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Mapping of Inundation Damage Prediction using GIS Technology

Kyunghoon Ahn[1], Jion Lim[2]*, Joowon Kim[3] and SangjinAhn[4]

[1,2,3,4] International Center For Urban Water Hydroinformatics Research & Innobation (ICUH), 169 Gaetbeol-ro, Yeonsu-gu,406-840 Incheon, Korea
[1]blueema@naver.com, [2]916wisdom@naver.com, [3]kjw-0517@hanmail.net, [4]hydrosys@chungbuk.ac.kr

Abstract

The purpose of this study is making the map of inundation damage prediction with analysis result of rivers flood and urban inundation in order to prepare against emergency of urban inundation and levee break due to extraordinary flood and regional heavy rain. This is for protecting the residents' life and property with rapid management in the damage predicted area. In order to effectively calculate the aspect of inundation area, the study was conducted on Gwangmyeong, as the real example of inundation area, which reflects damage area of each scenario(frequency) using one dimensional HEC-RAS model and two dimensional SWMM. Based on the CAD and GIS produced from this study or existing similar studies, was used Arc-map program which makes the map with each scenario(frequency). In order to reflect the topography of the real area, we scanned the high resolution satellite picture on the flooded area for more accuracy and focused on raising efficiency of as the better map of inundation damage prediction.

Keywords: *Inland inundation, River inundation, GIS-map, Map of inundation damage prediction*

1. Introduction

Extraordinary weather phenomena such as heavy rainfalls due to global warming have been causing the emergency of collapse of dam and levee, and the damages by typhoon such as 'Rusa(2002)', 'Memi'(2004), 'Nari'(2007), and 'Muifa(2011) actually increased the necessity of comprehensive studies on making map of inundation danger. Accordingly, in order to protect the life of the residents in the inundated area and to better let them know the information of inundation danger, this study was conducted on mapping of inundation damage prediction using high resolution satellite picture, on comparative analysis with the existing map of inundation danger, and on the utilization.

The map of prediction of damage from storm and flood is what the inundation area of each frequency is indicated on a map and the spatial information of potential inundation area is connected with GIS.

So, it plays an important role for establishment of national water management and for protecting of the life of people because it makes the residents recognize the danger of inundation in their area in advance and them escape safely with the given information in case of inundation. In the local government also, it can be utilized for real time forecast & warning of inundation, establishment of inundation prevention plan, regulation of land use and for flood insurance system. According to the analysis of the existing studies on flood , there have been a lot of studies on the map of flood danger and inundation analysis considering flood event frequency [1].

In order to restore the inundation area practically, this study was conducted on the map of flood damage using GIS and adaptability analysis, on the estimation of critical damage area with each type or area of inland/river risk, and on mapping of inundation damage prediction using GIS. The study goes beyond the limit of the existing map of flood

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damage, increases the precision of the map for rapid and exact estimation of inundation area, makes the preparation system set against heavy rainfall with the advance analysis, increases the advance reaction capability against disaster, and after all goes to contribute to national image promotion of disaster management.

2. Studied Area

In this study, Gwangmyeong was selected as an object of mapping of inundation damage prediction. Examining the spread of population in Gwangmyeong, about 89% of total population concentrate in Gwangmyeong dong, Cheolsan dong, and Haan dong, and the population density is more than 10,000 /km2. It is therefore estimated a severe life damage in case of damage from storm and flood, and the big risk of inundation damage by the uncontrolled development and the increase of flood runoff due to drastic urbanization. That is the reason of the selection.

Gwangmyeong, a satellite city of Seoul, is geopolitically located in the center of eastern Gyeonggi do, faces Seoul northeast, Anyang southeast and Siheung southwest. The city has mountainous region which connects the city center from north to south, and hilly mountains such as Gureum mountain (EL. 237.0 m) in the center, Dodeok mountain (EL. 182. 4 m) in the north, Seodok mountain (EL. 180.0 m) in the south, which divide the city from east to west. The city has scattered hilly mountains of height 100~200, fully opened area south, and populated urban area which is flat in the north. Around a mountainous region in the center, Anyang river(national river) in the east and Mokgam river (local river) in the west, flow from south to north into Han river (national river). And also there is a Gahak river(local river) of tributary of Mokgam river in Gwanmeyong.

Regarding land use, among the total 38.5 km2, 8.32 km2 (21.60%) is agricultural land, 14.38km2 (37.4%) is forest land. Urban area increased and forest & agricultural land decreased. The urbanization made impermeable layer increased so that it will be estimated the change of runoff and then increase of flood and inland inundation damage.

As for the watershed characteristics, it is estimated for national rivers and local rivers in Gwangmyeong with low form factor to have low flood peak. Most creeks have low form factor. But Noonsa river is 0.82 and Soha river 0.74 which are quite high, so that it will be estimated an outflow concentration tendency.

The status of rainfall was investigated using the materials of Seoul weather station that is nearest to Gwangmyeong. Annual average precipitation of Seoul weather station is 1,549.0 mm which is more than 1,409.5 mm in whole country. Especially the precipitation in 1998, 2003, and 2010 is 2,349.1mm, 2,012.0mm, and 2043.5mm each which are more than the average, it is because of the influence of severe rainfall, typhoon ‘Maemi’ in 2003, and ‘Kompas’ in 2010.

As for the monthly precipitation, it is to be known that 63.5% of the total precipitation was concentrated in July and August, and it is considered because of typhoon and severe rainfall in summer. [2]

3. Study Method

This study was proceeded by following methods. First, among the area having comprehensive plan of reduction of damage from flood and storm, the area – that has computerized database - with high possibility of the damage was selected as an example of study. Second, based on the material of river section and flood frequency, rainfall runoff simulation was conducted using HEC-RAS modeling and XP-SWMM. Third, in order to indicate the inundation area extracted by the rainfall runoff simulation on the high resolution satellite picture, coordinate was corrected with world geodetic system(WGS-84) and the area was combined with the high resolution satellite picture. Finally, a map of damage prediction with polygon type scenario(frequency) was made. The following Figure 1, is the study flow chart.

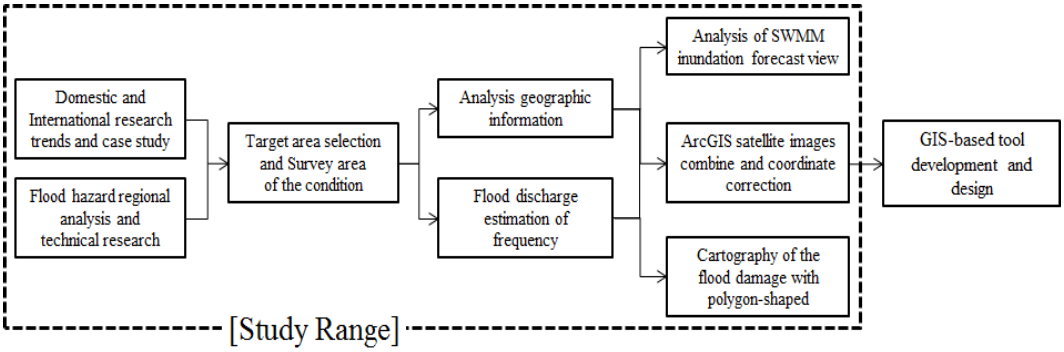

Figure 1. Study Flow Chart

4. Analysis of Inundation Damage

For the estimation of inundation area in Gwangmyeong, a basis analysis of flow in case of rainfall was done using channel routing model. Through the basis analysis and using one dimensional HEC-RAS analysis module, river inundation area was analyzed (Figure 2.) with a review of discharge capacity and a flood analysis. And two dimensional XP-SWMM was applied to the analysis of inland flood. Especially the analysis of inland flood indicated the analysis with drainage area and indicated inundation area with agricultural land.

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4.1. Analysis of River Disaster

As for the river disaster, in department plans such as basic plan of river, small streams implementation projects and protection of river disaster projects, the management plans have been established for rivers using different design frequency according to each design standard. For Gwangmyeong, damage prediction areas by river were selected by HEC-RAS modeling which calculates flood elevation of river using watershed characteristics and the materials of river topography.

The materials of Seoul weather station was used for rainfall analysis. For the analysis of rainfall frequency, Log-Normal distribution(LN2P, LN3P), Gamma distribution(GAM2P, GAM3P), Log-Pearson Type-3 distribution(LP3P), Gumbel(GUM), and Generalized Extreme Value(GEV) distribution were used. For parametric estimation method, Probability Weighted Moments –the most proper for the studied area - was adopted. FARD was used for analysis of probable precipitation. For design precipitation, was adopted the second group having the highest frequency of heavy rain that is more than the average precipitation for the whole period and was adopted 50% cumulative series of the non-dimensional cumulative curve.[3]

Calculation of flood elevation was done with different frequency (20 years, 30years, 50years, 80 years, 100years, 150years, 200years), and it was decided as design flood elevation & design river width shown Table 1. with HEC-RAS program by standard step method.

Table 1. HEC-RAS Result

Station (NO.)	Cumulative distance	Design precipitation	Design water level (EL.m)	Design river width (m)	Height of left levee (m)	Height of right levee (m)	Remark
0	0	291	12.95	55	14.57	14.07	
1	110	291	12.95	59	15.35	14.45	
2	220	291	12.98	47	15.73	14.83	
+51	271	291	13.07	56	15.80	15.30	Gwangnam bridge
+80	300	291	13.17	55	15.42	15.15	Gwangnam bridge(new)
3	357	291	13.17	51	12.35	14.25	
4	441	291	13.18	49	12.49	13.49	
5	517	291	13.23	50	12.32	12.62	
6	627	291	13.28	51	12.72	12.42	
7	727	291	13.34	50	15.32	15.18	Gyoungryun bridge
8	827	291	13.40	49	12.72	12.32	
9	920	291	13.45	50	12.62	12.62	
+65	985	77	13.60	46	13.24	13.24	BOXbridge
+70	990	77	13.60	46	13.03	12.82	Gwangmyeong1weir
10	1,040	77	13.61	49	13.72	13.22	
11	1,130	77	13.61	50	13.75	13.45	
12	1,230	77	13.61	49	13.75	13.55	
+80	1,310	77	13.62	50	17.32	17.46	Okgil bridge
13	1,340	77	13.62	51	13.73	13.63	
14	1,440	77	13.62	51	13.68	13.68	
15	1,540	77	13.62	48	13.69	13.89	
16	1,635	77	13.63	47	13.96	13.96	
17	1,735	77	13.63	49	14.02	14.02	
18	1,845	77	13.64	49	14.14	14.64	
19	1,945	77	13.64	47	14.34	14.64	
20	2,072	77	13.65	48	14.06	14.46	
21	2,152	77	13.65	50	14.22	14.22	
22	2,257	77	13.66	50	14.52	15.02	
23	2,367	77	13.67	48	15.19	15.19	Noonsa bridge
24	2,462	77	13.67	48	14.59	15.59	
25	2,565	77	13.68	46	14.35	15.85	
26	2,660	77	13.69	46	14.76	15.26	
+50	2,710	77	13.71	45	14.67	15.17	Mokgam 1 weir
27	2,760	77	15.80	50	14.89	15.63	Regulation gate
28	2,868	325	15.92	50	14.43	15.23	
29	2,968	325	15.99	50	14.64	15.54	
30	3,071	325	16.04	50	14.64	15.64	

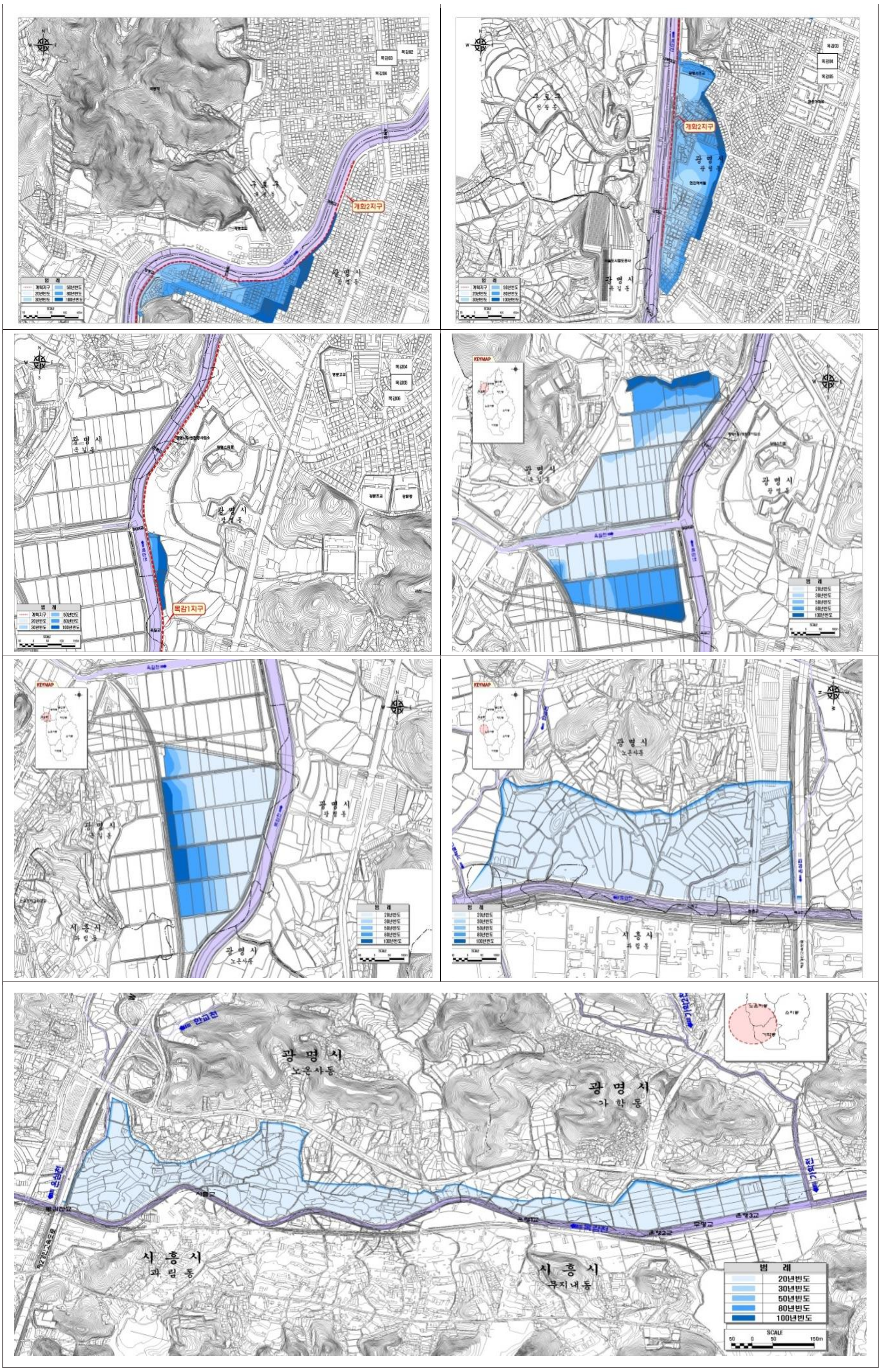

Figure 2. River Flood Area in Gwangmyeong

4.2. Analysis of Inland Inundation Disaster

For the analysis of inland inundation disaster in Gwangmyeong, flood peak for design rainfall is needed for the design or plan of simple storm sewer. But for the plan of retarding basin, regulating basin and rain water pump station having regulating basin, not only flood peak but also discharge hydrograph informing real time flood inflow are needed. So, SWMM(Storm Water Management Model) was used as the outflow model. SWMM is a single event model developed by US EPA in 1971-revised 3 times since then -to estimate the discharge, water level and contaminants density, it was done by simulation of discharge amount and water quality process related with urban discharge and combined sewer. This model is a nonlinear storage equation kind of Kinematic wave approximation which assumefriction slope is equal to basin slopes the basic equation of surface runoff. For runoff, continuity equation and Manning equation are used to decide the water depth and discharge in sub basin.[4]

As the simulation condition for SWMM modeling, when simulate storm sewer pipe line, it was considered the backwater effects of drainage pump station and assumed that all the water on the surface would flow into the storm sewer pipe line. And manholes were placed between the pipe lines, so that the simulation is as follows; in case there are not enough section of water flow in the pipe line and then overflow and then inundation. For the pump capacity, it was assumed that all the water from drainage sector would flow into the pump station, and for pump operation condition, it was assumed that it would discharge at the same time in the worst case. The results are shown in Table 2. Inundation areas without enough drainage capacity in drainage sector are shown in Figure 3.

Table 2. Critical Time and Maximum Pump Drainage Using SWMM

Pump station	Frequency	SWMM	
		Critical time(min)	Max. pump drainage (m^3/min)
Gwangmyeong	30years	60	1,161
Gwangmyeong1		50	1,673
Gwangmyeong2		50	462
Gwangmyeong3		60	616
Cheolsan		90	3,430
Haan		150	4,279
Soha		150	1,439

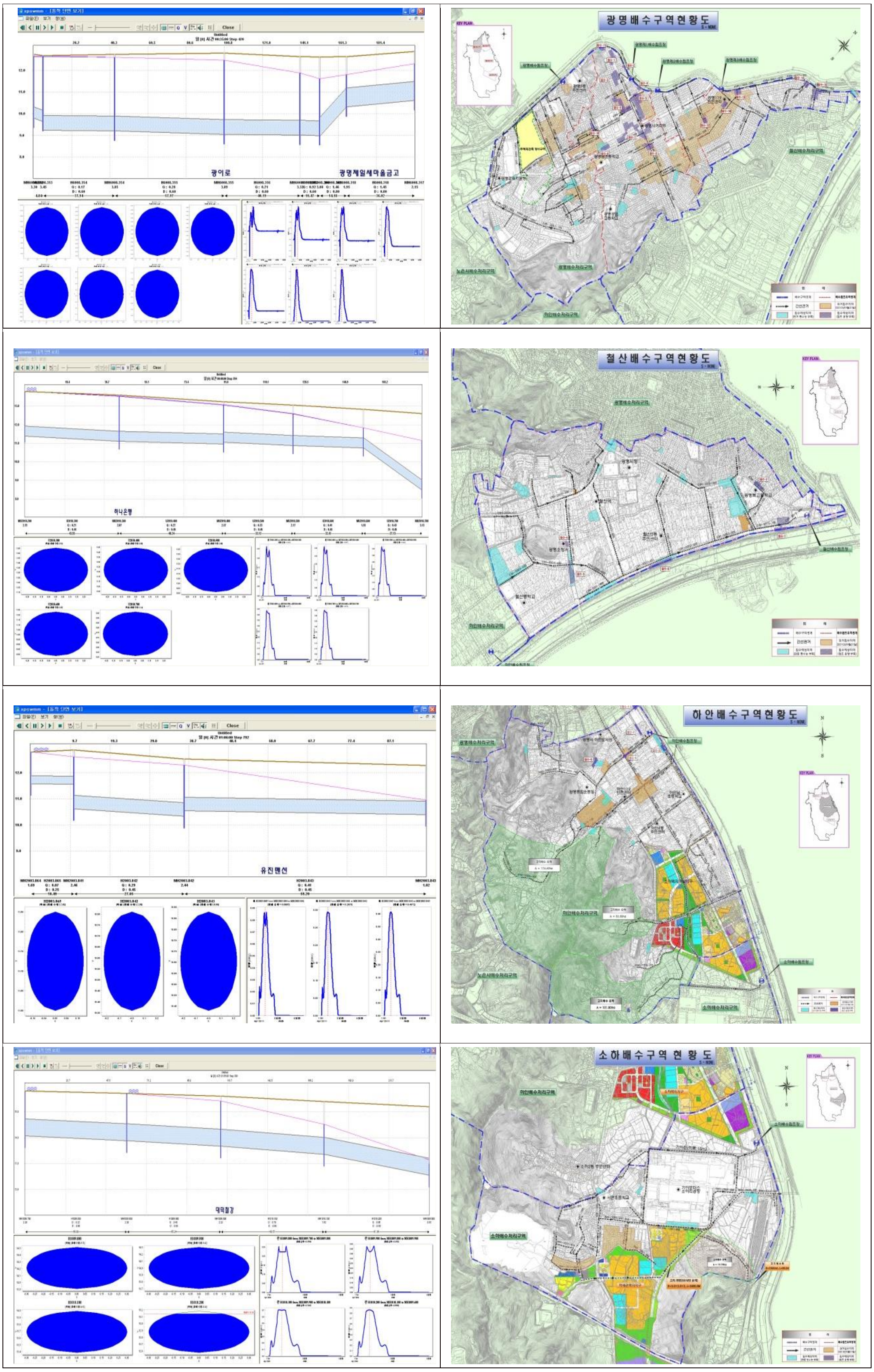

Figure 3. The Area without Enough Drainage Capacity

Table 3. Review Results on Discharge Capacity of Pipelines

Watershed Area		Pipeline Status			Discharge Capacity (Lack of Pipeline) Frequency(30YR)	
		Total	less than 800mm	more than 800mm	less than 800mm	more than 800mm
GM	Length (m)	17,580	7,911	9,669	705	926
	Rate (%)	100	45	55	4	5
GM1	Length (m)	15,028	10,201	4,827	1,138	519
	Rate (%)	100	68	32	8	3
GM 2,3	Length (m)	9,836	6,032	3,804	130	68
	Rate (%)	100	61	39	1	1
CS	Length (m)	24,713	14,455	10,258	1,563	1,627
	Rate (%)	100	58	41	6	7
HA	Length (m)	36,769	12,076	24,693	2,346	2,141
	Rate (%)	100	33	67	7	6
SH	Length (m)	14,919	5,128	9,791	648.90	888.28
	Rate (%)	100.0	34.37	65.63	4	6
Total	**Length (m)**	**118,845**	**55,803**	**63,042**	**6,531**	**6,169**
	Rate (%)	**100**	**47**	**53**	**5**	**5**

Results of reviewing the areas of lacking discharge capacity by watershed area (Table 3) show that for under 800mm pipe, there are Gwangmyung watershed GM (4%), GM 1(8%), GM 2,3 (1%), Cheolsan (CS 6%), Haan (HA, 7%), Soha (SH, 4%) with 1% to 8% lacking area. For over 800mm pipe, the lacking areas were GM (5%), GM1 (3%), GM 2,3 (1%), CS (7%), HA (6%) and SH (6%) with 1% to 7% lacking area. That is, of the entire watersheds of Gwangmyung city 118.845m, 5% (6,531m for under 800mm, 6,169m for over 800mm) was found to be lacking areas.

4.3. Mapping Inundation Damage Prediction

Based on the above materials, in this study, the map of inundation damage was made combining the computerized database with numerical map of National Geographic Information Institute in order to raise the precision of inundation damage area. Figure 4.shows the area, which is extracted by SWMM model and coordinate corrected with GIS basis georeferencing, on the high resolution satellite picture.

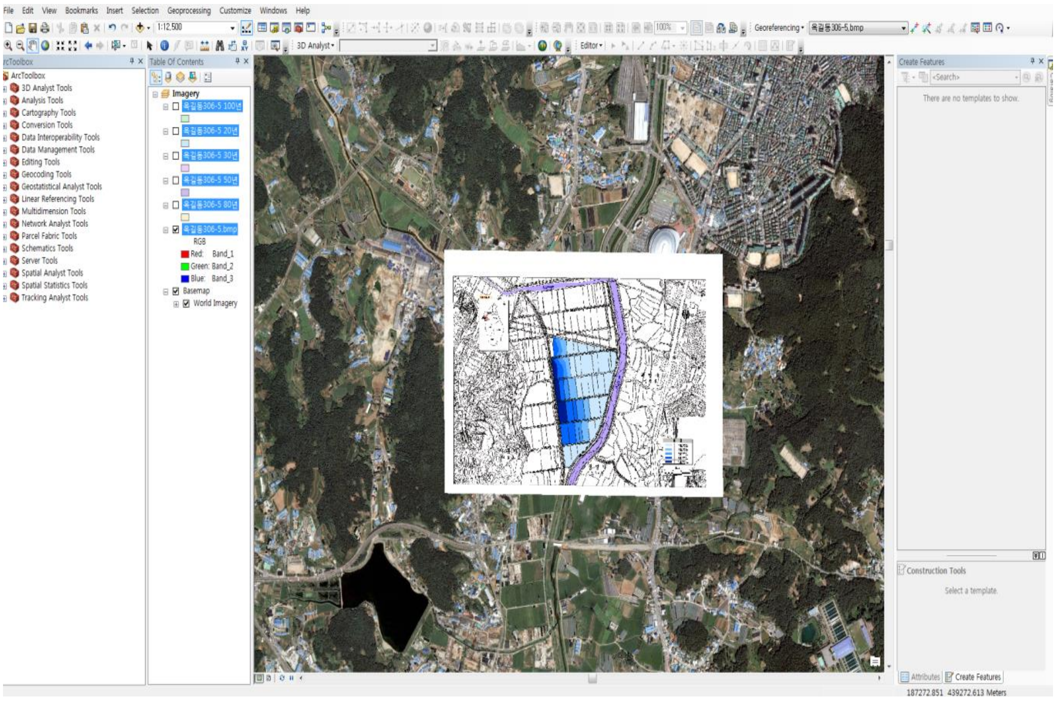

Figure 4. Inundation Area Overlapped with GIS-Map

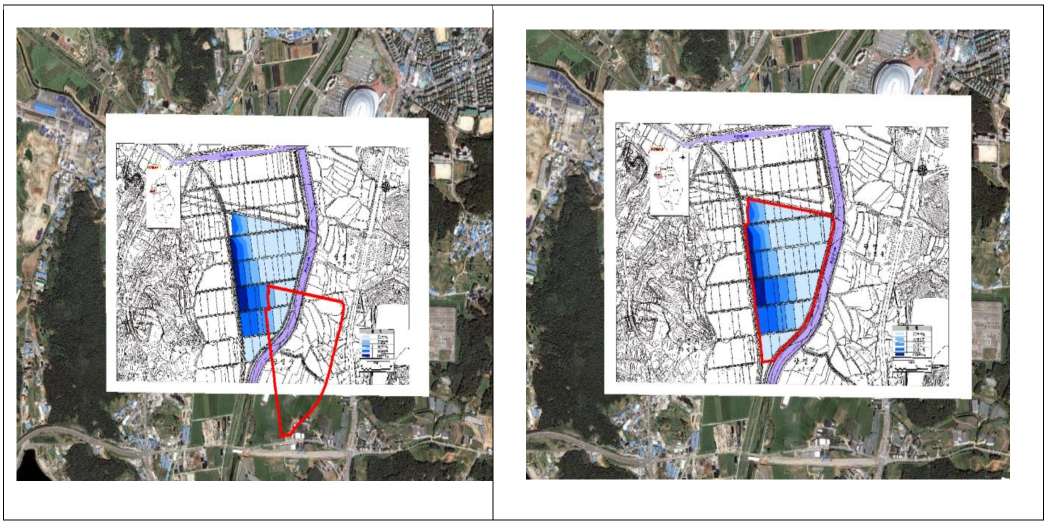

Figure 5. Coordinates Transformation of Computerized Materials

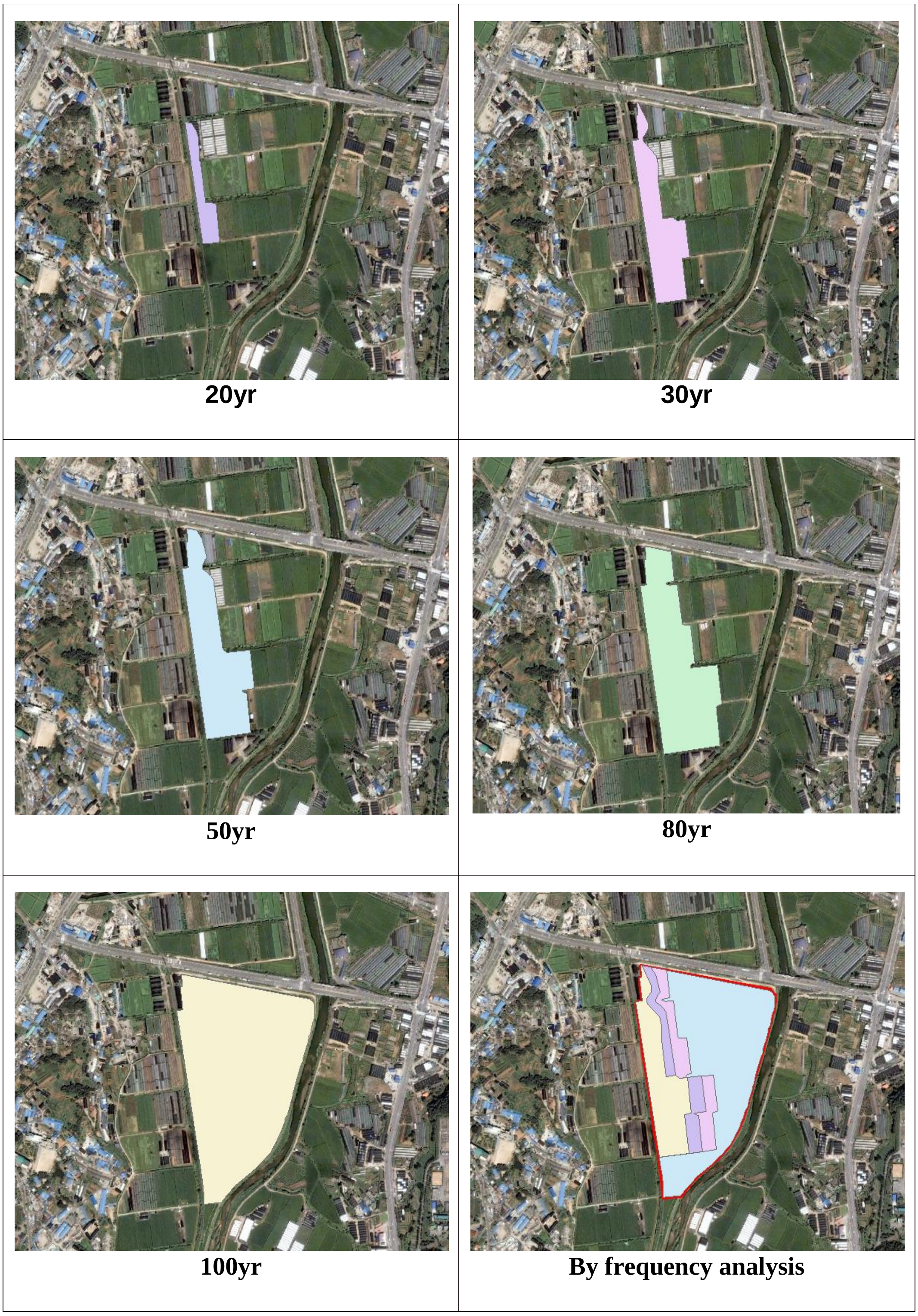

Figure 6. Mapping of Inundation Damage with Different Frequency

For analyzed inundation area, in order to coordinates unification of materials, World Geodetic System(WGS-84) and plane were corrected by transverse Mercator(TM), Figure 5, the area was overlapped with the high resolution satellite picture of ArcGIS online as shown in Figure 6., and the polygon type map of inundation damage prediction was made. It had therefore higher precision than existing one on numerical map.

5. Conclusion

In this study, river inundation area was analyzed using one dimensional HEC-RAS module with basis analysis, and inland overflow was analyzed using two dimensional XP-SWMM module with geographical information. The more precise map of inundation damage prediction was made by scanning the GIS basis satellite picture on the analyzed inundation area. So, the development of tool for more availability with coordinate unification will be proceeded to make systematically map of inundation damage in the national level.

The conclusions are as follows,

First, inundation area was predicted with one, two dimensional program constructing the input materials such as topography and rainfall. The precision increased because of the materials of actually surveyed river, already established GIS materials and geographical data.

Second, predicted inundation area was decided using real satellite picture with GIS Georeferencing. This has higher precision and reality than the existing map of inundation damage prediction based on numerical topography.

Hopefully, for the future, the mapping program shall be made for better making map of inland & river inundation damage prediction – with high efficiency and standardization - with a development of tool combining one and two dimensional analysis materials of inundation damage with GIS basis geographical materials and spatial analysis technology.

Acknowledgments

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Authors

Kyung Hoon Ahn, 2008. BS degree in Civil Engineering, In-cheon National University. 2010. MS degree in Civil Engineering, In-cheon National University. 2016~ Senior Researcher of ICUH (International Center for Urban Water Hydroinformatics Research & Innovaition).

Joo Won Kim, 1989. MS degree in Civil Engineering, Soong-sil University. 2011. Ph.D. degree in Civil and Environmental Engineering, In-cheon National University. 2014~ Executive Researcher of ICUH (International Center for Urban Water Hydroinformatics Research & Innovaition).

Sang Jin Ahn, 1963. BS degree in Civil Engineering, In-ha University. 1969. MS degree in Civil Engineering, Han-yang University. 1980. Ph.D. degree in Civil Engineering from In-ha University. 2007~Professor emeritus of Chung-Buk National University. 2011~ Director at the ICUH (International Center for Urban Water Hydroinformatics Research & Innovaition).

Ji On Lim, 2012. BS degree in Civil Engineering, kyung-pook National University. 2016~ Researcher of ICUH (International Center for Urban Water Hydroinformatics Research & Innovaition), (E-mail : 916wisdom@naver.com).