PREDICTION OF URBAN INUNDATION AND FLOODING OF URBAN RIVERS CAUSED BY HEAVY RAINFALL AND STORM SURGE IN TOKYO 23 WARDS

Masato SEKINE, Yonglin WU, Wataru BABA, Kumiko OGATA (Waseda University, Tokyo, Japan)

Introduction

In recent years, damage from large typhoons and localized torrential rain has been increasing in various parts of Japan due to extreme weather. Typhoon No.21 which occurred in September 2018 caused severe damage due to furious wind around Osaka Bay. Typhoon-triggered Storm surges and high waves causing massive inundation damage in Kansai International Airport and took a long time to recover. A ship colliding with the bridge which connecting the opposite bank and the airport. In addition, during the heavy rains in western Japan in July 2018, severe inundation damage occurred there. The Meteorological Agency announced an extraordinary heavy rain warning in Kyoto prefecture and other 10 prefectures. The number of casualties were over 200. Considering this current state, the importance of software countermeasures has been increasing more and more due to the frequent occurrence of inundation damage because the existing facilities or hardware countermeasures cannot work well to prevent from the damage due to extremely high natural impact. Sekine laboratory has clarified the risk of inundation occurring in highly urbanized areas such as the 23 wards of Tokyo using a sophisticated inundation prediction system S-uiPS (Sekine's urban inundation Prediction System). In this study, the prediction of urban inundation in 23 wards of Tokyo was performed on the assumption that both heavy rainfall and Storm surges caused by Typhoon would occurred simultaneously.

Study area and analysis overview

Characteristics of this target area

- This area is equivalent to more than 60% of the total area of the 23 wards and the total area is about 390 km^2.
- The western area has an altitude of over 50m, but the altitude decreases as it approaches the coastal area.
- Lowland area with an altitude of 5m or less spread along the Sumida River and the area near the river mouths of some urban rivers.
- A seawall has been installed at the seafront from the mouth of the Sumida River to the mouth of the Nomi River and it is shown in Figure 1 in a red solid line.

Summary of the prediction system

The database of prediction method S-uiPS contains information about :

(1) All road networks.
(2) All drainage networks.
(3) Rainwater storage capacity of water reclamation centers and pump stations.
(4) Rainwater storage pipes.
(5) Urban rivers flowing in the area.
(6) Land use of the urban block, such as the building coverage ratio and etc..

It is noted that any coefficients which should be calibrated are not included at all.

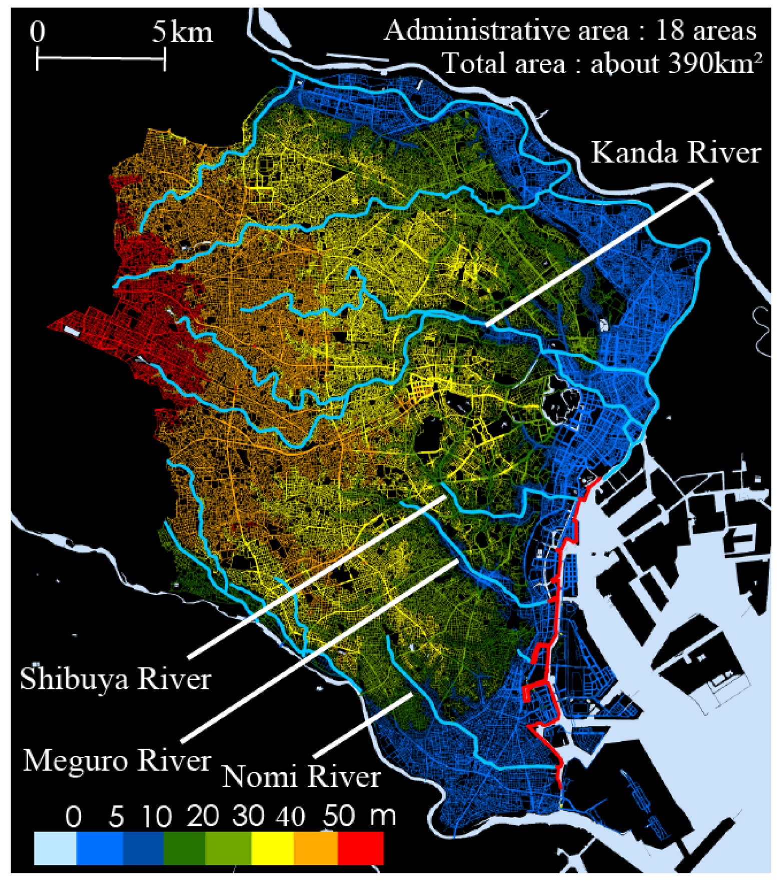

Figure 1. Elevation contour map

Rainfall and storm surge data

- The heavy rainfall of Suginami that occurred in a wide area around Suginami ward, Tokyo in September 2005 (Sekine, 2016) was used.
- As for the downstream boundary conditions of urban rivers, the temporal fluctuation of the tide shown in Figure 2 was used.
- The initial conditions for this computation were assuming that there was no rainfall until the start of the calculation, and that each river had a normal flow rate.

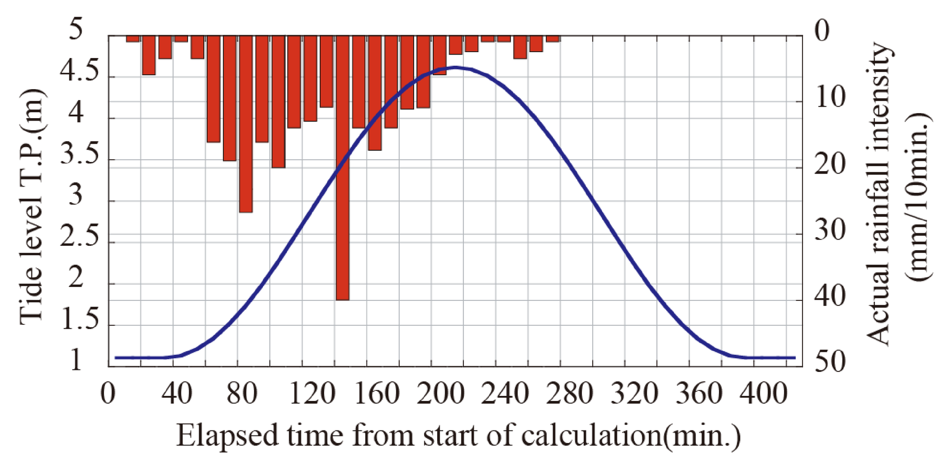

Figure 2. Temporal change of rainfall and tide level

Result and discussion

Inundation process

- At 120 minutes after the start of rainfall, the inundation occurs in a wide area in the target area. In particular, flooding of more than 80 cm occurred mainly in the coastal areas and lowlands along rivers.
- The water level of the river rises as the rise of the tide, and the effect of the high intensity rainfall indicates that the drainage pipe becomes full in most areas not only along the river.
- At 225 minutes, the area where the inundation depth exceeds 80 cm has been expanded, mainly along the riverside and the coastal area. In addition, the high water level of river makes the reverse flow in drainage pipe from rivers and the situation becomes more complicated.
- When the rainfall stops and the tide level begins to decrease, the inundation depth tends to decrease except for the lowlands along the river. This is because the drainage system is recovering from the full state.

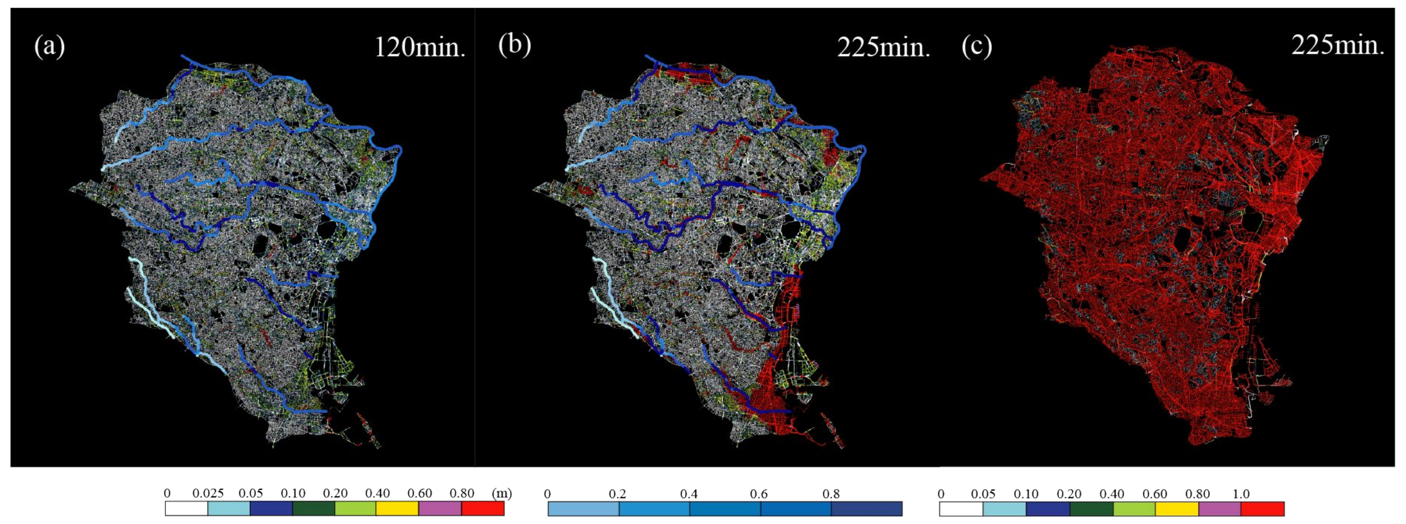

Figure 3. (a)(b) contour map of on road inundation depth at 120, 225 minutes from the beginning of rainfall, (c) contour map of drainage full rate at 225 minutes. Legend (from left): Road inundation depth, River relative water depth, Sewerage full rate.

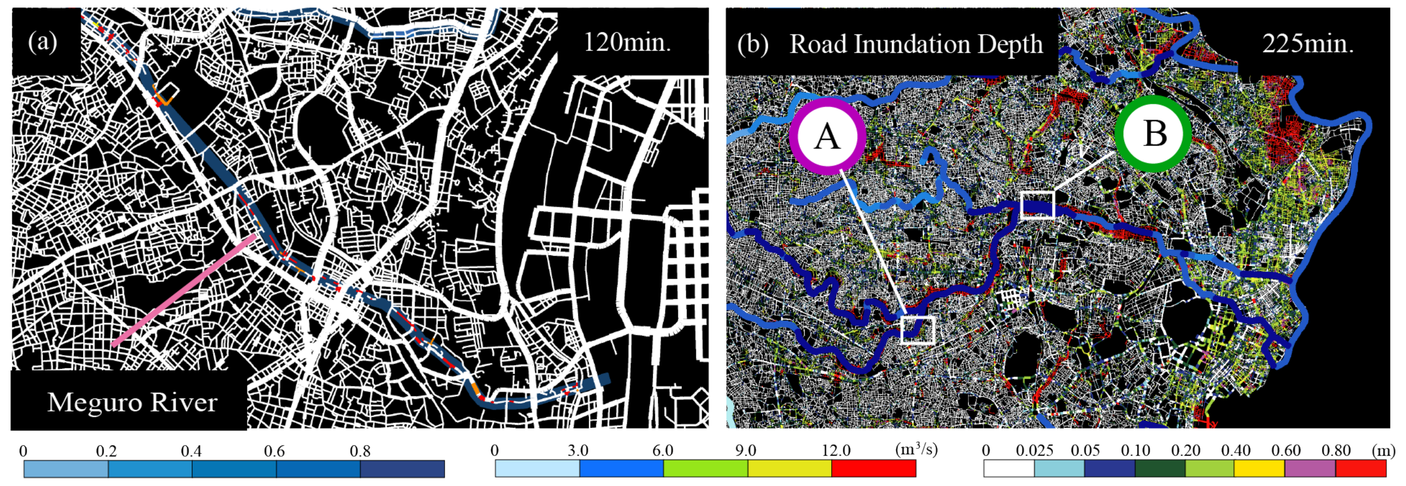

Figure 4. (a) Overflow discharge contour map along the river, (b) Inundation depth contour map along the Kanda River.Legend (from left): relative water depth from river, overflow discharge from river to road and inundation depth on roads.

Inundation in urban river basins

- The relative water depth of the urban rivers becomes large at the stage of 225 minutes(Figure 3).
- The overflow from river to urban area occurs along the Meguro River at 120 minutes after the time just before the rainfall peaked (Figure 4).
- Points A and B indicated by circles are sufficiently far inland from the river and sea, inundation exceeding 0.8 m occurs at points along the river (Figure 4.b).
- The drainage pipe leading to the river becomes full and the capacity of drainage is significantly reduced(Figure 5. c and d).
- Under such conditions, the tide level and the river water level rises, and the discharge from drainage pipe to the river became zero or negative.
- The area where the inundation depth exceeds 0.8m spreads along the river, and in such area the overflow from the river occurred. It should be noted that the point A is about 15 km upstream from the river mouth of the Kanda River indicated by the circle and is the junction with the Zenpukuji River (Figure 4.b).

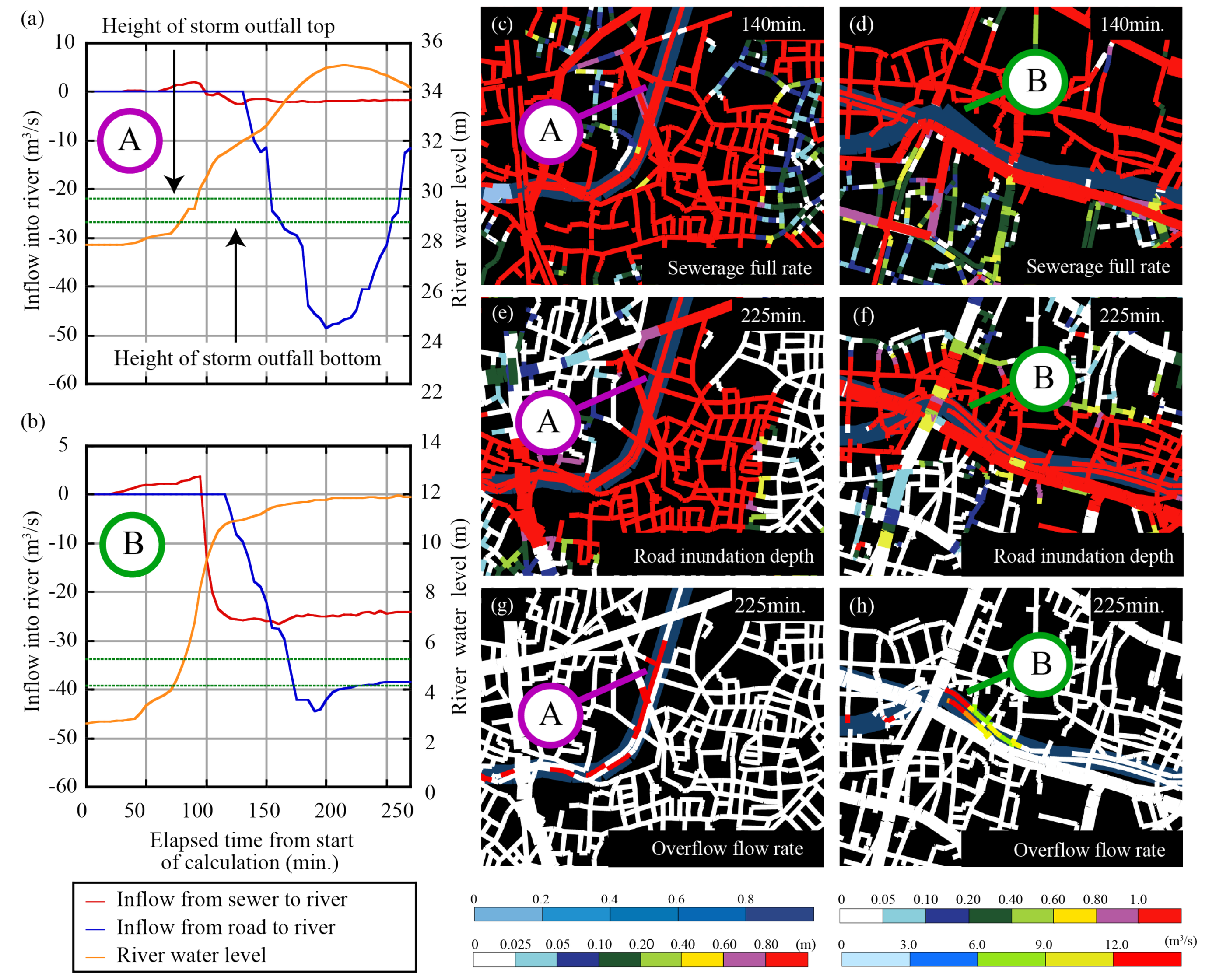

Figure 5. Results of computation at points A and B along the Kanda River: (a) and (b) Time change of inflow from road and sewer to river, (c) and (d) Contour map of drainage full rate at 140 minutes, (e) and (f) Contour map of road inundation depth at 225 minutes, (g) and (h) Contour map of overflow discharge from the river to the road at 225 minutes. Legend (from upper left to right): Relative water depth of river, drainage full rate, inundation depth on road and overflow discharge from river to road.

Conclusions

If a large amount of rainwater is discharged from the drainage pipe to the river due to the rainfall and/or the tide rises due to storm surge, the water surface elevation in upstream reach of the urban river flowing directly into Tokyo Bay also rises quickly.
The flow in river propagated in upstream direction, and the inundation in inland area faced urban river even far from the river mouth becomes so severe. It is because the river water flows into a drainage pipe reversely and also flows over the revetment wall into inland area.
The flooding from the Kanda River may cause enormous damage, if such storm surges and the torrential rain occur simultaneously.

References

Ministry of land, infrastructure, transport and tourism (2015).
Sekine,M. (2011), *Journal of JSCE*, Ser. B1 Hydraulic Engineering.
Sekine, M. and Ogata, K. (2018), *Journal of JSCE*, Ser. B1 Hydraulic Engineering.
Sekine, M. and Kondo, K. (2016), *Journal of JSCE*, Ser. B1 Hydraulic Engineering.
Port and Harbor Bureau, Construction Bureau of Tokyo Metropolitan Government (2018).