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ORIGINAL ARTICLE

Climate Change Adaptation Policy Making According to the Philosophy of Disaster Prevention

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***Abstract*:** Cities in Japan have large disaster risks, and therefore flood control countermeasures as climate change adaptation policies are important. The Japanese government has experienced the Great East Japan Earthquake and large flood disaster has greatly changed policies of flood control. In this paper, we look at changes in these disaster prevention policies. Next, it turned out that there was a problem to realize the new policy. The reason why it does not lead to concrete policies is that it is difficult to quantitatively predict climate change, and it is difficult to revise plans and build new infrastructure according to climate change projection. And in parallel with climate change prediction, disaster prevention with possible maximum rainfall in the area was decided. However, it is difficult to respond to disasters that are significantly different from the conventional scale. On that basis, we proposed ideas on disaster prevention required for local governments and conducted risk assessment in actual river basin with hydrological model. As a result, we found that there is a risk of damage that can not be dealt with by conventional assumption.

Keywords: flood prevention, hydrological model, climate change.

1. Introduction

1.1.Background

The most important problem for the today's civilized society is climate change. It is essential to both mitigate and adapt to the climate change. Disaster prevention as a mitigation policy is of great significance for the society.

Measures such as greenhouse gas reduction are being adopted worldwide to mitigate climate change. However, the climate change adaptation policies are still under development because they should be based on the impact assessment and considering countermeasures for each region and task

In assessing the impact of climate change on health and agriculture, the relationship between rise in temperature and its effect is relatively clear. In these fields, there is a linear relationship between the rise in temperature and its influence. Or the influence can be seen when the temperature rises above a certain threshold value.

However, in the field of water-related disasters, the relationship between rise in temperature and rainfall is complicated, therefore it is difficult to predict the

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rainfall phenomena. The climate change projection model is not sufficient for the risk assessment of water-related disasters considering the temporal spatial resolution and uncertainty of the model.

Particularly, in Japan, which is vulnerable to flood damage, a disaster prevention policy as a climate change adaptation policy is essential but it is difficult to realize such a policy.

1.2 Objectives

In this research, we organized the changes in tasks and policies to realize a disaster prevention policy as a part of climate change adaptation measures. Thus, we proposed a new disaster prevention policy. We conducted a simulation in Kochi City confirmed the feasibility of these measures.

2. Changes in Japan's flood disaster prevention policy

2.1 Responding to increasing flood damage

The Ministry of Construction pointed out that the number of flood victims decreased owing to the embankment and dam development by the 2000s(Figure1). However, the risk of flood in urban areas has become obvious, considering events such as the flooding in an underground shopping mall in Fukuoka flood in 1999 and the flood in Nagoya City area in 2000.

The analysis done on the basis of those floods indicate that in addition to hardware-oriented measures, soft measures such as information transmission and evacuation guidance are essential.

In 2001, the Flood Control Act was revised, the hazard maps for large rivers were published, and 4 years later, the hazard maps for small and medium rivers were published.

2.2 Responding to the water disaster prevention as a mitigation policy

In recent years, the Japanese government and the Ministry of Land, Infrastructure and Transport (MLIT) have focused on the prevention of water-related disaster as a mitigation policy.

In 2007, the subcommittee on climate change adaptation for flood control was set up in the river sector committee of the Panel on Infrastructure Development of MLIT. The

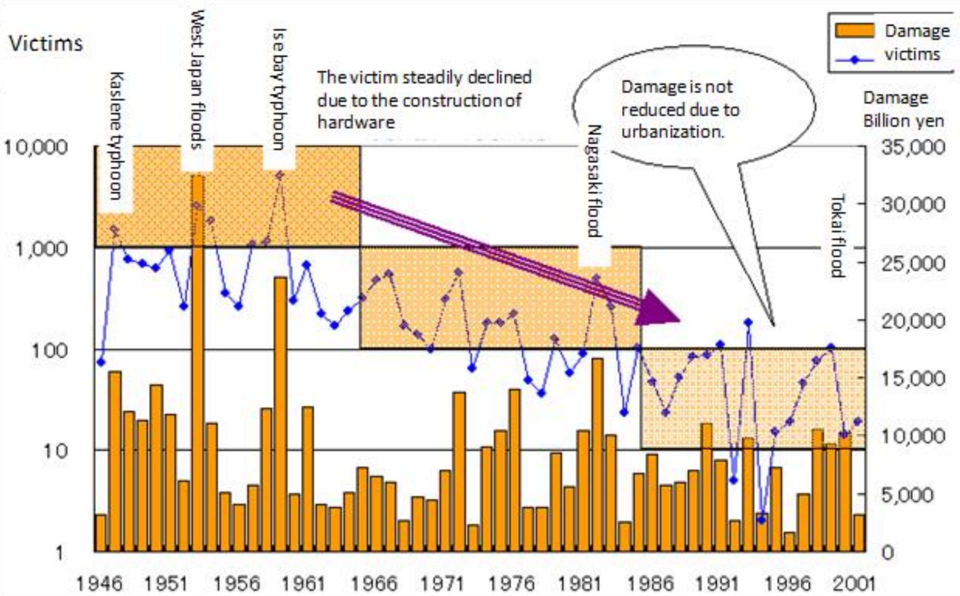

Figure1 Historical trend of the number of flood victims and economic damage

subcommittee compared the goals and achievement rates of the world with those of the flood control policy in Japan. Governments worldwide aim to achieve extremely high flood safety, while in Japan, the government aims to flood once in several decades, and hence, it was pointed out that the degree of achievement in Japan is low.

In the next year, MLIT made public recommendations for disaster prevention under changing climatic conditions based on the lessons learned from heavy flood disasters and IPCC AR4 report. These recommendations warned about the increase in floods, but the prediction of the flood risk was not quantitative depending on the uncertainty of model prediction.

However, rapid aging and population decline make flood control measures more difficult due to the following reasons: It is difficult to build new structures under budget limitations(Figure2). Further, owing to the aging population, the vulnerable population will increase, and the local disaster prevention organizations such as the fire brigade will be weakened by the decline in population. The goal of adaptation measures has been to reduce the number of victims to zero and to limit the damage in the important areas.

Moreover, it was pointed out that hardware alone cannot prevent severe flood damage, and that comprehensive measures are necessary.

2.3 New flood prevention policy

Even after the publication of the recommendations, damages due to floods have been frequently reported.

For example, Typhoon No. 12 in 2011 claimed nearly 100 people dead or missing in the Kii Peninsula heavy rainfall. In 2014, landslide disasters occurred in Hiroshima city, and numerous victims occurred. During the heavy rains in northern Kyushu in the year 2012, the water level crossed the planed water level in the Yabe River.

In 2015, MLIT published a new report. They recommend steady facility construction and maintenance to mitigate the damage caused by floods. This is a position that enhances traditional policies. For floods beyond the capabilities of the facility, it was suggested to strengthen the levee damage control by flood fighting activities and observation activities,

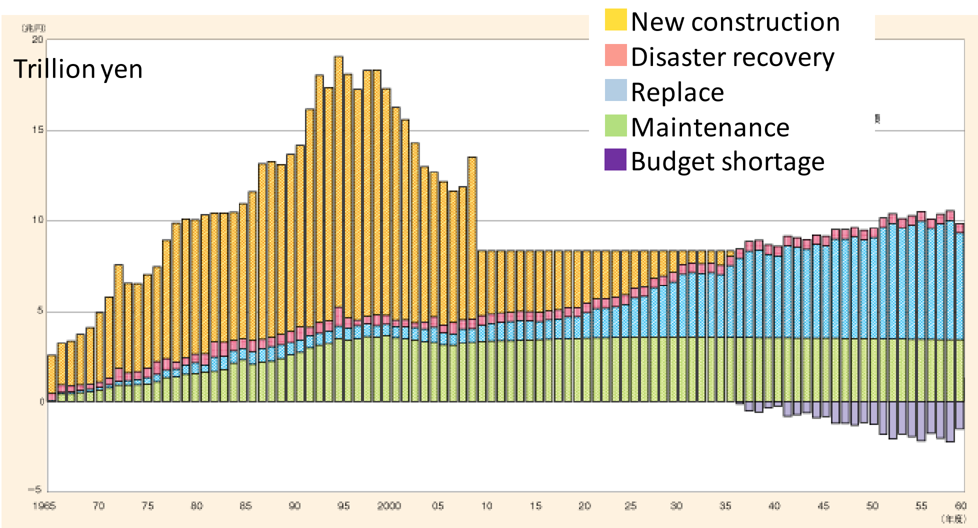

Figure2 Hisrical and future trend of infrastructure budget

to review the river improvement plan, and to strengthen embankments on the premise of overflow. Because quantitative prediction is difficult for the future expansion of the scale of rainfall, they propose to study climate change prediction and construct a facility capable of improving capacity

2.4 Flood prevention policy for "new stage of flood"

Almost at the same time, another committee made an important recommendation. This recommendation states that the increase in heavy rainfall will be regarded as "a new stage" and that the disaster prevention policy will be changed drastically.

In response to the Great East Japan Earthquake, the idea of disaster prevention underwent a major revision.

For example, for earthquakes and tsunami, the idea of countermeasures according to the scale of the event was put in place. For frequent disasters, the government aims to prevent damage to property and human life by constructing structures such as levees. In Tsunami disaster prevention, it happens once, about a hundred years, or it is maximum in modern times ,it called L1 tsunami.

For low-frequency large-scale disasters, the government aims to reduse the damage with facilities and protect life via measures such as evacuation guidance. In Tsunami disaster prevention, it happens once about a one thousand years and it is the worst in history, and it called L2 tsunami.

In the L2 tsunami, even if it can not completely protect cities and property, it should restore social function at an early stage and prevent bad effects on the economy.

For example, the Tsunami of the Great East Japan Great Earthquake was greater than the worst tsunami in the last 100 years and was about the same as the tsunami at the Johgan earthquake in the year 869 AD.

So if this idea is applied to flood control, design flood once every 100 years is prevented by levees and dams, and in maximum floods citizens lives should be protected at least.

In the field of river engineering and hydrology and meteorology, the worst rainfall and floods have been analyzed as possible maximum precipitation (PMP) and possible maximum flood (PMF).

However, it is difficult to reflect these analyzes in policies in terms of engineering judgment, economic viewpoint, or feasibility of facility construction maintenance in Japan.

The new flood prevention policy is similar to PMP and PMF.

The committee divided the Japanese archipelago into multiple regions based on the rainfall characteristics as Figure3. And in each regions, DAD (depth-duration-area) analysis of past heavy rainfall was done. As a result, the maximum rainfall is calculated for a certain area at each rain time.Figure4 means maximum rainfall of Shikoku south region in 24hour

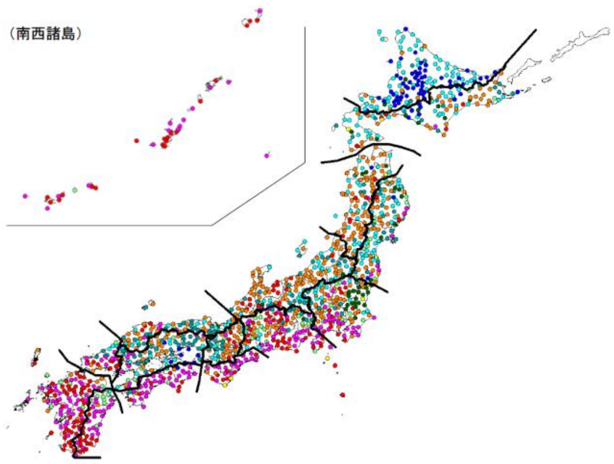

Figure3 Divided the Japanese archipelago based on the rainfall characteristics

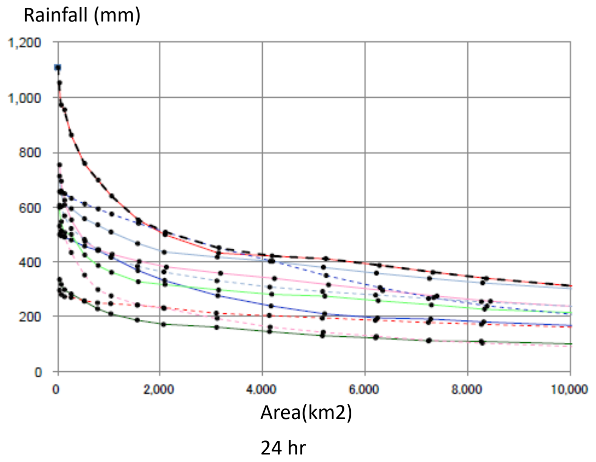

Figure4 Maximum rainfall of Shikoku south region in 24hour

The river administrator covers the biggest one, the region's maximum rainfall or once in 1000 years.

The maximum rainfall to consider is about twice the planned rainfall.

2.5 New flood prevention act

Additionally, the government revised the flood prevention act. The river administrator had released a flood hazard map once in decades or so already. Furthermore, the hazard map of the worst flood conceivable must also be released. Figure 5 is these 2 hazard maps.Local governments need to protect the lives of residents. However, damage prediction using the new hazard map is difficult because the inundation area and flooding depth are large. Sometimes most evacuation facilities in the town become unusable, and the flood plume of the scale to destroy houses is predicted in some cases. Local governments cannot take measures in such cases.

The river administrator has established a committee with local governments for this risk. However, prediction of damage which greatly expanded from the conventional assumption confused the local government.

In addition, the Flood prevention act was revised again, and it stipulated that facilities with disaster vulnerable people such as senior citizens' welfare facilities should make evacuation plans.

3. New philosophy of disaster prevention

We have to organize the philosophy of disaster prevention. First, we avoid damage by structures such as levees or dams. In the case of disasters of scale that cannot be controlled by structures, local governments should protect citizens lives using measures such as evacuation guidance. Additionally, if the local governments cannot respond, the citizens will protect their lives by self-help and mutual assistance. In old times with insufficient civil engineering technology, citizens protected their lives and wealth in the community. We should pay

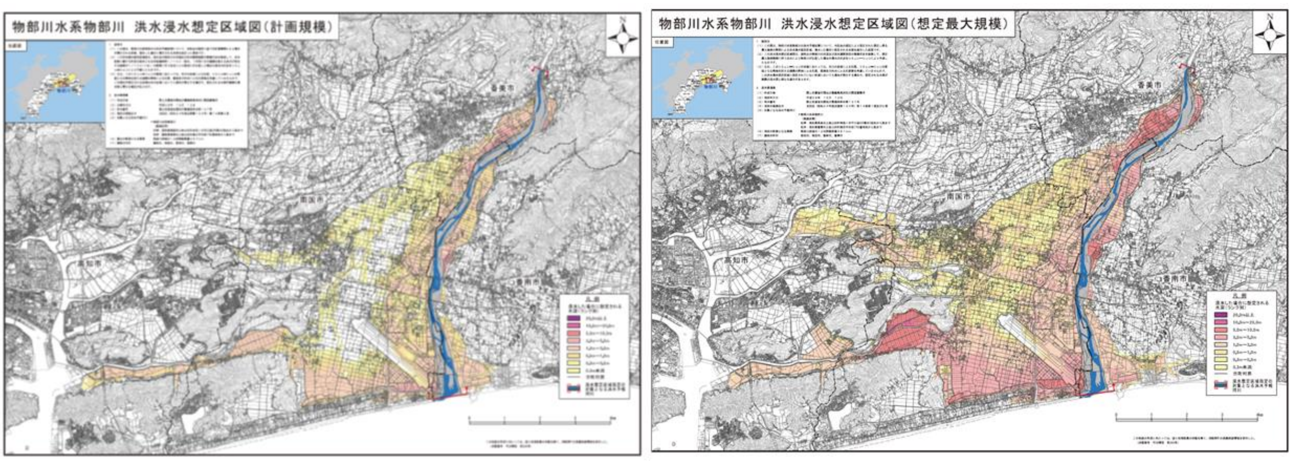

Figure5 Hazard maps of design flood and worst flood in Monobe river

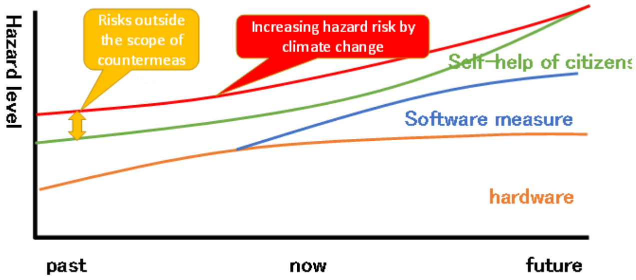

Figure6 Expansion of flood disaster scale and change of way of flood prevention in administrative and citizen

attention to the role of citizen's self-help assistance again.(Figure 6)

It is also necessary to consider the worst-case damage and methods to avoid loss of life. At the same time, it is necessary to expand gradually the assumption of flooding until its worst state, and to analyze how the damage proceeds.

Furthermore, the scale of damage of the disaster will be changed not only based on individual phenomena but also by combinations such as floods and storm surges.

4. Toward practice of disaster mitigation policy as climate change adaptation measures

A project called SI-CAT (Social Implementation Program on Climate Change Adaptation Technology) aims to develop the recent research results on climate change into adaptation measures for municipalities. The group that I participated in supports adaptation measures for the local governments. The risks of climate change faced by municipalities are diverse, and in addition to water disasters, health damage such as heat stroke and influence on agriculture and forests are considered. Water disasters are important as they pose a clear risk to human lives, and municipalities are forced to respond to such disasters through legislative reform and other measures.

We constructed a hydrological model as an impact assessment model and input climate change forecast data to predict flood damage. However, the output of the climate change prediction model has uncertainties, such as differences in results between models, and the spatiotemporal resolution is also insufficient. Therefore, we plan to utilize the results of statistical downscaling and mechanical downscaling by other groups. The last step of the hydrological model is the two-dimensional (2D) inundation model.

The last step of the hydrological model is the 2D inundation model. This model outputs flooding depth and inundation area. According to the results, damage to human life and property can be predicted. The results of this risk analysis help the administration take decisions on investment in development of structures and plan evacuation guidance.

As described above, disaster prevention as a climate change adaptation measure needs to be developed in many stages. This involves information with high uncertainty. Therefore, it is necessary to promote climate change adaptation measures and measures to cope with the largest possible flooding to the greatest extent possible.

5. Hydrological model as impact assessment model in Kochi City

We will examine these disaster prevention policies for Kochi City. It has mountainous areas where heavy rainfall is likely to occur and low-rise urban areas that are vulnerable to storm surges and

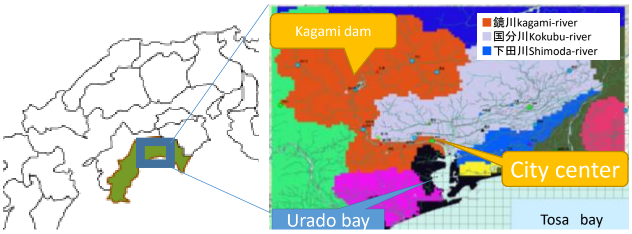

Figure7 Target basin

inundation flooding.(Figure7)

For the Kagami river passing through the urban area, we constructed a flood discharge model from the mountain area, and a one-dimensional river channel model, considering the influence of the sea level on the river. Discharge model is WEB-DHM, it is based on distributed data. Grid size is 250m.

We verified the accuracy of the model using past flood data. Target even is 2014T12. Input data is station rainfall data and Tosa bay sea level.

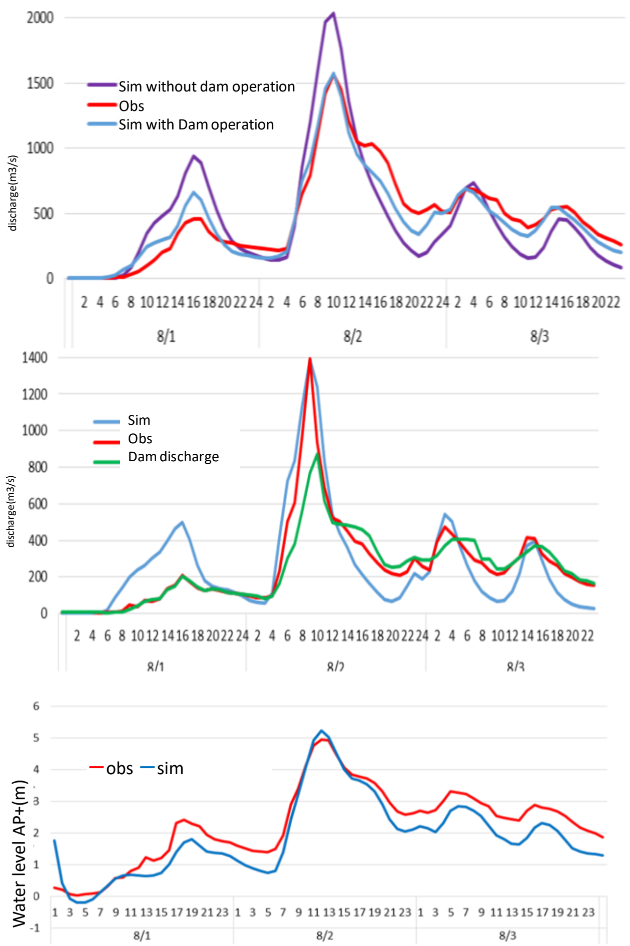

Figure8 Validation of model in 2014T12 (Kagami dam, city entrance, city center)

Figure8 is the result of models in 2014T12.

WEB-DHM can represent flood discharge and dam effect in Kagami dam and city entrance point.

And river channel model can represent flood water level and sea tide effect in city area.

6. Expanding flood risk of climate change and latent maximum flood risk

Next, using the climate change projection model output, we forecast the expansion of the scale of the flood once in a century. Original climate change projection model is CMIP5 dataset and it is daily data, and this original output is special downscaled provided from SI-CAT. Daily rainfall data is distributed to hourly rainfall data according to 2004T23 heavy rainfall waveform.(Figure9)

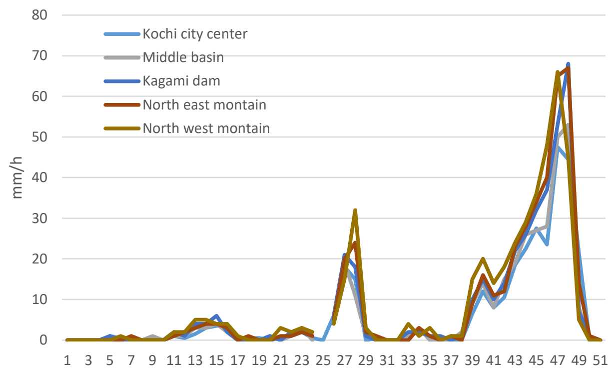

Figure9 2004T23 heavy rainfall waveform

In parallel, we input the rainfall waveform of the Kochi heavy rainfall in 1998 to the entire catchment basin. Kochi heavy rainfall in 1998(Figure10) is the rainfall at the assumed maximum external force in Shikoku south region. In the heavy rainfall event of 1998, the area with strong concentrated rainfall expanded in other directions in the Kagami River basin.

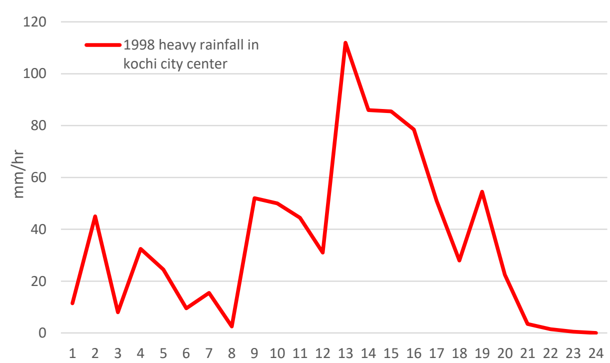

Figure10 1998 heavy rainfall waveform

Therefore, there is concern that increase in the discharge rate can exceed the discharge rate for the

1998 event. Furthermore, the flow rate was calculated by applying the method of the MLIT guideline as it was.

According to the comparison results in Figure11, the PMF due to the assumed maximum rainfall is much larger than the probability flow increased by climate change. Also, although not covered by this research, the PMF may increase more with climate change.

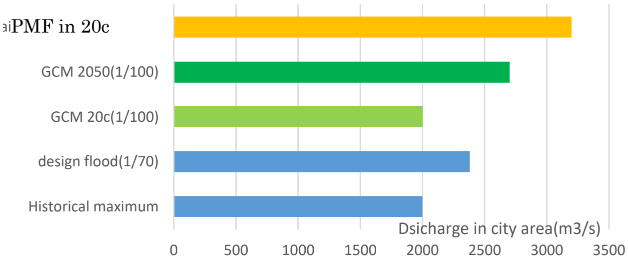

Figure11 Expantion of disicharge in Kochi city area

7. Impact assessment of maximum flood in Kochi City

Then, the water level at each point was calculated, and inundation of the urban area was predicted by the 2D inundation model.

It was found that the flood sometimes flowed further away from the river owing to a slight highland present in the city.(Figure12)

Additionally, the Kochi city area is surrounded by a high levee as a measure against storm surge and tsunami. And now, Kochi Prefecture is reinforcing these levees for measures against tsunami(Figure13). So it is highly possible that these levees will continue functioning even if it is a large flood.

In addition, this model does not reproduce the inundation flood caused by rainfall and the function of sewage network.

Figure14 show the result of flood simulation in the southern part of the urban area and it presumes that there is a possibility that if the flood depth becomes large, it will flow out of the urban area beyond the levee.

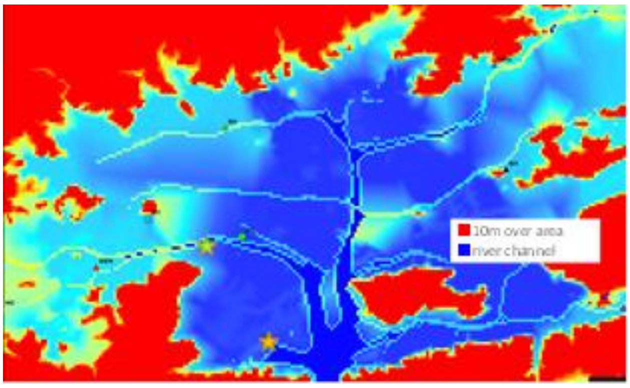

Figure12 Elevation map of 2D model

Figure13 Reinforcing of river mouth levees

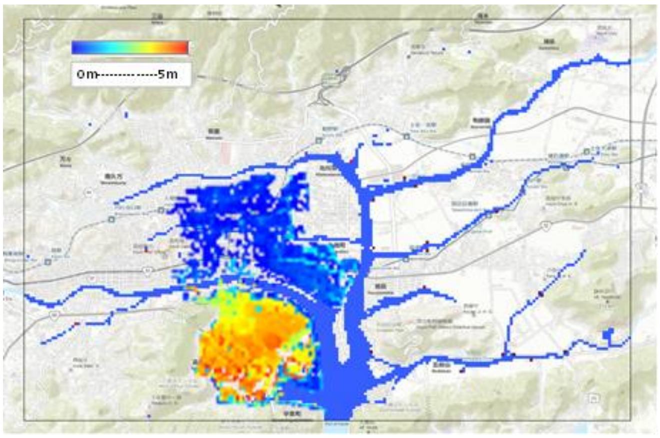

Figure14 Inundation of south area

Also, there is a risk that citizens will be isolated by long inundation.

It also suggests that the strengthening or raising the tide ridges poses the risk of flood damage.

The results of this analysis suggest that it is possible to avoid inundation in areas and buildings that are higher than the levee.

In cities with risks of Japan's tsunami, local governments have designated robust and high-rise public facilities and private buildings as tsunami evacuation buildings. Numerous tsunami evacuation buildings were designated in Kochi City and the majority of the population can be accommodated.

Figure15 Public museum designated Tsunami evacuation building and its singbord

The idea of the Tsunami evacuation building should also be extended to large-scale flood damage.

However, some of the tsunami evacuation buildings have specified terraces and rooftop as evacuation sites and are not suitable for evacuation during rain.

In addition, water discharge from urban areas after the tsunami is also a research topic, pump stations are under earthquake resistant and waterproof reinforcement. So the same countermeasures are useful after large scale flood damage.

8. Conclusion

Studies on climate change adaptation measures have indicated an increase in stochastic flow rate, but it is difficult to devise policies alone. On the assumption of the worst situation, the damage was simulated in a stepwise manner up to the worst case. It was found that it is possible to explore concrete measures by analyzing detailed damage.

The highest rainfall in the region expands owing to climate change is an important issue in meteorology. Furthermore, this is an important issue in formulating local disaster prevention policy.With the progress of this research, the local government needs to reconsider its plan. However, as long as the framework of planning is established, it is possible to deal with it.

In the future, as a basis for evacuation guidance to eliminate victims, we plan to analyze the combination of flooding analysis and life risk.It will also be combined with economic impact assessment to reduce economic damage caused by floods.

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