ise-bay typhoon”.

the occasion of an Ise-bay Typhoon in 1959 (531 km^2 with only 310 km^2 caused by storm surge). In Figure 3, the grey-scale presentation cannot show a detailed spatial distribution of maximum flood depth but from the legend of the figure one can recognize the range of maximum flood depths and the resolution of the simulation.

In this scenario, overflow due to storm surge begins 18:00, and the tidal level shows the maximum at 22:00, while the levee breaches along rivers due to flooding happens after 01:00 of the next day. On the other hand, storm with stronger wind than 20 m/s begins at 18:00 [5].

3 Recognition of risk in Phase 0

This type of disaster is characterized by wide-area flooding which continues for a long time. It expands to around 500 km^2 expanding to the three prefectures and including many communities (cities and towns). Against ordinary disasters, evacuation is completed within communities and hence communities and their heads are responsible for evacuation by issuing commands and preparing shelters. However, against catastrophic floods discussed in this paper, we have to face the problems of boundaries of communities. For example, few shelters are available in flooded communities. Evacuation must be carried out over the community boundaries.

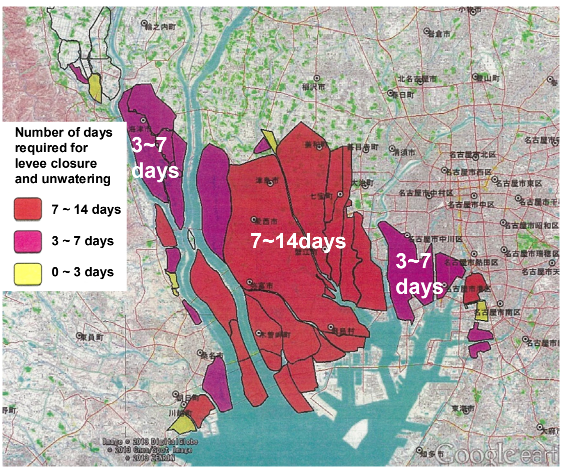

Figure 4: Period required for drainage.

Once the levees are broken, a wide area is flooded and immediately the levees should be closed and drainage efforts are required in Phase I. Closure of levee breaches and drainage have several technical problems (district division and arranging pumping vehicles), but we roughly calculated the necessary terms of drainage for individual districts, as shown in Figure 4 [8]. Some areas may remain flooded for a few weeks and during this period people cannot live their daily lives. Considering that the tasks to be done in Phases I and II are many, there is less possibility to support life in such a flooded area. Thus, preliminary evacuation from the area expected to be exposed to severe flooding is strongly recommended and it should be achieved before the disaster happens. That is "preliminary evacuation in a wide area" (over communities). If a disaster happens, people staying in refuges inside the seriously flooded area must move to the shelters in the dry areas because they cannot continue their daily lives without lifeline services there (secondary evacuation), and they need special transportation in the flooded areas.

The numbers of evacuees of respective cities or towns (or wards of Nagoya city) who have no shelters within their communities were surveyed and the results are shown in Figure 5 [5–7], where several neighbouring communities are grouped as one block. The most important emergency support function of Phase 0 is preliminary evacuation to a safe area (where flooding is not predicted) and the evacuation destination must be different communities and such evacuation necessitates a long journey.

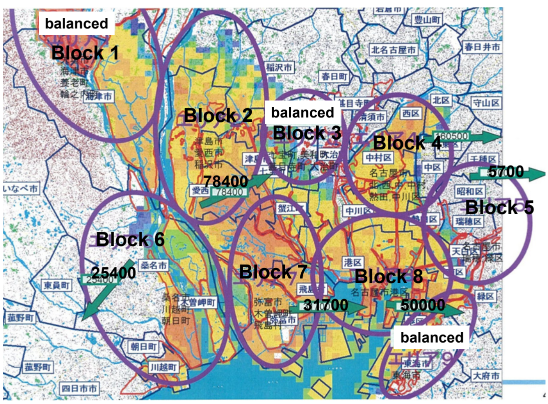

Figure 5: Numbers of wide-area evacuees.

Recent development of weather forecasting techniques can tell us with high probability the attack of a super typhoon with an extremely strong magnitude 36 hrs before its arrival. Forecasting will be improved during the time that the typhoon approaches, but the difficulties increase in the long-journey of evacuation of many people within a limited time [6, 7].

Phase 0 is divided into several stages as follows and related to the "storm surge warning level", which will be issued from the meteorological service as shown in Figure 6 [5]:

Stage 0: 36–24 hrs before landing;
Stage 1: 24–12 hrs before landing (storm surge warning leve1 1);
Stage 2: 12–9 hrs before landing (storm surge warning leve1 2);
Stage 3: 9–6 hrs before landing (storm surge warning leve1 3);
Stage 4: 6–0 hr before landing (storm surge warning leve1 4).

Usually, each warning level corresponds to each action for evacuation guidance as follows:

Level 1: Recommendation of voluntary evacuation;
Level 2: Evacuation completed for handicapped persons;
Level 3: Issue of evacuation advisory by community head;
Level 4: Issue of evacuation order by community head.

However, in this case of a catastrophic typhoon, since evacuation requires long travelling distances and time, the above guideline is not available or it may be too late.

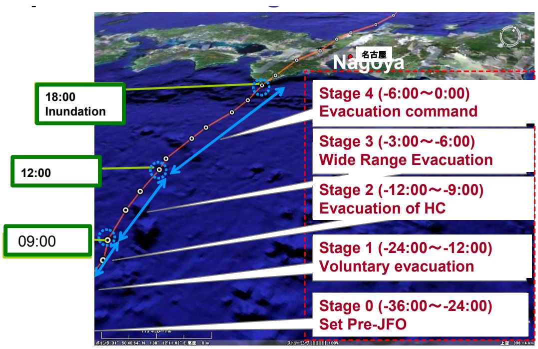

Figure 6: Stages in Phase 0 for super Ise-bay typhoon.

4 Preliminary evacuation in wide area

As mentioned in the preceding chapter, the most important issue in Phase 0 is how to achieve preliminary evacuation in wide area with long travelling distances and time. By considering the numbers of evacuees of various districts shown in Figure 5, the evacuation direction of each district is indicated [5]. Though evacuees may select their own shelters (direction and route in evacuation) in “voluntary evacuation”, somehow controlled evacuation becomes necessary after the evacuation advisory is issued, otherwise many evacuees cannot be saved during the limited time and with limited shelters. For the time being, Figure 5 shows organized evacuation in one of the possible plans. If such large scale evacuation is realized, it requires agreements between communities of origin and the destination of the evacuation.

Such evacuations with large numbers of evacuees and long distance within the limited time require some kind of mass transportation. In the case of ordinary evacuation, the means of transportation should be limited to pedestrian (walking) in Japan, but in this case the evacuation distance is too far. Automobiles, buses (arranged and hired by communities) and trains are taken into account. In order to realize the plan, respective agreements between transportation companies and communities are necessary. We investigated the time required for evacuation completion for each community (from the center of the origin community to the center of the destination communities) for several sets of combinations of cars, buses and trains. The capacity and travelling time on the main routes such as highways and national roads to connect origin and destination communities are investigated for transportation by cars and buses. The statistics of railroad companies are taken into account in the calculations for transportation by train.

Three cases of combinations are tested:

Case 1: cars (70%), buses (10%), trains (20%);
Case 2: cars (40%), buses (40%), trains (20%);
Case 3: cars (10%), buses (40%), trains (50%).

The results are summarized in Table 1, where the required time for completion of evacuation is balanced with the number of evacuees from the origin block and capacity of destination community. Table 1 suggests that there is an unbalance between numbers of evacuees and capacities for respective communities (as a total the capacity is less than the number of evacuees) and that the advantages in the required time for evacuation change depend on the cases (combinations of transportation means are different from one another).

Though no detailed names of communities are indicated in Table 1, Nagoya city lacks the capacity of shelters and most citizens and the ward governors consider that taller buildings may become refuges. However, once the area is flooded, it might be quite difficult to support daily life there. People should know that their daily lives depend on various lifelines, which are at risk of damage and require a long time for their repairs. On the other hand, in the Nagoya city area, if evacuees change their evacuation means from cars to trains, the required time for evacuation can be efficiently reduced. Bus transportation is most efficient for some other communities. Evacuation by individual cars requires a long time though many inhabitants would use their own cars because buses and trains are not a convenience in their daily lives.

Table 1: Required time of preliminary evacuation: case study of transportation means, combination among car, bus and train.

Block	O-community	No.of evacuee	Capacity of shelter (D-Community)	Time for Evacuation (hrs) Case 1	Case 2	Case 3
2	A	79,400	70,900	40	24	41
	B			50	30	35
4a	C	53,300	59,300	5	3	3
	D			27	16	7
4b	E	57,000	51,700	28	17	42
	F			6	4	2
4c	G	160,800	58,400	13	8	10
	H			41	25	8
5	I			22	13	5
8	J			50	30	9
7a	K			15	9	11
	L			3	2	1.5
6	M	26,100	37,100	25	15	11
	N			7	5	2
7c	O			1.3	1.2	1.1

It is necessary to educate citizens to use mass transportation under such emergency conditions. In addition, it may be possible to control main roads more efficiently for one-way directed evacuation (contra-flow). However, this area is on the centre of east-west main route for all kinds of transportation and difficult to control without strong rules particularly for early preliminary evacuation.

Furthermore, we can recognize the differences of difficulties in preliminary evacuation among communities, and depending on such conditions respective strategies should be investigated.

5 Headquarters for risk management for super typhoon

Once a disaster happens, headquarters for disaster control with its field operation office is set up and they collect information, make a repair and restoration program and manage various emergency support functions. In other words, disaster mitigation actions after Phase I are controlled and managed by the headquarters.

In the case of catastrophic disaster due to a super typhoon, we can have 36 hrs lead time for preparation against estimated serious flooding based on the recent advancement of meteorological forecasting of typhoons. The most effective action to reduce disaster is a preliminary evacuation of a few hundred thousand inhabitants to dry area far from the community of origin. As discussed in the preceding chapters, without any control and support, the necessary evacuation cannot be achieved [6, 7]. Furthermore, in order to make a wide evacuation possible, the agreements with destination communities and perhaps bus-companies should be set up by the communities of origin for evacuation. Even if such agreements exist, some trouble caused by multiple bookings will happen because of the wide scale disaster by a super typhoon. On the other hand, some agreements cannot be realized because people are afraid such troubles may be realized.

In this study, we propose to organize headquarters for risk management in Phase 0 for information sharing, in particular among communities, disaster mitigation organizations and other stakeholders (see Figure 7). Through information sharing, strategies should be decided and improved over time [6, 7]. Fundamental time lines of functions to be carried out by respective organizations must be preliminarily planned, but they should be adjusted with some modifications by considering the imbalance of resources among stakeholders on the real case. And the headquarters will become a centre of information sharing and will recognize modifications of time lines of respective organizations to advise them of a possible adjustment of resources. Actually, the headquarters organized after a disaster happens play a role of such adjustment among organizations and stakeholders related to the imbalance of resources for disaster mitigation (repair, restoration and supporting victims). What this study would demonstrate is as follows: Such headquarters in Phase 0 have not yet been proposed in Japan, but as mentioned above, there are many issues to be settled before a disaster happens if risk management is considered for a super typhoon.

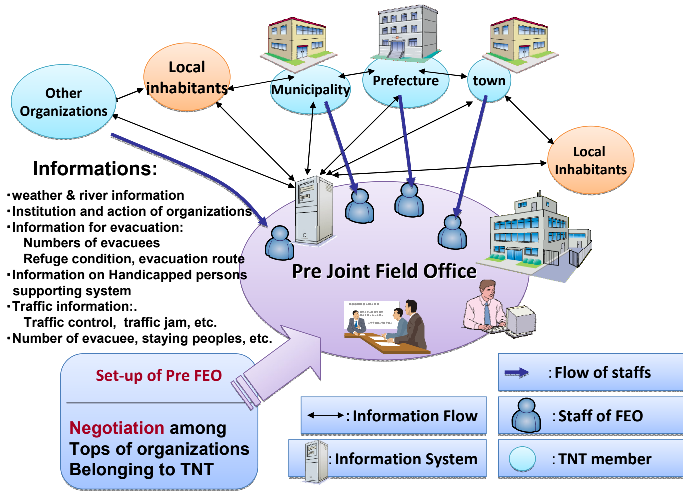

Figure 7: Image of joint field office (headquarters) in Phase 0.

Furthermore, such headquarters will smoothly continue to operate in disaster control after a disaster happens.

Headquarters in Phase 0 might be organized step by step. As soon as the weather forecast proclaims that a possible major typhoon may attack the target area, the river manager and meteorological service will set up a centre for information sharing (Stage 0 in Chapter 3, 36–24 hrs before the arrival of the typhoon). The 36 hrs before typhoon arrival must be a trigger to organize such a preliminary form of headquarters. From these headquarters, various information will be distributed to the members of the final headquarters. In stage 1 (24–12 hrs before arrival), communities that are expected to be flooded will produce preliminary evacuation plans with certificates of the agreements to support them and headquarters will check necessary and/or possible arrangements. The preliminary evacuation plan has to be performed immediately in this stage. In stages 2 and 3 (12–6 hrs before arrival), the progress of preliminary evacuation will be checked and necessary support will be arranged. In stage 4 (6–0 hrs), the remaining functions should be checked and dangers of evacuation during the approach of the typhoon should be assessed to prepare for a change of strategy (wide-area evacuation to emergency evacuation to the nearest refuges). In the tasks involved in the above, information sharing and possible necessary arrangements are required and headquarters should show the initiative.

Furthermore, headquarters organized before a disaster happens can be smoothly followed by the headquarters after a disaster happens (Phase I).

6 Continued functions in Phase I

After the super typhoon has landed, preliminary evacuation in a wide area becomes impossible because of violent storms (wind and rainfall, and flooding due to storm surge). The strategy should be changed to action to save lives. The remaining inhabitants in the areas where serious flooding is expected should evacuate to the nearest temporary refuges, such as high buildings. Communities should prepare some preliminary agreements with building owners for emergency refuges. However, if one understands that a super typhoon brings long term flooding, the efforts to support daily lives there must be difficult because of the failure of lifelines. Secondary evacuation from flooded areas requires several techniques, and thus, preliminary evacuation is recommended as a total system. However, actually perfect preliminary evacuation is extremely difficult (some inhabitants will not evacuate in spite of evacuation advice and remain where they are), and an appropriate separation between emergency evacuation and preliminary evacuation as an actual action plan is a sensible issue.

In the case of serious flooding in a land below sea level, which is caused not only by a typhoon but also is caused by a tsunami after an earthquake, necessary emergency support functions in Phase I are clearly distinguished from those against disasters without flooding. First, closure of levee breaches and then drainage are the most important tasks. Without these closures and drainage, rescue activities cannot be made successfully although helicopters and boats will help.

7 Concluding remarks

The area facing the Ise-bay is a low land more than 300 km^2 below sea level and exposed to a risk of flooding by storm surge and floods due to super typhoons. We postulated the “super Ise-bay typhoon” as a possible maximum one, and discussed risk management and emergency response in this paper. From the view point of emergency management against flooding of wide areas with failures of lifelines, preliminary evacuation in a wide area was investigated as the key in a risk management action plan. In this area, a few hundred thousand citizens are considered as evacuees who must travel long distances within a day. Without a plan and means for controlled evacuation, they cannot succeed. In this paper, some model of the combination of transportation means was investigated by using simulation. The numbers of evacuees and capacity of shelters are not balanced, and depending on conditions of the respective communities the appropriate combination of transportation means for evacuation are different from one another. It is one of the difficulties in this problem but conversely this point may give us a key to find an appropriate action plan. Furthermore, we have proposed headquarters for information sharing and arrangements of resources among different stakeholders, and it is expected to smoothly continue with headquarters for disaster control after the disaster happens.

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