Scenario-Based Urban Flood Forecast with Flood Inundation Map

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MOLIT
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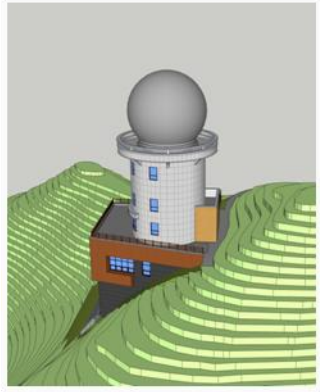
Han River Flood Control Office

CONTENTS

I. BACKGROUND AND CONCEPT OF RADAR APPLICATION





REPEATING FLOOD DISASTERS !



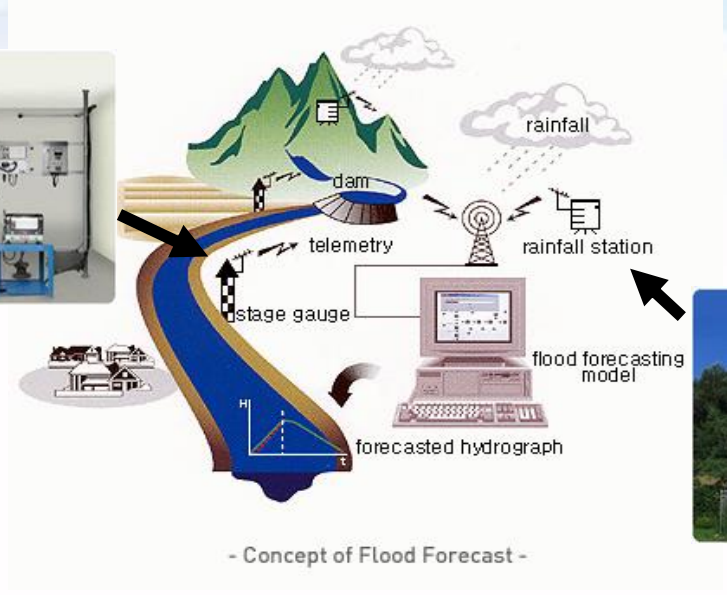





FLASH AND UNEXPECTED FLOODING...

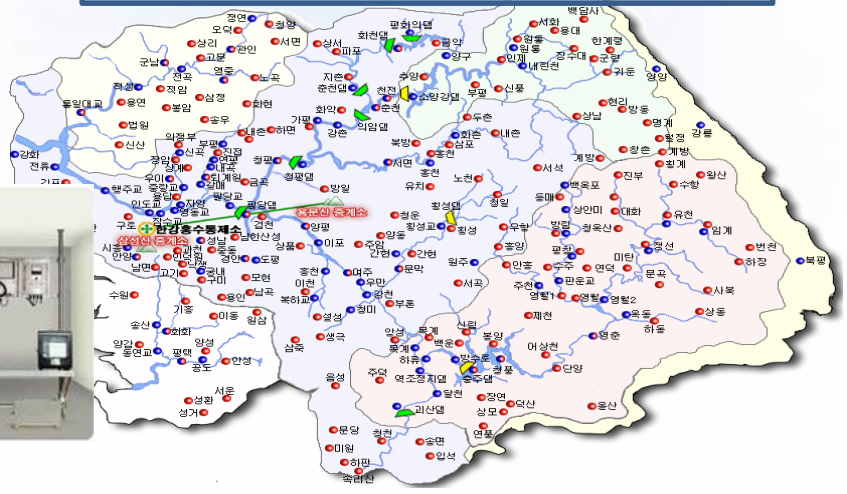
LIMITATIONS OF CURRENT FLOOD FORECAST

CURRENT FLOOD FORECAST SYSTEM



- Concept of Flood Forecast -

Hydrologic stations distribution in Han river



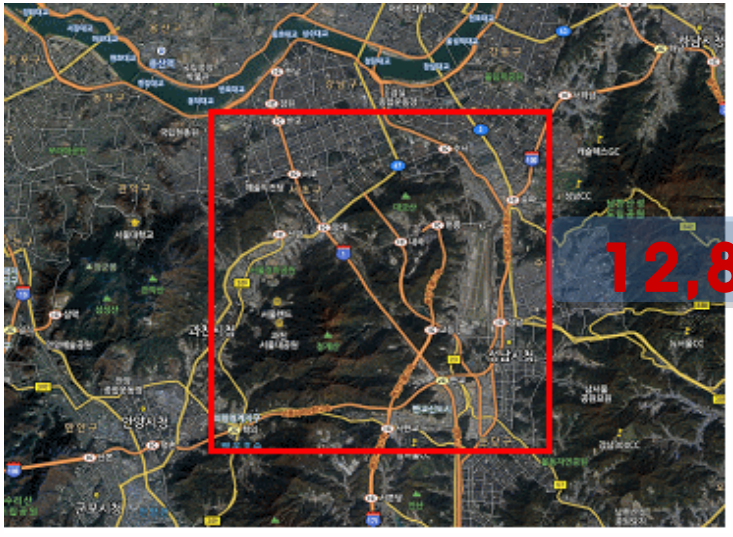
- Traditional flood forecast based on point rain gauges has shown the limits in space and time resolution
- Installation and operation of fully-covered necessary rain gauges are not easy due to budget and maintenance problems

RAIN RADAR ADVANTAGES

RAIN RADAR OFFERS UNIQUE ADVANTAGES

- Coverage over large areas
- Temporal updates as short as 2.5 minutes
- High resolution in space

Ground rain gauge :
one per 200㎢(14km×14km), 10 min interval

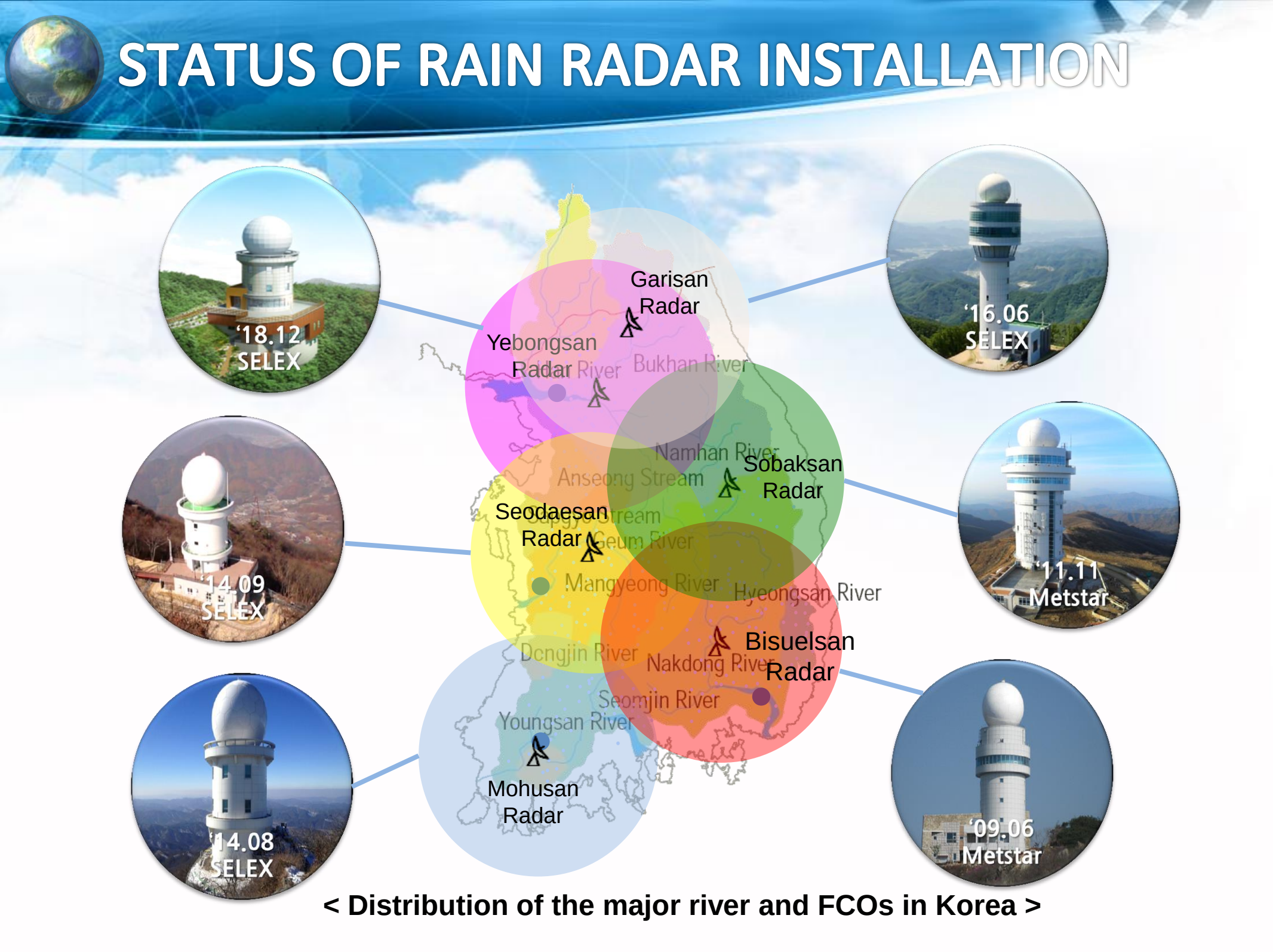


12,820 : 1

Rain radar :
~ 0.1563㎢(125m×125m), 2.5 min interval

Using rain radar which can observe areal rainfall, flash flood and urban inundation forecasting is possible!

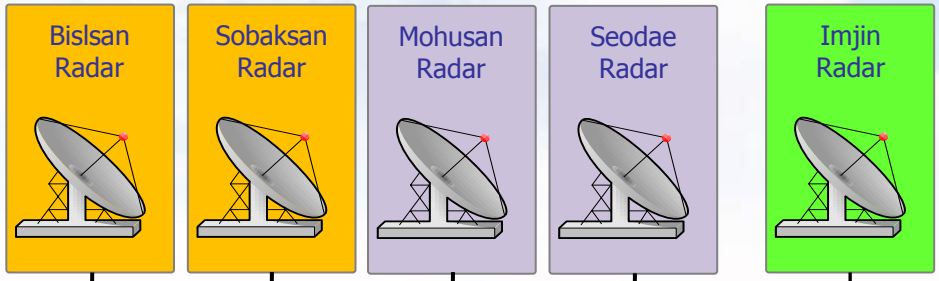
STATUS OF RAIN RADAR INSTALLATION



< Distribution of the major river and FCOs in Korea >

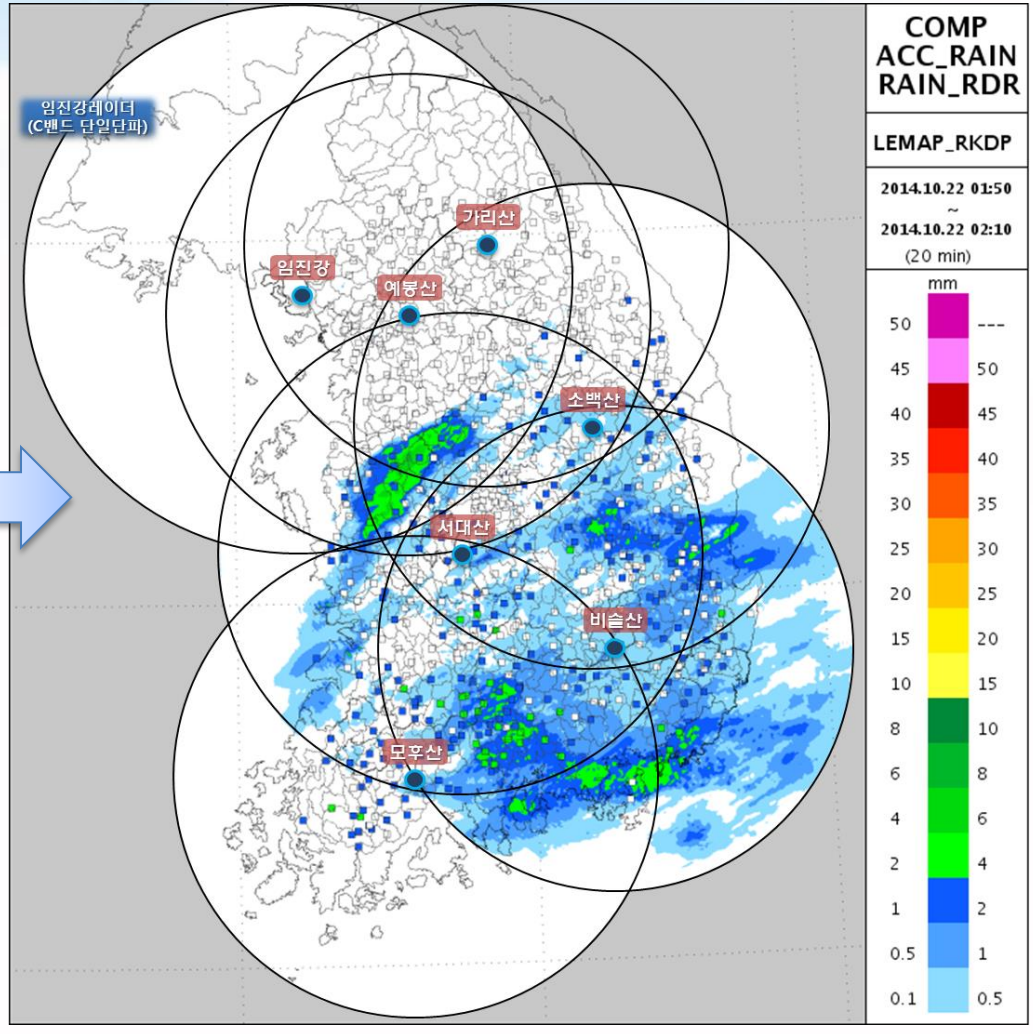
OPERATIONAL RAIN RADARS

Dual Pol **Single Pol**



Composite Server

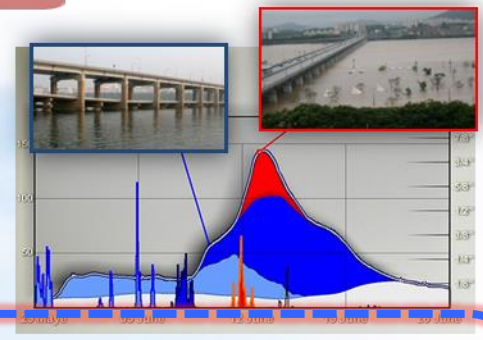
- Bisl/Sobak/Mohu/Seodae/Gari 2.5min composite
- Imjin River 6 min
- Bisl/Sobak/Mohu/Seodae/Imjin 2.5min Composite
- 10 min accumulated rainfall (before and after adjustment)



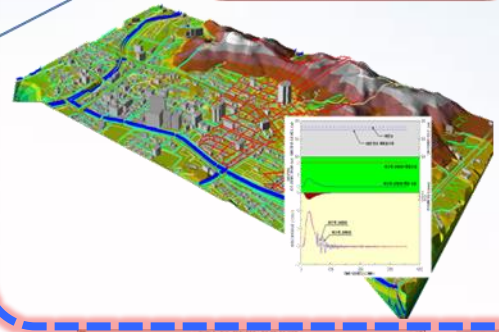
CONCEPT OF RADAR APPLICATION

Radar observation

River flood forecast

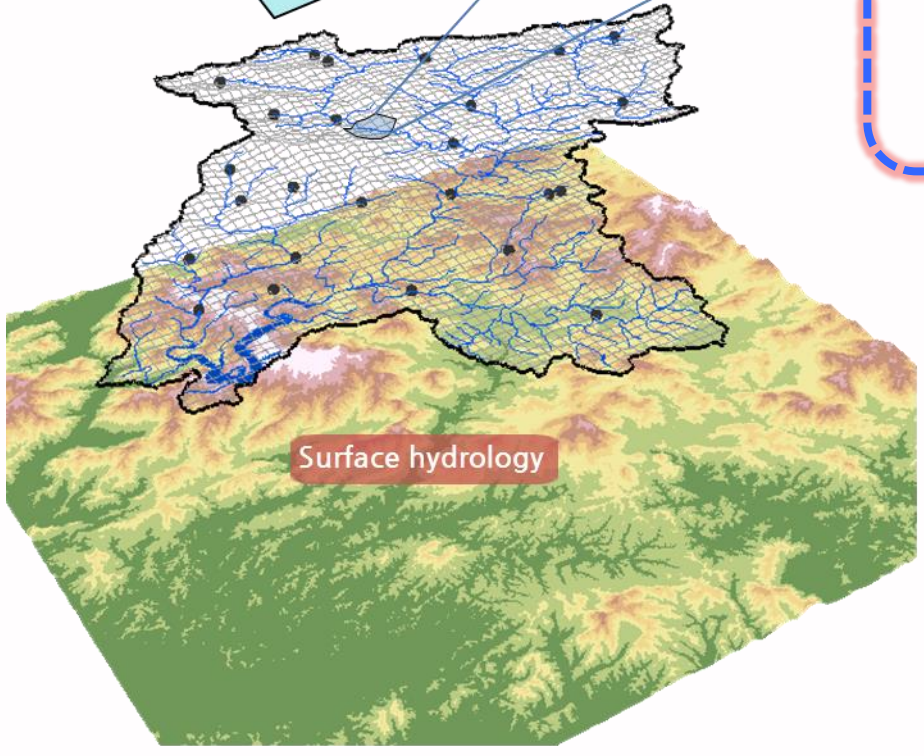


Urban flood forecast



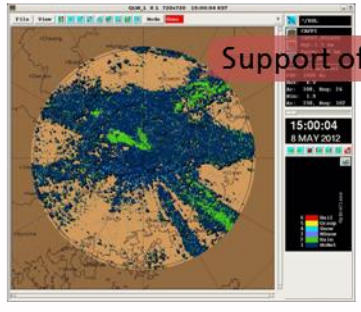
Flash flood forecast

Surface hydrology



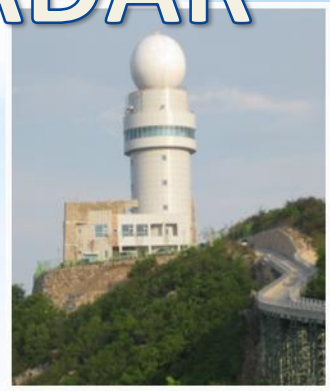
Monitoring of precipitation disasters

Support of snow disaster prevention

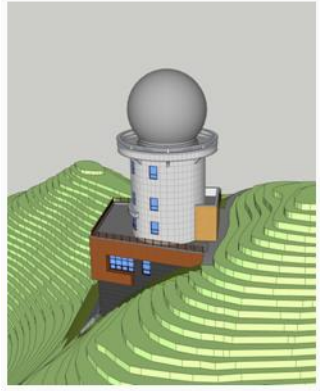


Support of agriculture disaster prevention

II. FLASH FLOOD PREDICTION USING RADAR



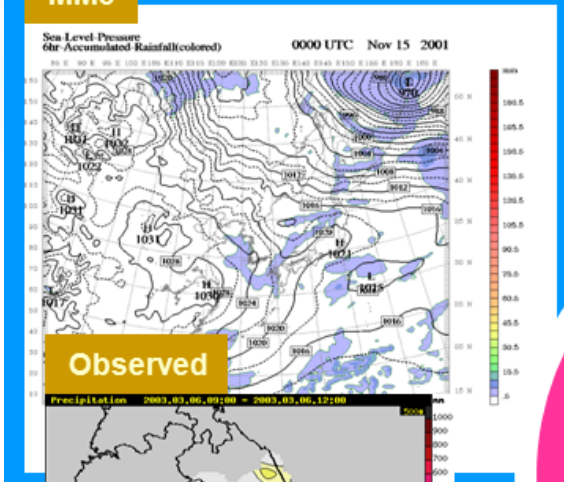


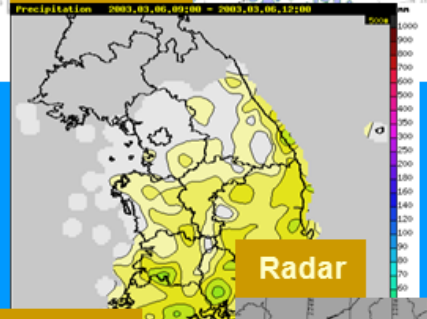
COMPONENTS OF FFG SYSTEM

Meteorological Components

MM5

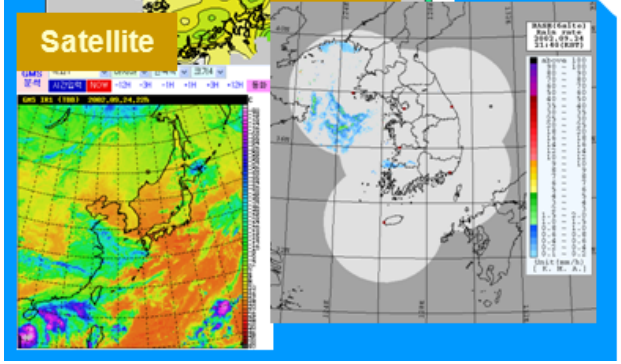


Observed



Radar

Satellite



Hydrologic Components

Threshold Runoff

- Manning's Bankfull Discharge
- Two Years Return Period Flow
- Snyder's Synthetic Unit Hydrograph
- GIUH

Estimation of Soil Moisture

- Sacramento SMA Model
- Mesoscale TOPMODEL
- VIC Model

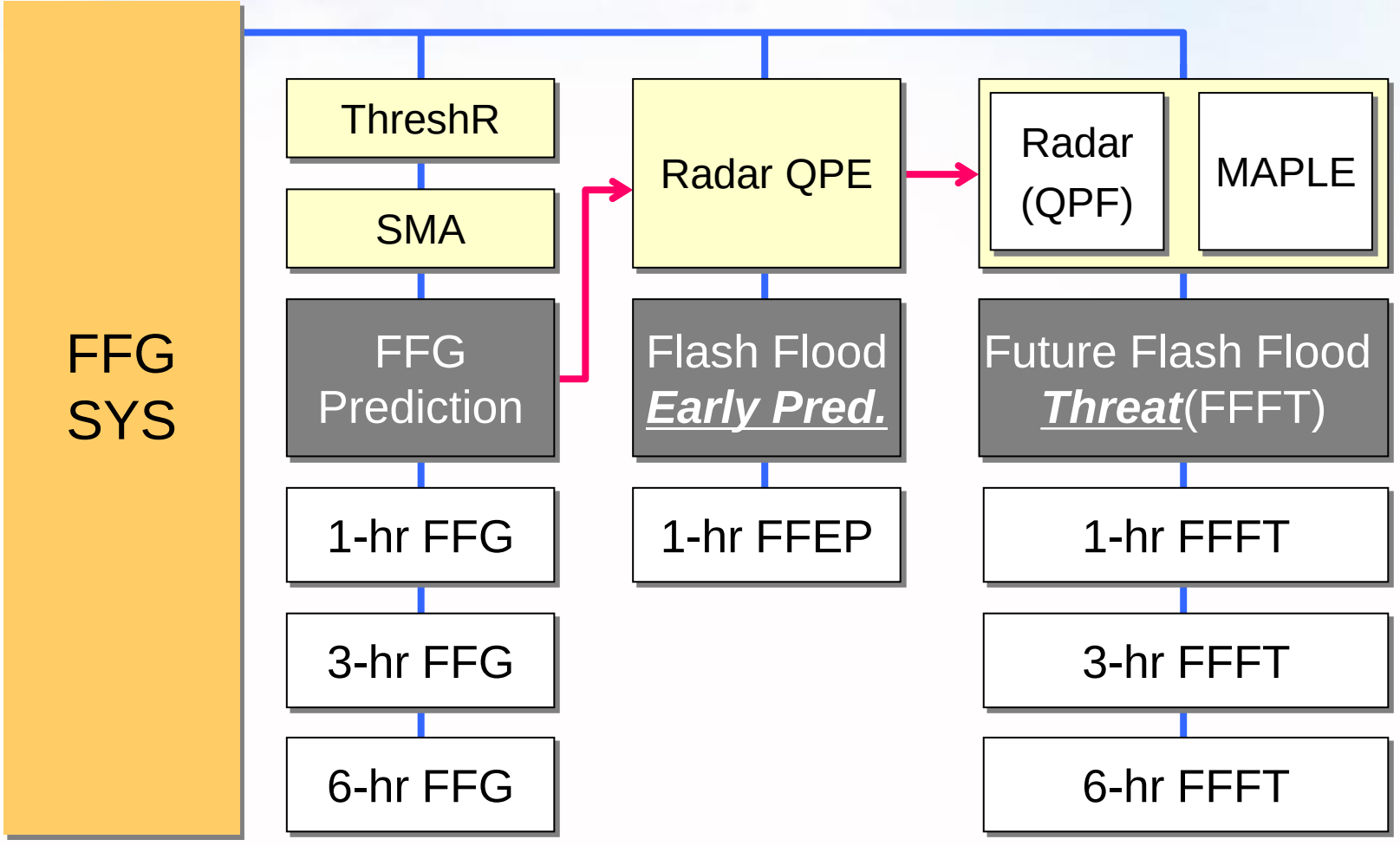
Flash Flood Watching & Warning

FFG Computation

INTEGRATED OPERATION IN REAL-TIME

INTEGRATED OPERATION FOR REAL-TIME PREDICTION

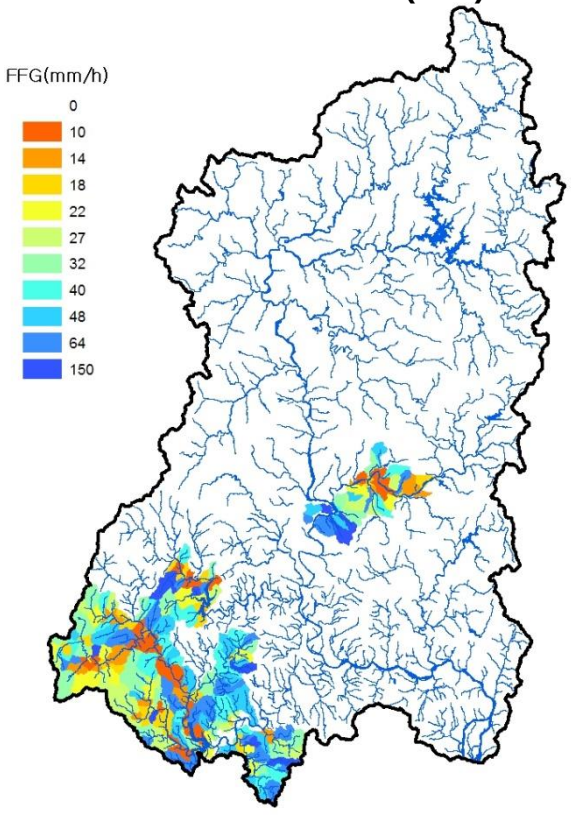
- Early flash flood prediction using radar QPE information
- Prediction of flash flood threat using QPF from Radar and MAPLE



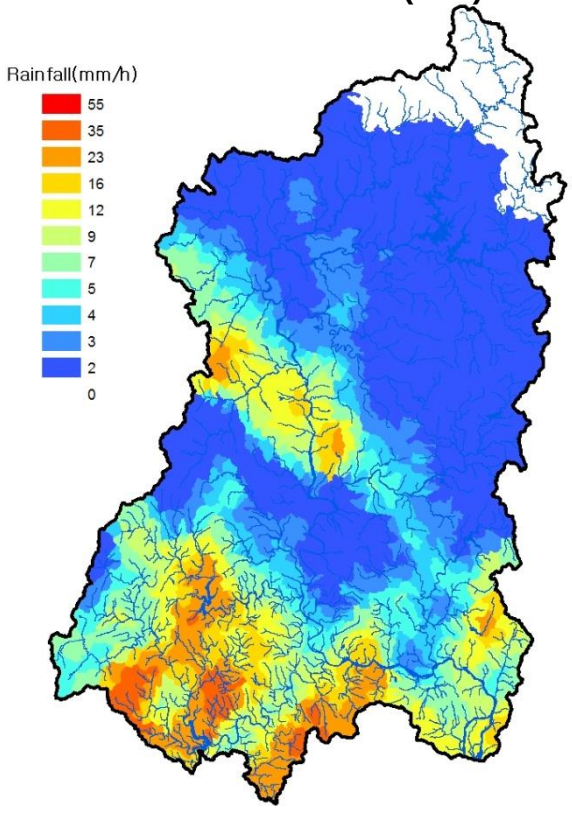
REAL-TIME RESULTS OF FFP SYSTEM

PREDICTED RESULTS AT 23:00 KST AUG/02/2014

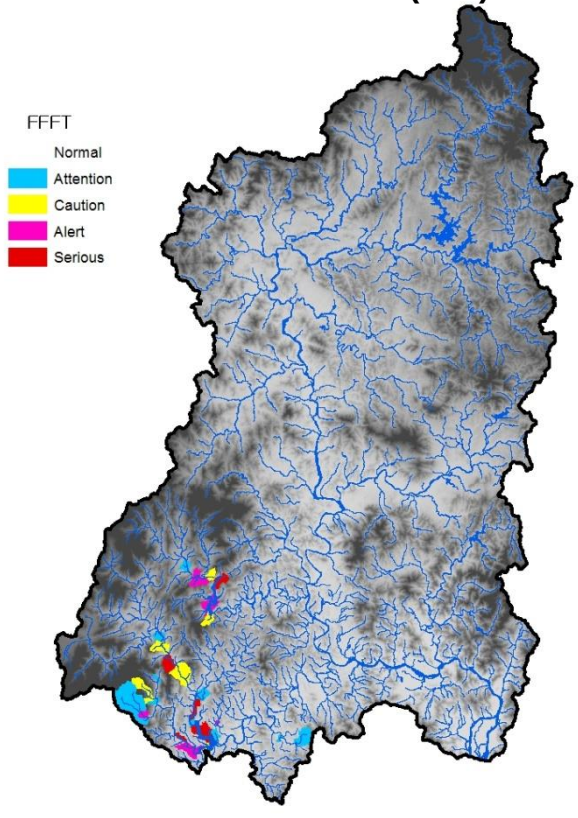
Flash Flood Guidance
2300 KST 08/02/2014(+1H)



Radar Rainfall Forecast
2300 KST 08/02/2014(+1H)



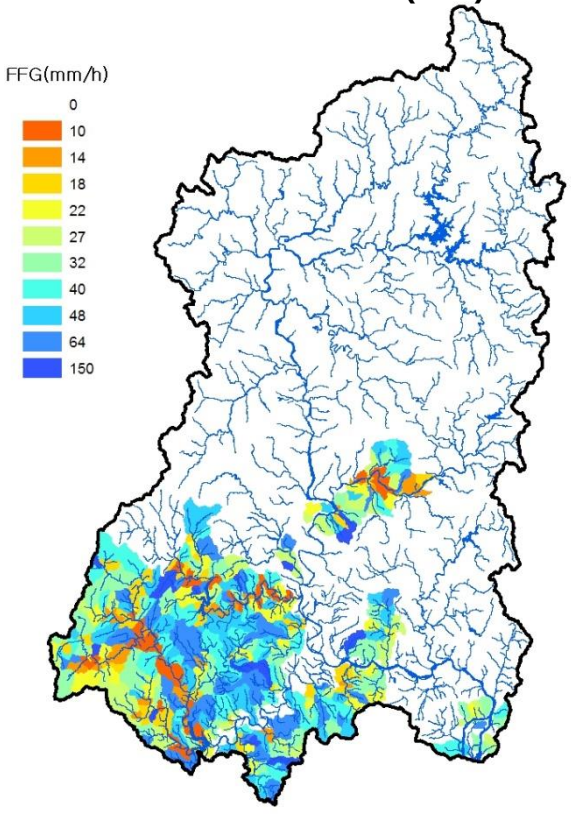
Future Flash Flood Threat
2300 KST 08/02/2014(+1H)



PREDICTED RESULTS AT 01:00 KST AUG/03/2014

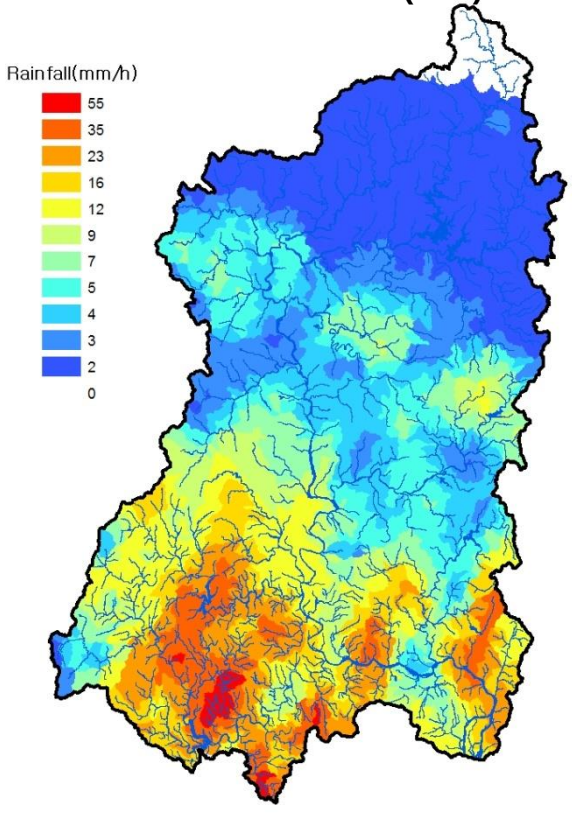
Flash Flood Guidance

0100 KST 08/03/2014(+1H)



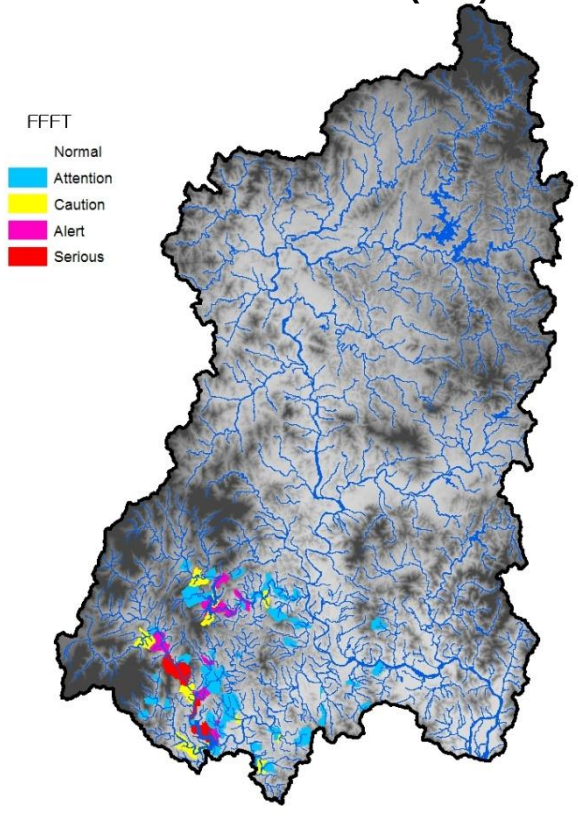
Radar Rainfall Forecast

0100 KST 08/03/2014(+1H)



Future Flash Flood Threat

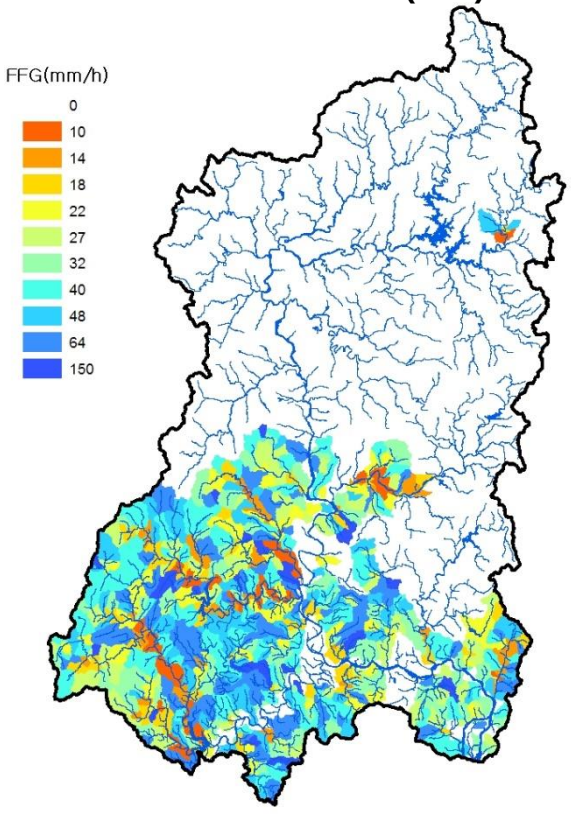
0100 KST 08/03/2014(+1H)



PREDICTED RESULTS AT 03:00 KST AUG/03/2014

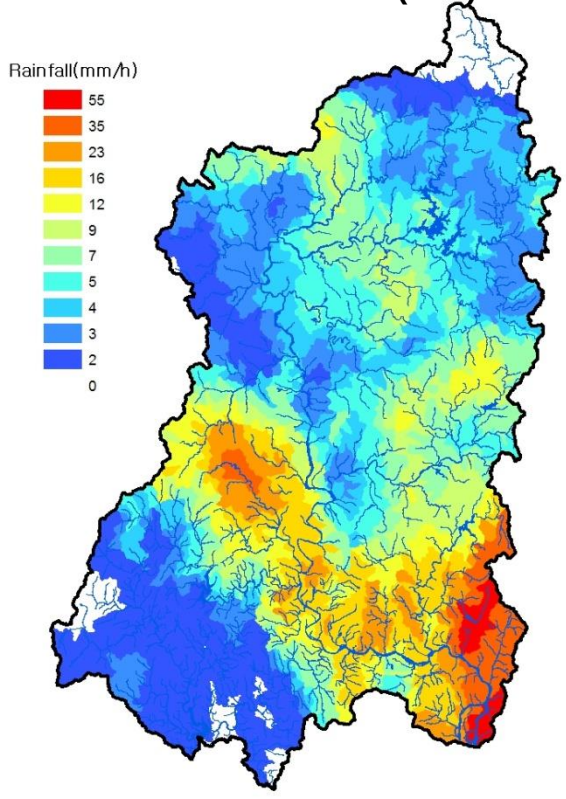
Flash Flood Guidance

0300 KST 08/03/2014(+1H)



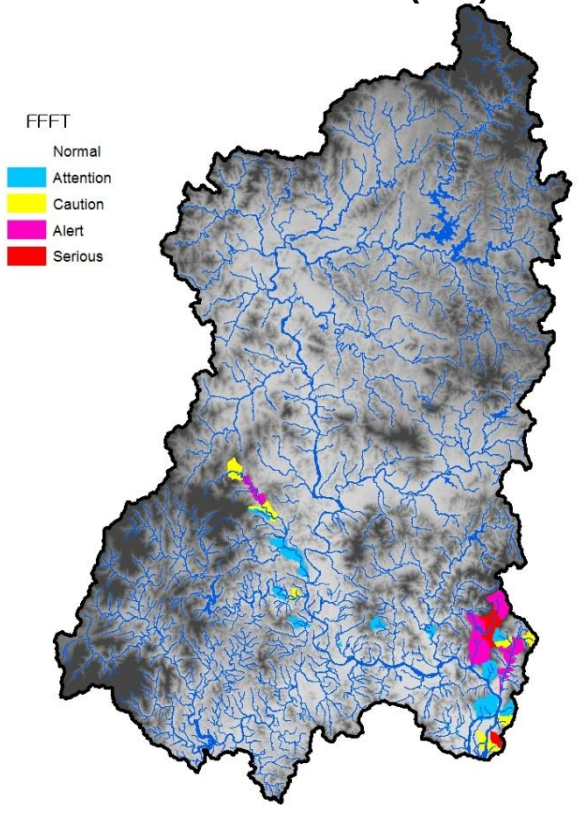
Radar Rainfall Forecast

0300 KST 08/03/2014(+1H)

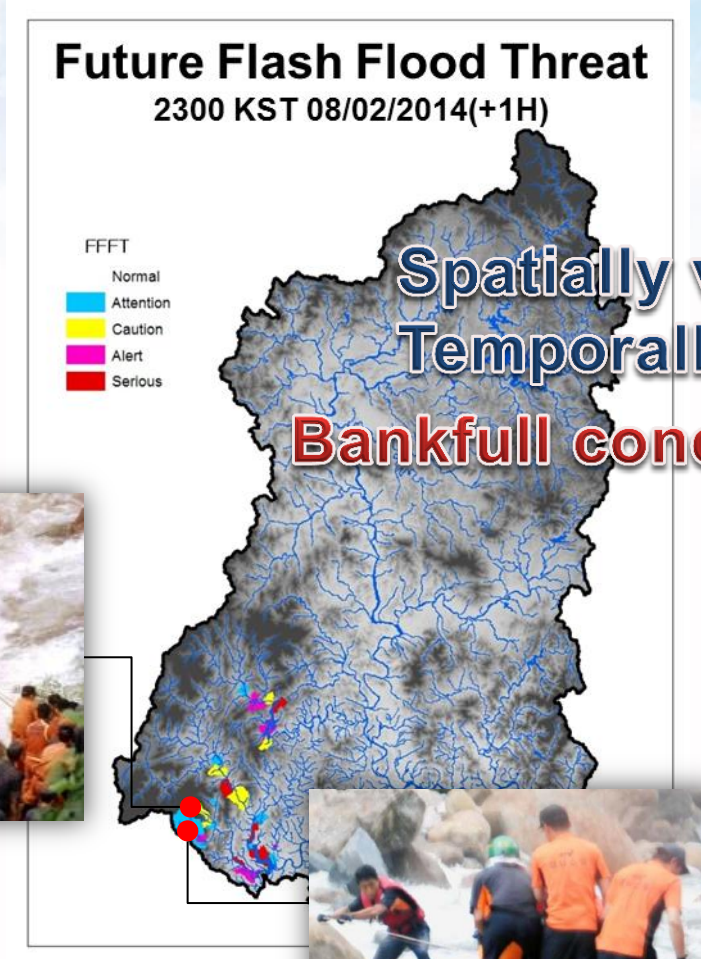


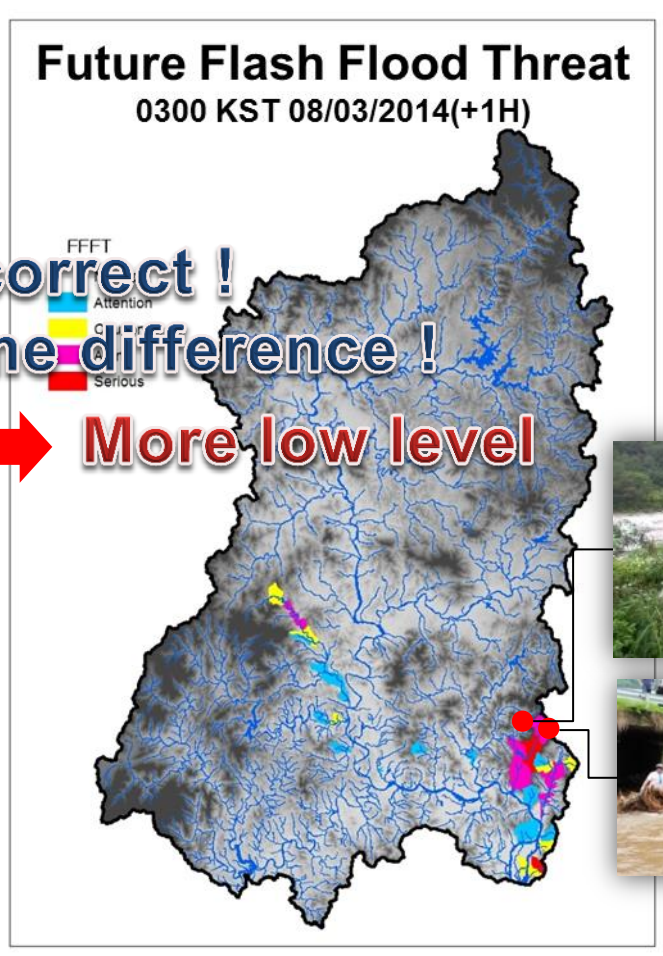
Future Flash Flood Threat

0300 KST 08/03/2014(+1H)



ANALYSIS OF LOCALIZED FLASH FLOOD PREDICTION RESULTS

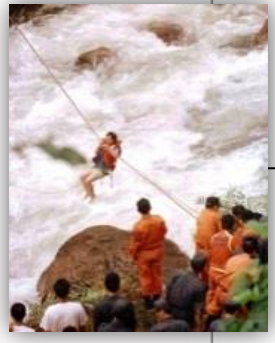




Spatially very correct !

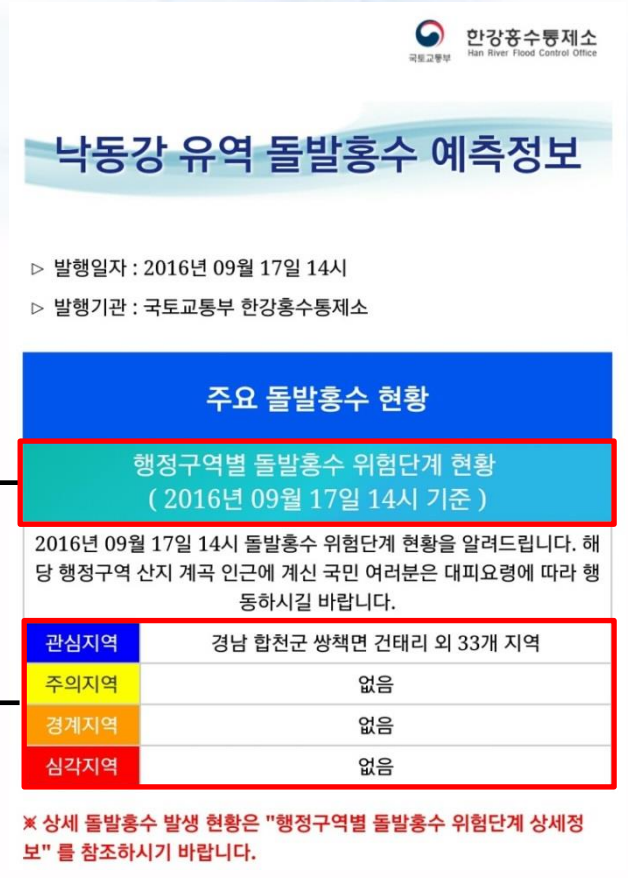
Temporally some difference !

Bankfull concept ➡ More low level



ISSUED MESSAGE FOR PROVINCIAL GOVERNMENT

- MMS(Multi-media Message Service) linked next images is sent to the person in charge of disaster preparation



한강홍수통제소 Han River Flood Control Office

낙동강 유역 돌발홍수 예측정보

▷ 발행일자 : 2016년 09월 17일 14시

▷ 발행기관 : 국토교통부 한강홍수통제소

주요 돌발홍수 현황

행정구역별 돌발홍수 위험단계 현황
(2016년 09월 17일 14시 기준)

2016년 09월 17일 14시 돌발홍수 위험단계 현황을 알려드립니다. 해당 행정구역 산지 계곡 인근에 계신 국민 여러분은 대피요령에 따라 행동하시길 바랍니다.

관심지역	경남 합천군 쌍책면 건태리 외 33개 지역
주의지역	없음
경계지역	없음
심각지역	없음

※ 상세 돌발홍수 발생 현황은 "행정구역별 돌발홍수 위험단계 상세정보" 를 참조하시기 바랍니다.

돌발홍수 위험단계별 대피요령

위기경보	통보기준	판단기준	행동요령
관심	점검	무릎 높이를 넘는 돌발홍수 발생 가능성 존재	수시로 기상정보를 파악하고 돌발홍수정보 관심 유지
		산지 계곡을 건너기 어려운 경우	어린이, 노약자를 동반한 경우, 즉시 대피
주의	통제	허리 높이를 넘는 돌발홍수 발생 가능성 존재	산지 계곡에서 철수하거나 부득이한 경우, 고지대로 대피
		산지 계곡에서 보행이 어려운 경우	차량운전자는 신속히 안전한 곳으로 이동
경계	대피준비	가슴 높이를 넘는 돌발홍수 발생 가능성 존재	산지 계곡을 무리하게 건너지 말고 우회로 이용 대피
		산지 계곡에 불어난 물로 인해 사람이 휩쓸려 갈 수 있는 경우	우회로가 없을 경우, 고지대로 대피
심각	대피	하천의 제방 높이를 넘는 돌발홍수 발생 가능	산지 계곡에서 즉시 철수 및 고지대 대피
		심각한 재산 및 인명피해 발생 가능성이 확실한 경우	119에 신고하여 도움 요청

※ 다음 돌발홍수 예측 정보는 상황발생 시 제공됩니다.

행정구역별 돌발홍수 위험단계 상세 정보

행정구역	돌발홍수 위기경보 단계				하천
	관심	주의	경계	심각	
경남 합천군 쌍책면 건태리					상신천
경남 합천군 쌍책면 다라리					상신천
경남 합천군 쌍책면 상포리					상신천
경남 합천군 쌍책면 성산리					상신천
경남 합천군 쌍책면 오서리					상신천
경남 합천군 율곡면 갑산리					상신천
경남 합천군 율곡면 낙민리					상신천
경남 합천군 율곡면 내천리					상신천
경남 합천군 적중면 죽고리					상신천
경북 안동시 남문동					낙동강
경북 안동시 남부동					낙동강
경북 안동시 대석동					낙동강
경북 안동시 동문동					낙동강
경북 안동시 동부동					낙동강
경북 안동시 명륜동					낙동강
경북 안동시 목성동					낙동강
경북 안동시 법상동					낙동강

Prediction time

Prediction result by critical stage

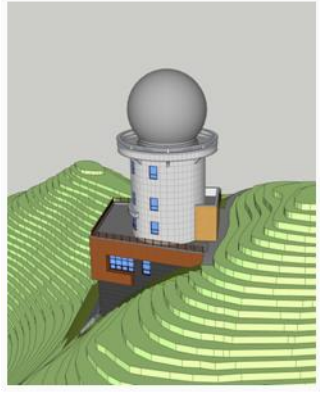
Behavioral know-how by critical stage

Detail information by provincial government and critical stage

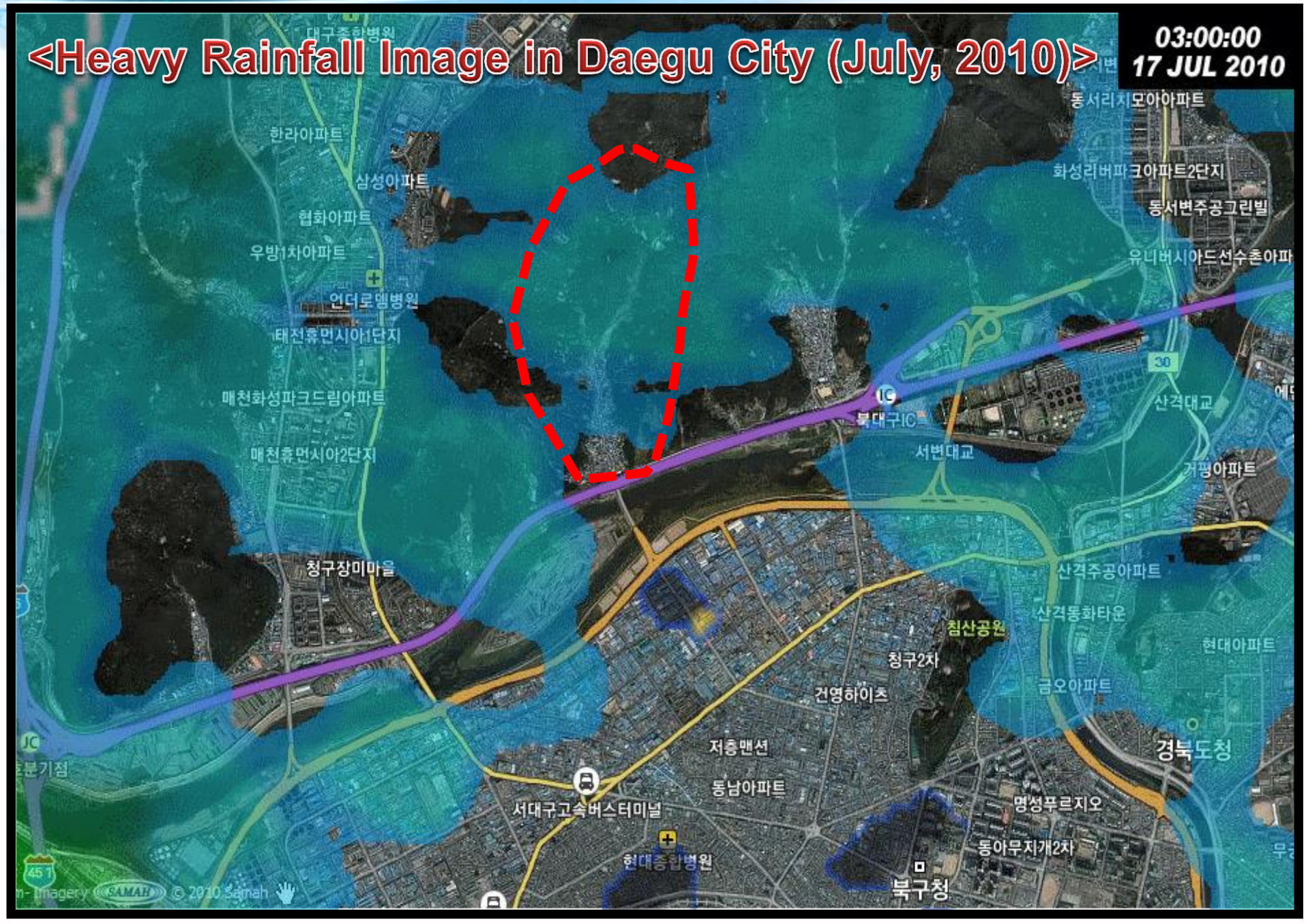
III. URBAN FLOOD PREDICTION USING RADAR





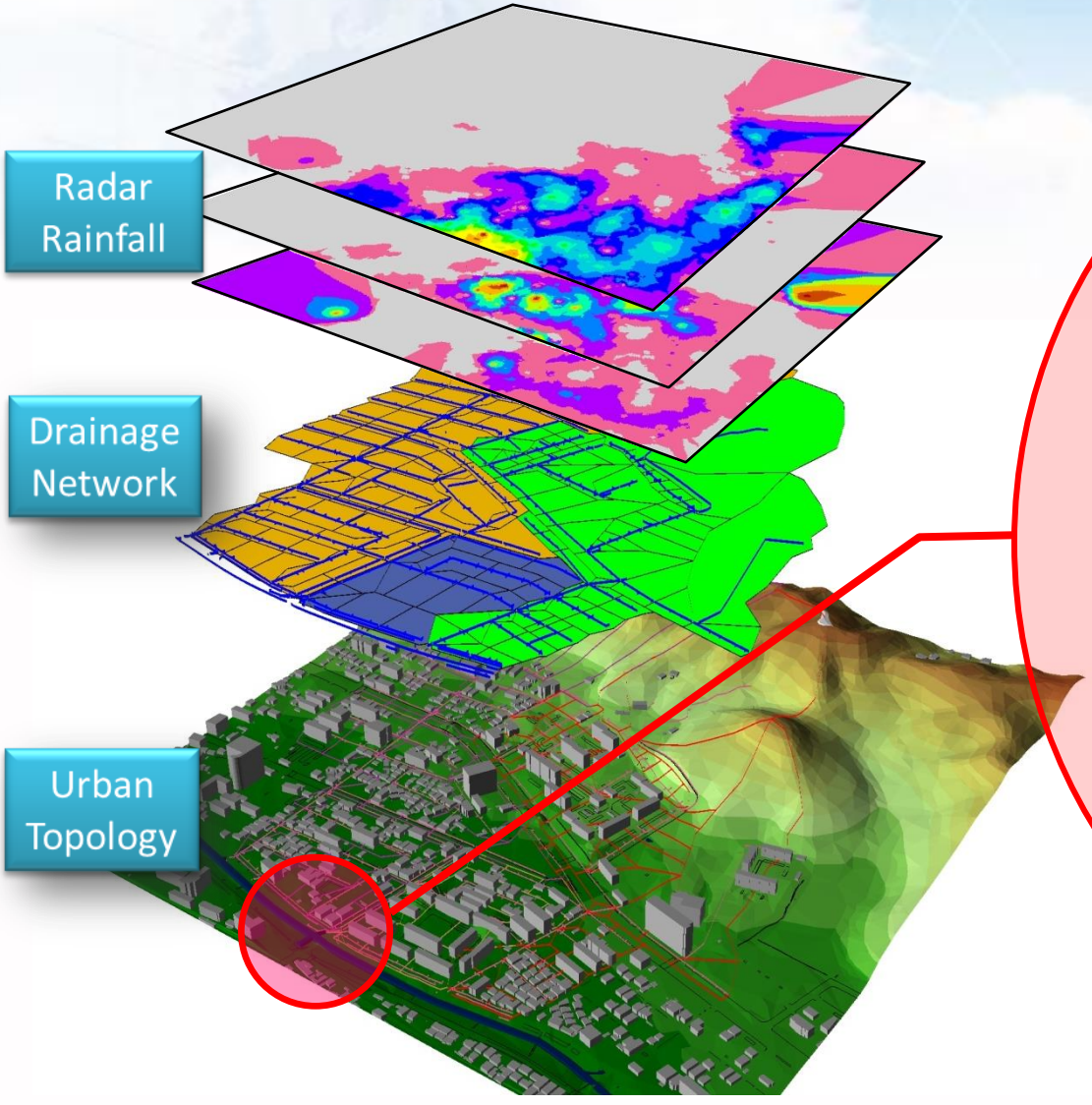



RADAR RAINFALL IN UNGAUGED URBAN AREA

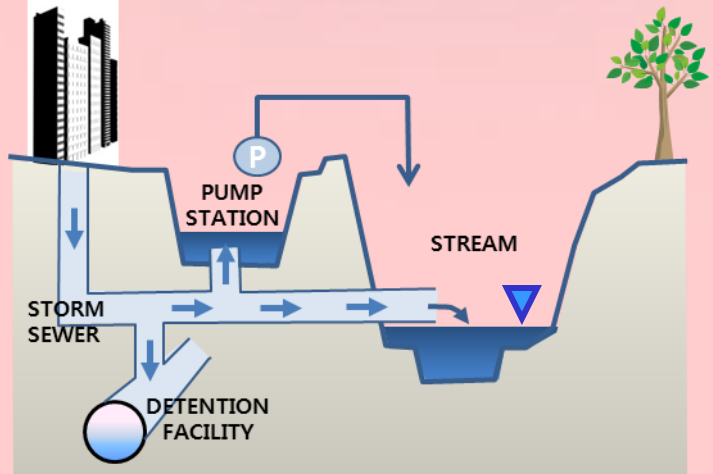


MODELING OF URBAN FLOOD PREDICTION

CLASSICAL DRAINAGE NETWORK 1D MODELING

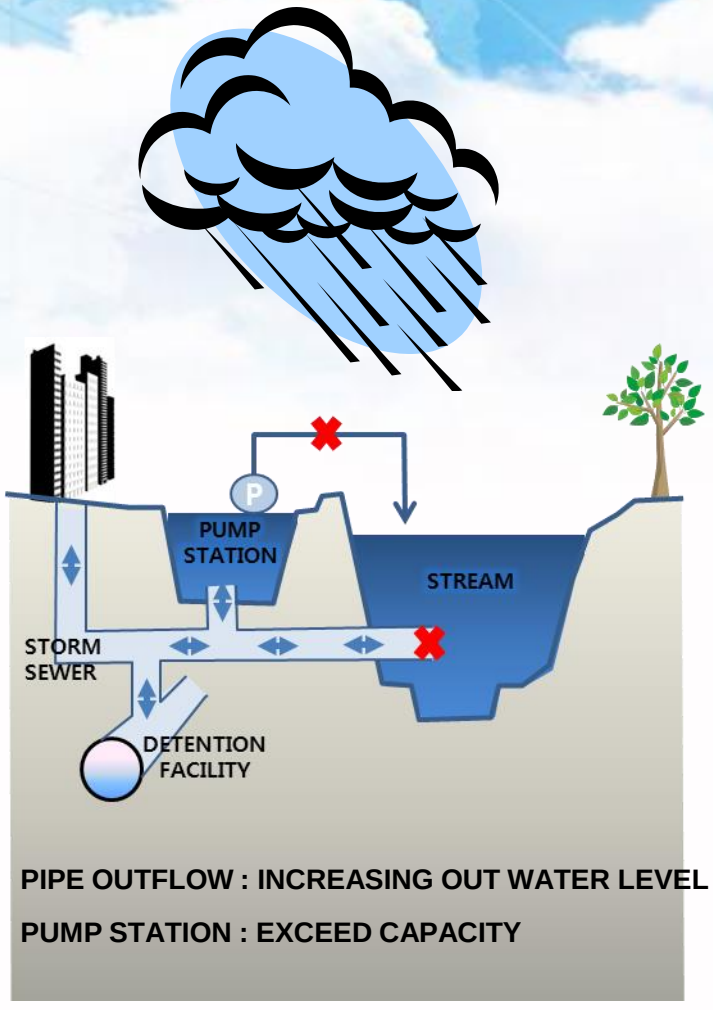


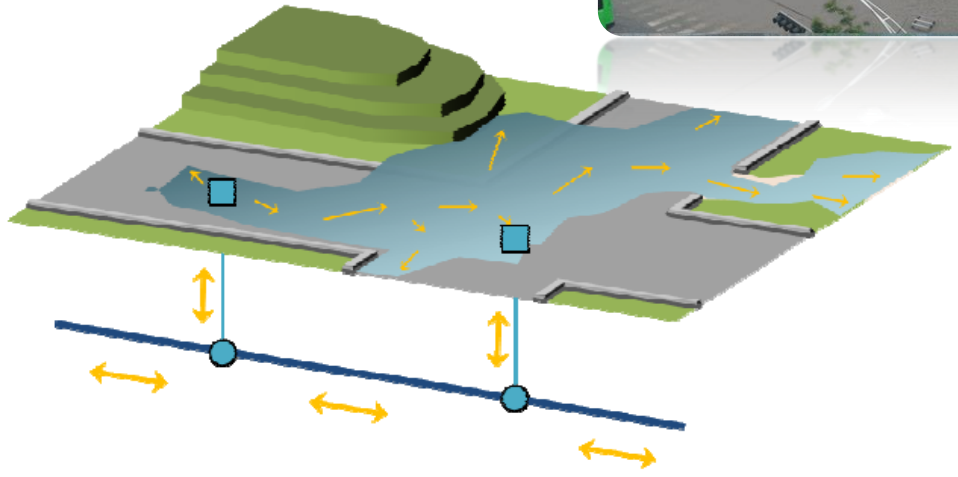
STORMWATER RUNOFF WITHIN PIPE SYSTEM



AVAILABLE MODEL : MOUSE, SWMM, MIKE URBAN….

1D-2D MODEL : 1D MODEL COUPLED TO 2D SURFACE MODEL





- Exchanges between the collection system and the surface are handled through coupling links that the **nodes** (such as manhole) of the collection system network are connected to **cells** of the 2D surface model

2D SURFACE MODEL : 2D DIFFUSION WAVE MODEL

- The 2D engine solving the Saint-Venant 2-dimensional flow equation
- The hydrodynamic flow computation with the 2D surface model allows flow velocities with 2-directions components

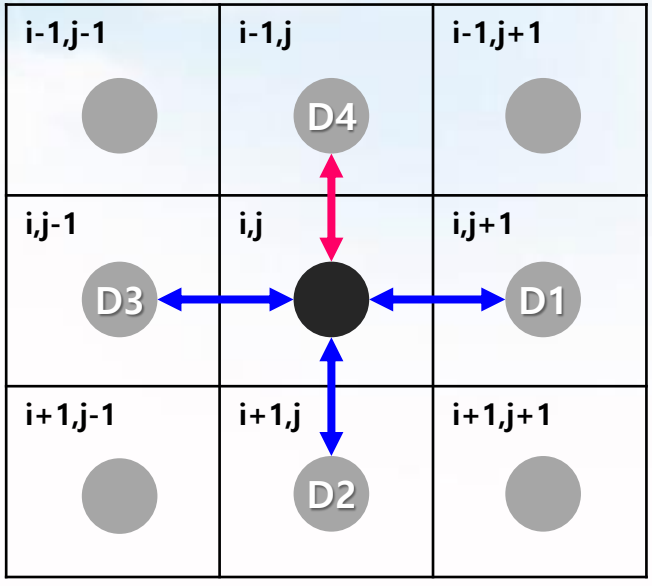
Cont. Equation

$$\frac{\partial h}{\partial t}+\frac{\partial q_x}{\partial x}+\frac{\partial q_y}{\partial y}=0$$

Momentum Equation

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+\upsilon\frac{\partial u}{\partial y}=g\left[S_{0x}-S_{fx}-\frac{\partial h}{\partial x}\right]$$

$$\frac{\partial \upsilon}{\partial t}+u\frac{\partial \upsilon}{\partial x}+\upsilon\frac{\partial \upsilon}{\partial y}=g\left[S_{0y}-S_{fy}-\frac{\partial h}{\partial y}\right]$$



H-Q Equation

$$q=\frac{1}{n}h^{5/3}S_f{}^{1/2}$$ (Manning's Equation)

(Gain cond.) $when\ S_{fx}^t(i-1\rightarrow i)\geq 0,\ q_D^t(i-1\rightarrow i)=\frac{1}{n(i,i-1)}[d^t(i-1)]^{5/3}\left[S_{fx}^t(i-1\rightarrow i)\right]^{1/2}$

(Loss cond.) $when\ S_{fx}^t(i\rightarrow i-1)<0,\ q_D^t(i\rightarrow i-1)=-\frac{1}{n(i,i-1)}[d^t(i)]^{5/3}\left[-S_{fx}^t(i\rightarrow i-1)\right]^{1/2}$

Water Depth Variation

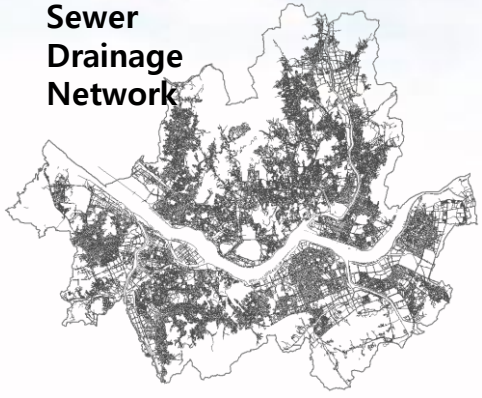
$$h_{i,j}^{t+dt}=h_{i,j}^t+e\cdot dt+\frac{c_1^t q_{D1}^t+c_2^t q_{D2}^t c_3^t q_{D3}^t+c_4^t q_{D4}^t}{ds}dt$$

CASE STUDY IN SEOUL METROPOLITAN

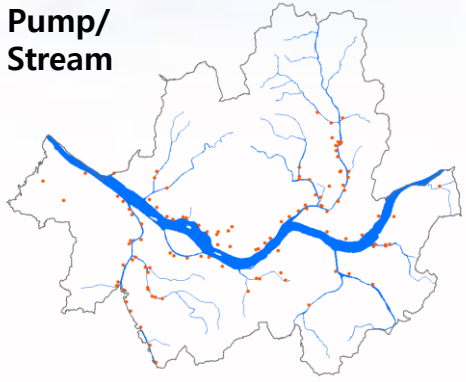
DELINEATION OF UNIT DRAINAGE AREA WHOLE SEOUL

- Total 83 unit drainage area delineation considering DEM, historical inundation damage cases

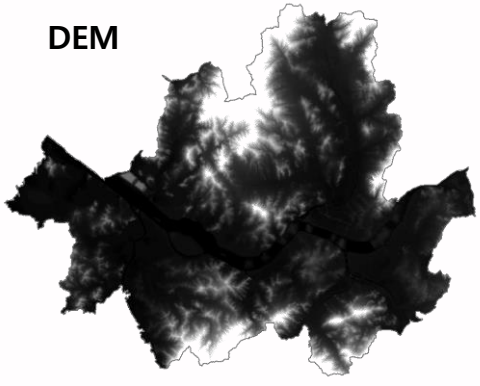
Sewer Drainage Network



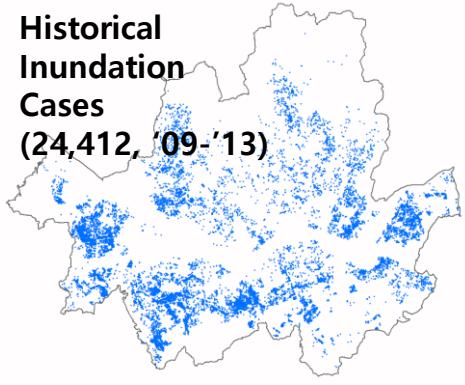
Pump/ Stream



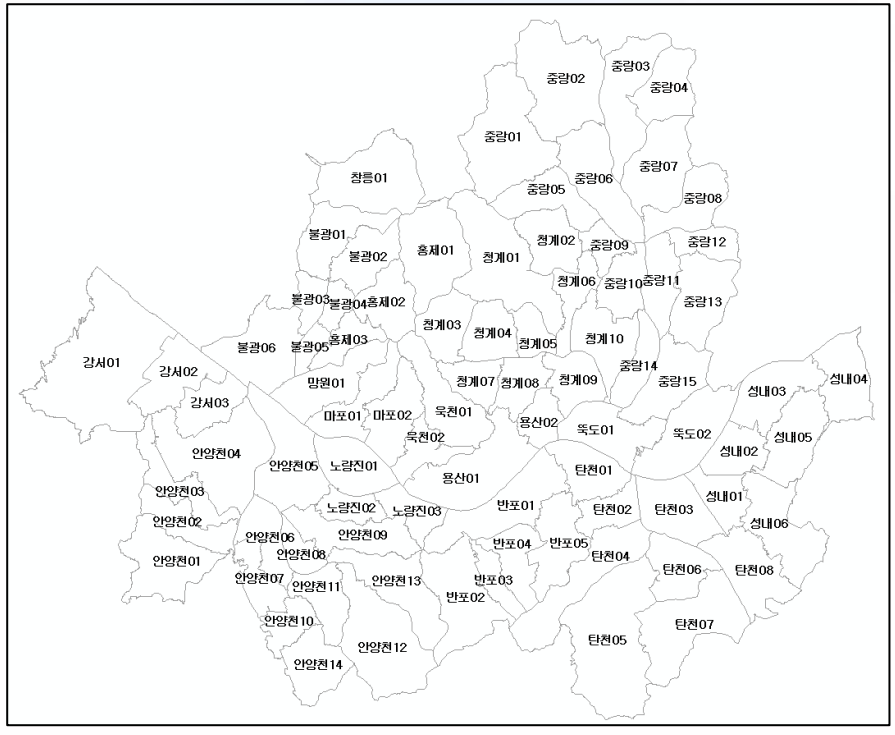
DEM



Historical Inundation Cases (24,412, '09-'13)



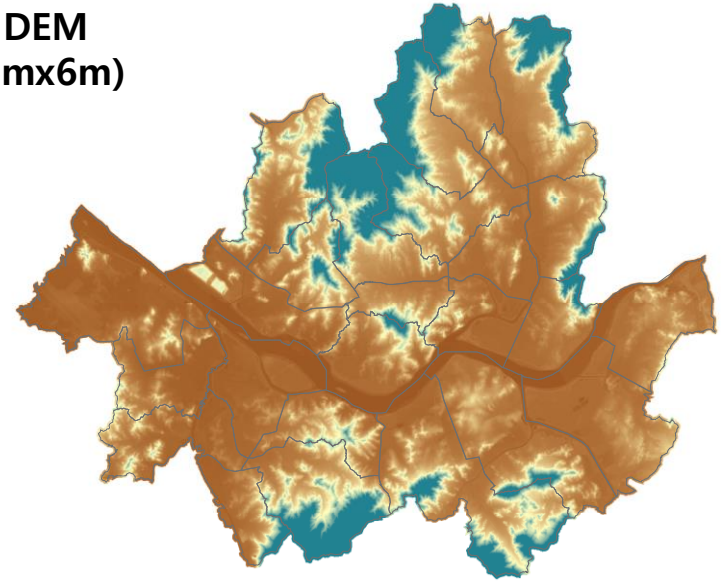
83 Unit Drainage Area



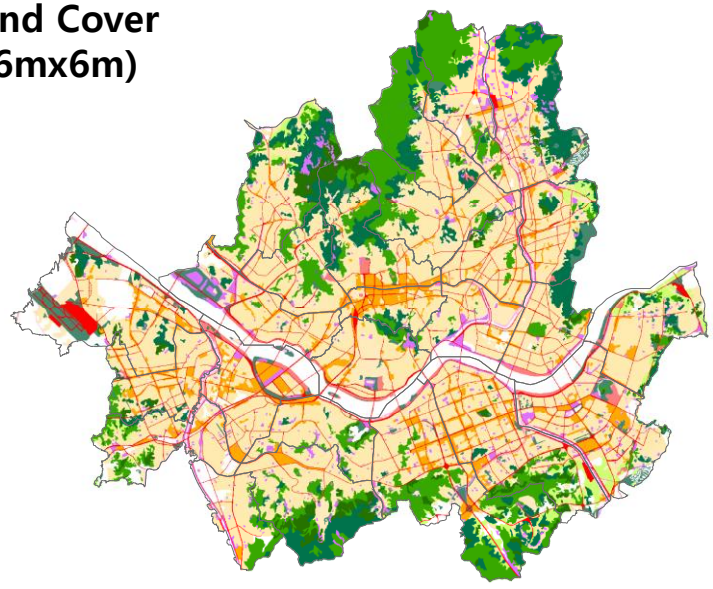
※ From this slide, the results were provided by Dr. Byengju Lee in HEC-KOREA Company.

TOPOGRAPHIC DATA AND DRAINAGE PIPE NETWORK

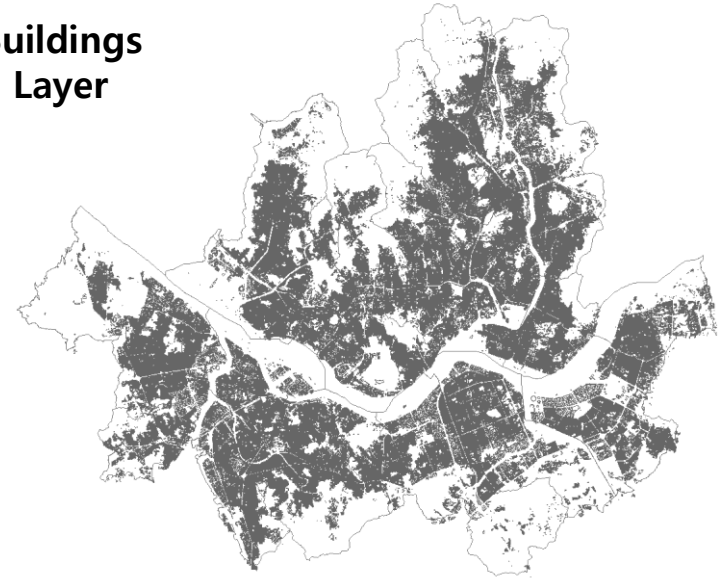
DEM
(6mx6m)



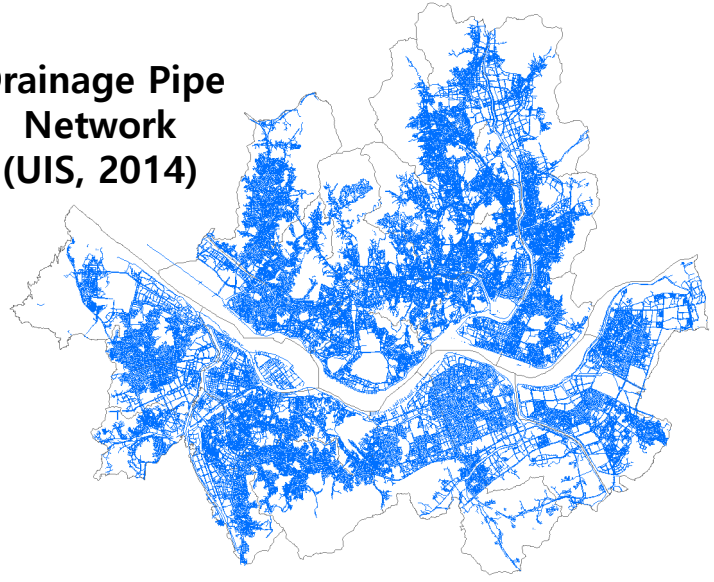
Land Cover
(6mx6m)



Buildings
Layer



Drainage Pipe
Network
(UIS, 2014)



SENSITIVITY OF PIPE DENSITY AND SPATIAL RESOLUTION

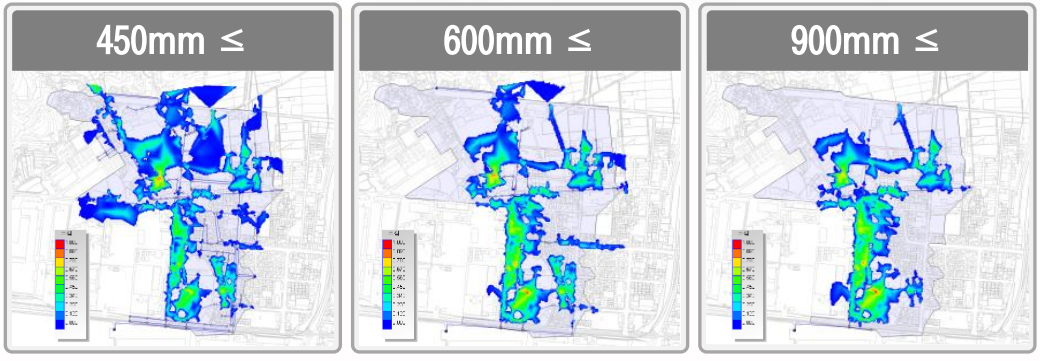
▸ Sensitivity analysis of pipe network density

- ➡ Inundation area is more than 30% different decreasing pipe density (450mm ➔ 900mm)
- ➡ Recommend more than 450mm diameter in low density area

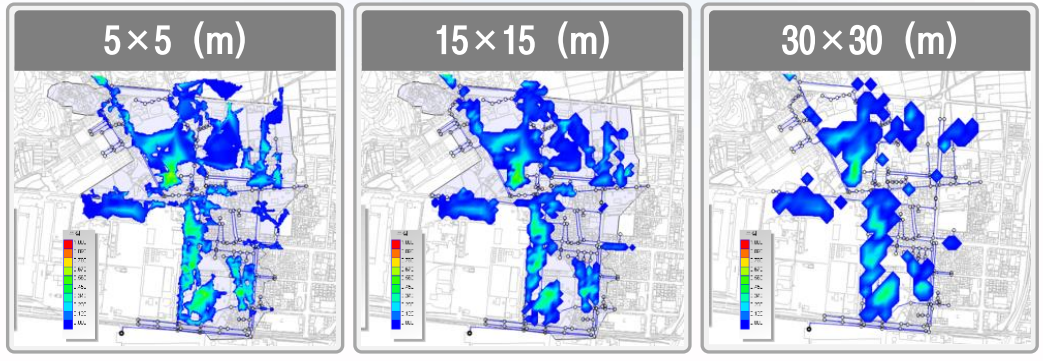
▸ Sensitivity analysis of spatial resolution

- ➡ Inundation area is more than 35% different increasing spatial resolution (5m×5m ➔ 30m ×30m)
- ➡ Recommend more than 10×10m in small urban area

Inundation result according to network density



Inundation result according to grid size



Inundation area acc. to rainfall frequency and network density

Items	Inundation Area (ha)			
	30yr Fre.	50yr Fre.	80yr Fre.	100yr Fre.
450mm	20.9	23.7	25.2	25.9
600mm	15.0(−28%)	17.6(−26%)	19.5(−23%)	20.4(−21%)
900mm	12.7(−39%)	15.0(−37%)	17.1(−32%)	18.1(−30%)

( ) is percentage of inundation area per 450mm diameter

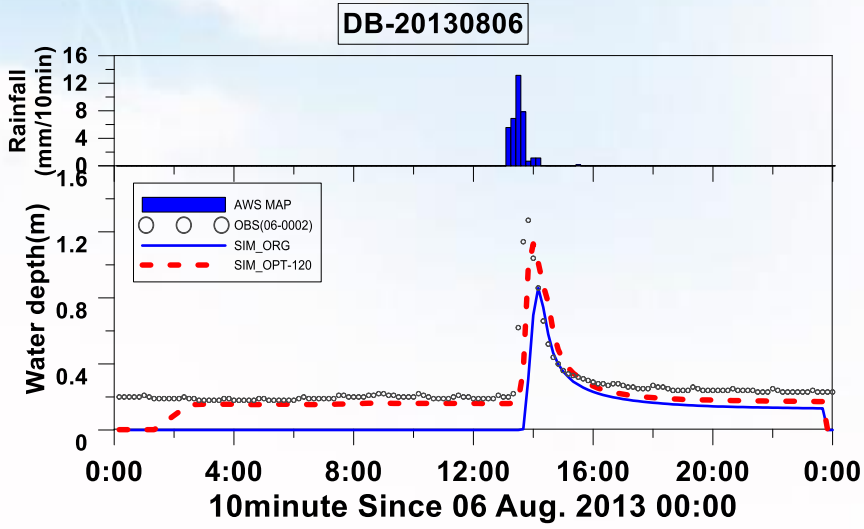
Inundation area according to grid size

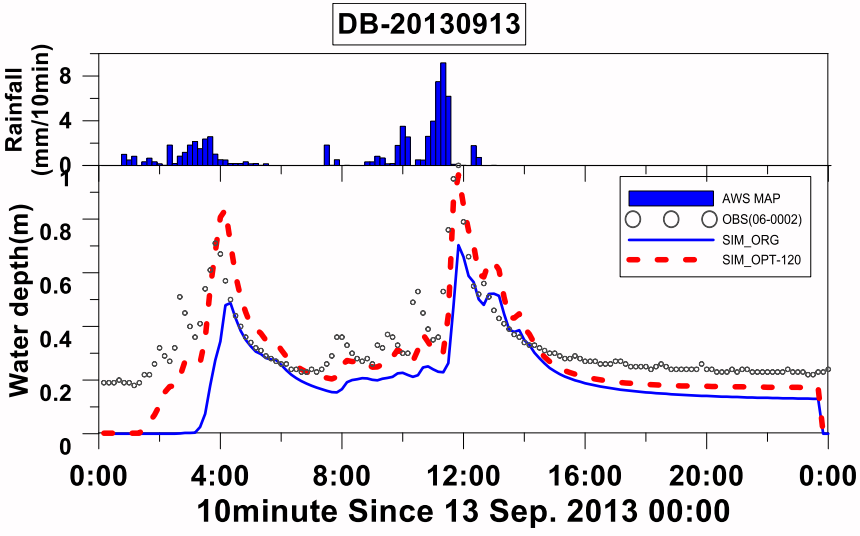
items	Inundation Area (ha)		
	5×5 (m)	15×15 (m)	30×30 (m)
450mm	20.9	17.6 (−15.8%)	13.7 (−34.4%)

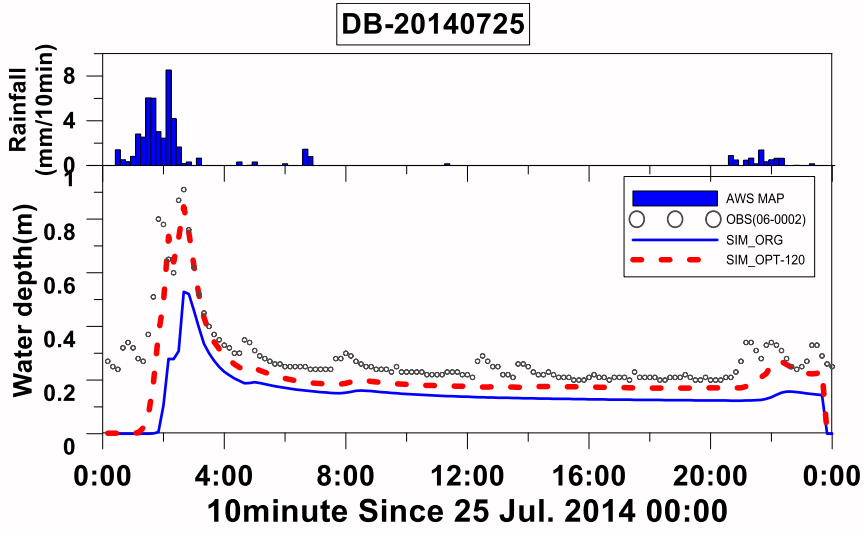
( ) is percentage of inundation area per 5×5m grid

SWMM 1D MODEL OPTIMIZATION

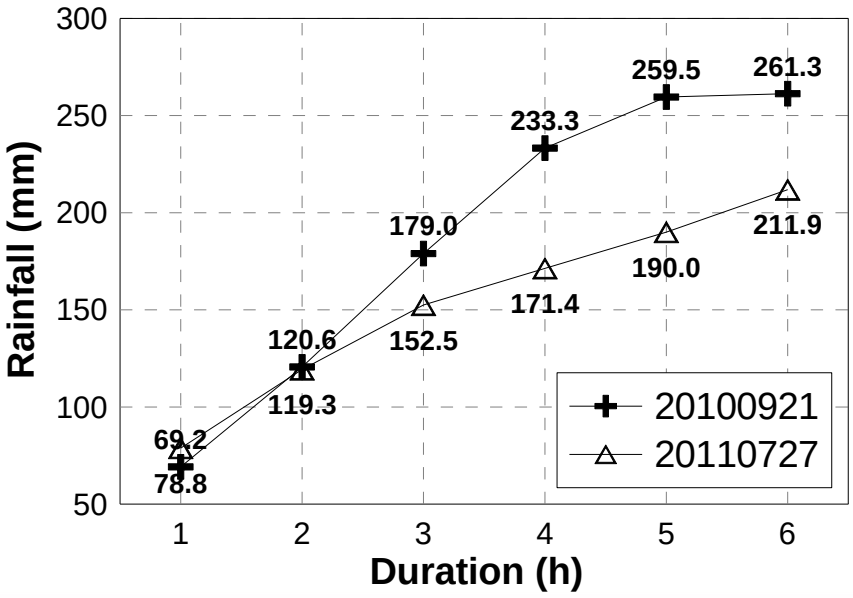
- Water level monitoring in 104 sewer networks by using UW type level meter
- Calibration of SWMM parameters by using observed water level

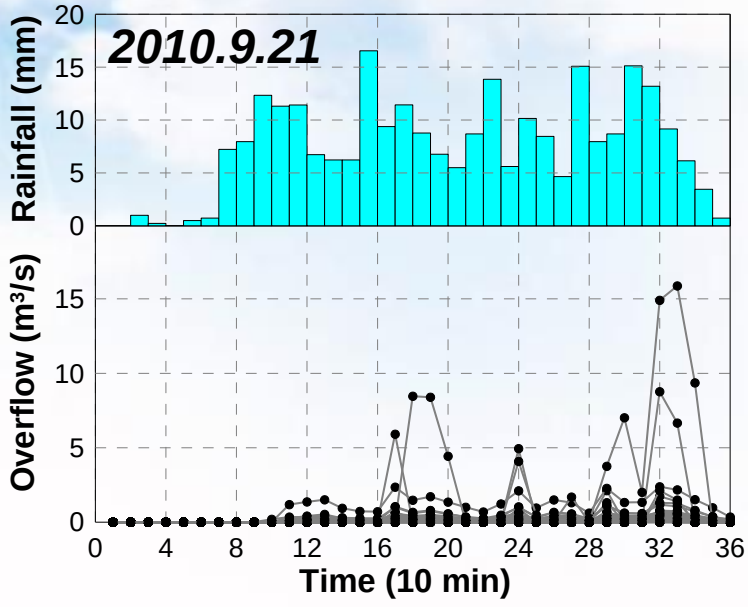


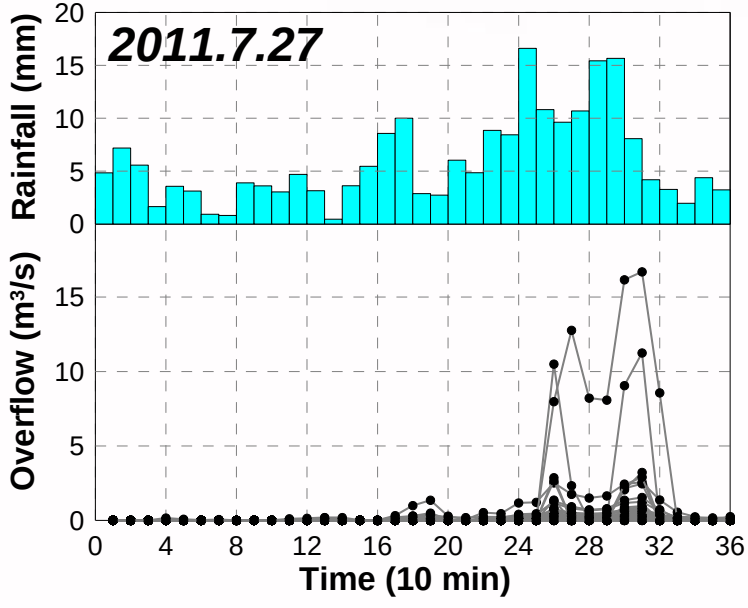




MANHOLE OVERFLOW CALCULATION

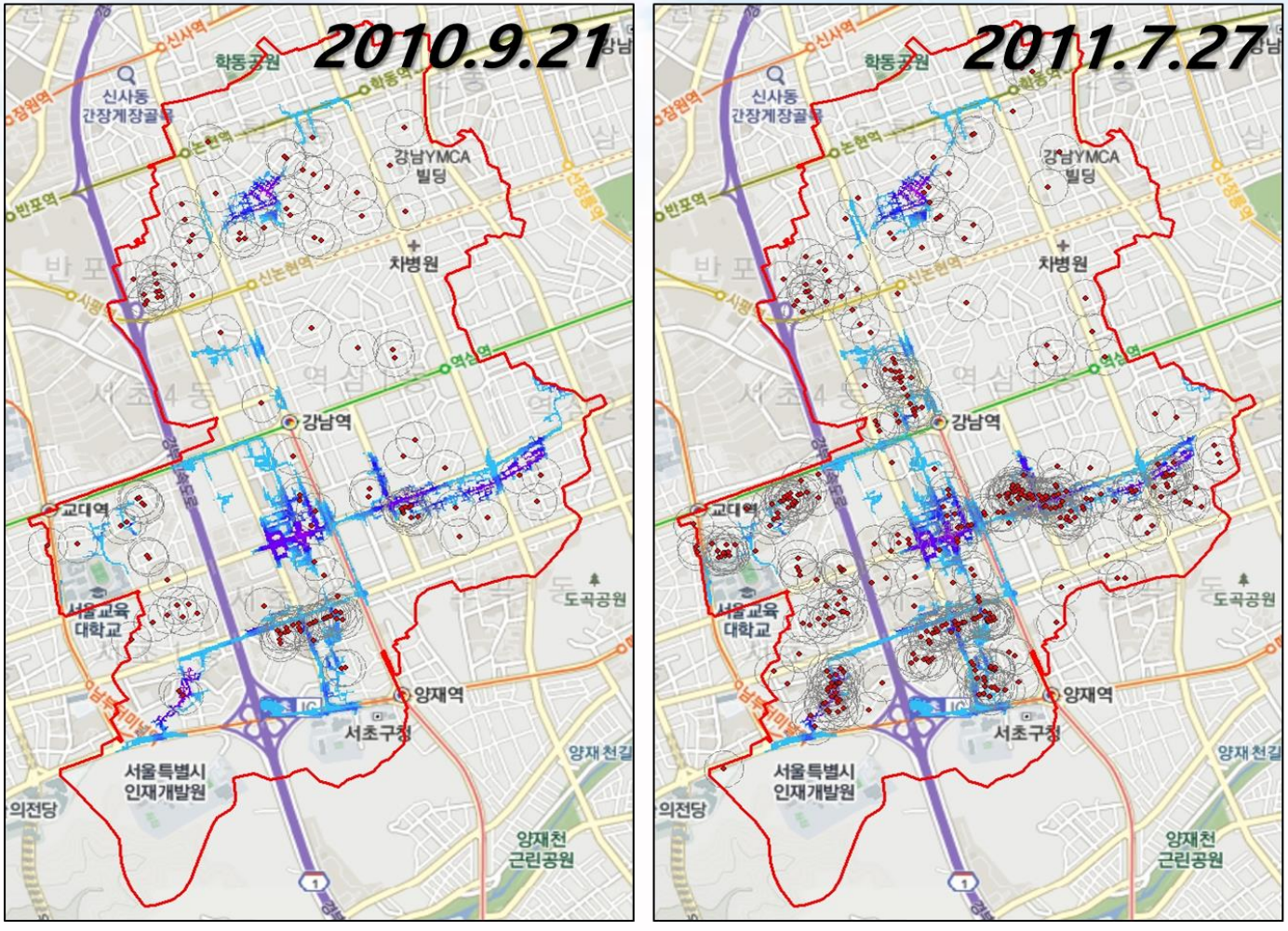




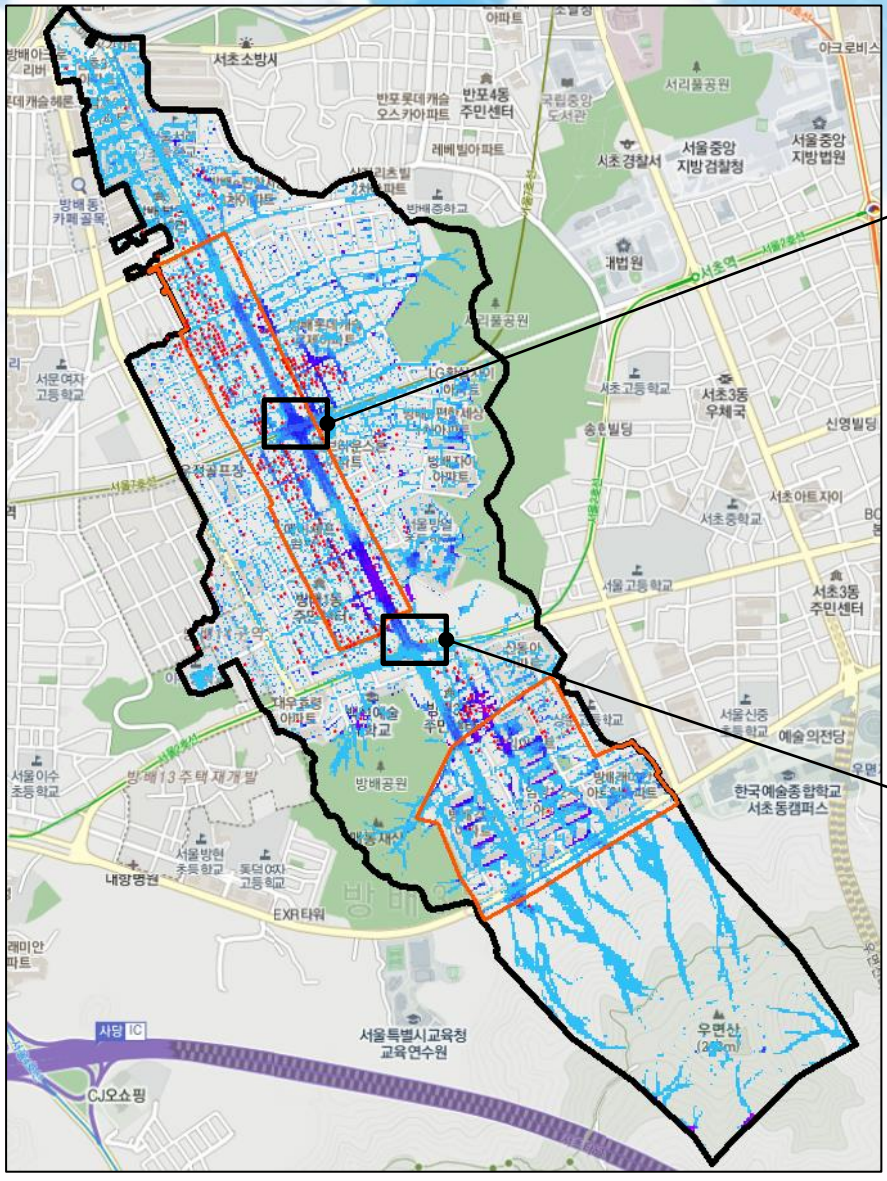


2D SURFACE MODEL OPTIMIZATION

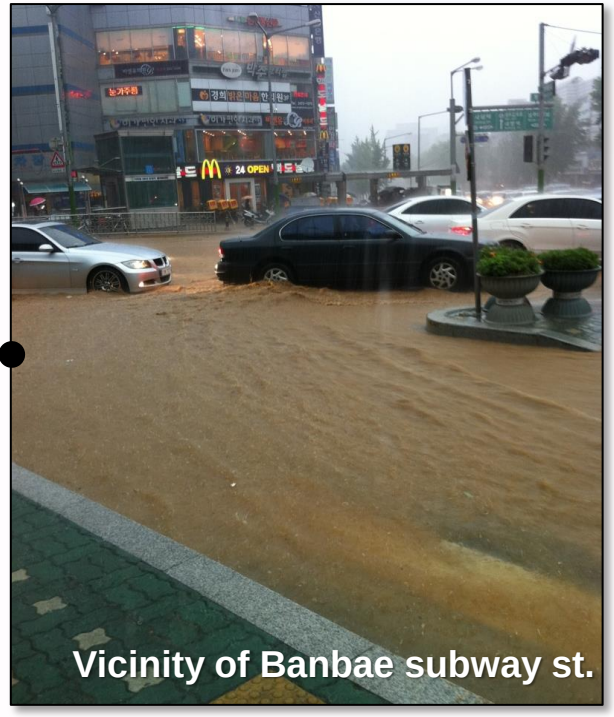
- Spatial resolution : 6m, temporal resolution : 0.1sec
- Accuracy(POD) : 2010(0.61), 2011(0.57)



2D SURFACE MODEL OPTIMIZATION

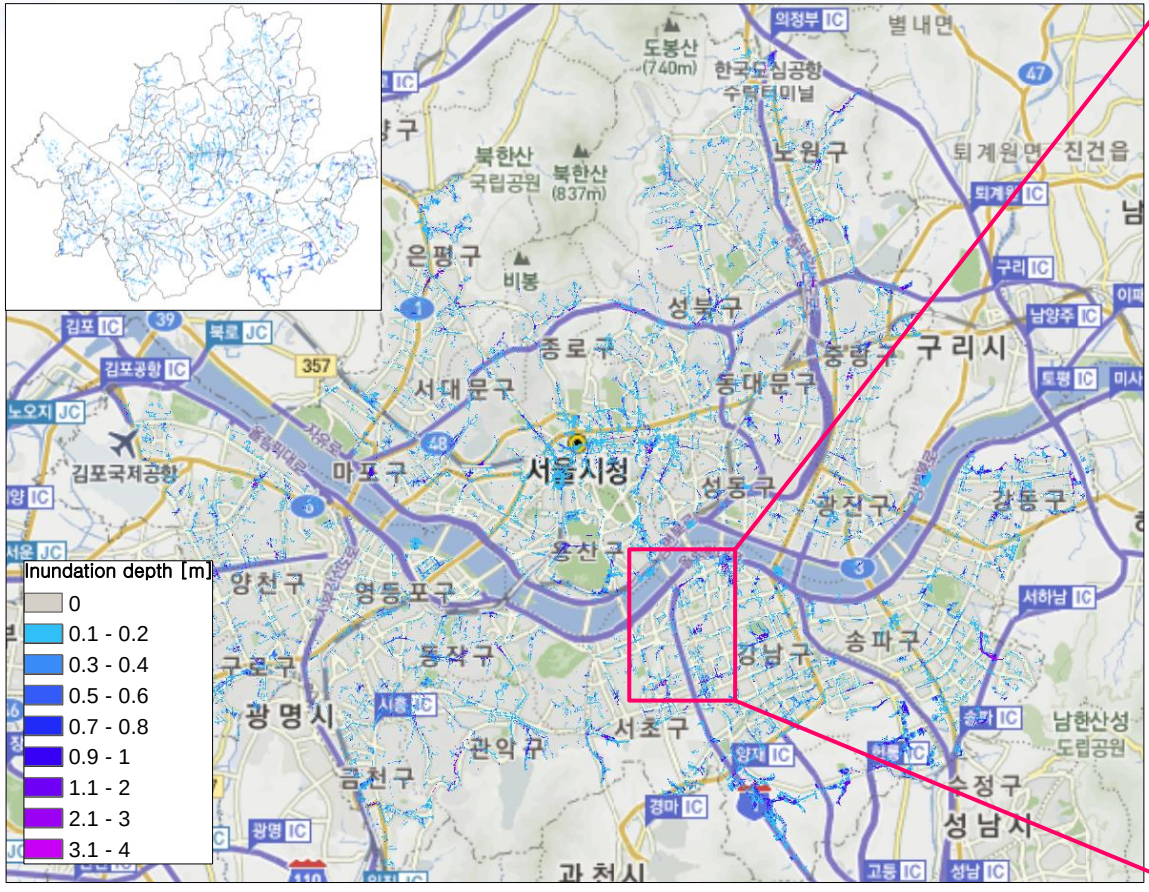


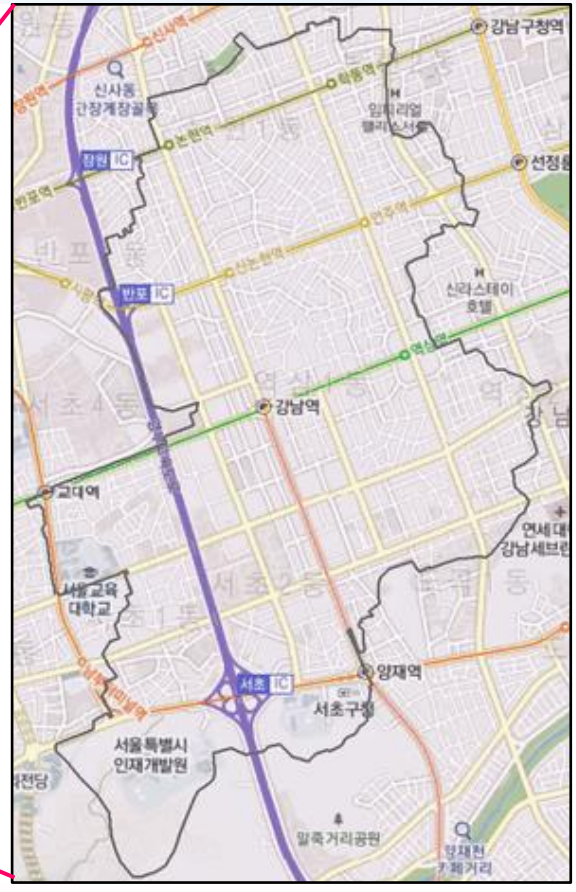

Vicinity of Naebang subway st.


Vicinity of Banbae subway st.

INUNDATION DEPTH ON WHOLE SEOUL METEROPOLITAN

- Spatial Res. : 6m, Temporal Res. : 0.1sec
- Simulation Results of 50yr Frequency Probability Rainfall (99.2mm/60m)



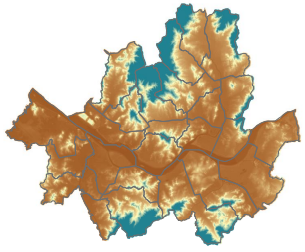


SCENARIO-BASED APPROCH

PRODUCE PROCESS OF INUNDATION SCENARIO

URBAN INUDATION ANAYSIS → ***RAINFALL SCENARIO(320)*** → ***INUNDATION SCENARIO***

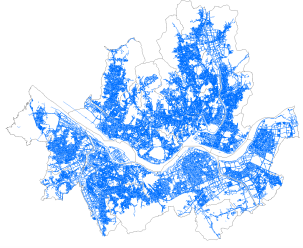
DEM(6m)



LAND COVER(6m)

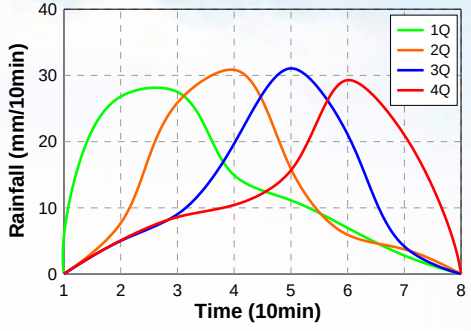
BUILDINGS LAYER

SEWER NETWORK



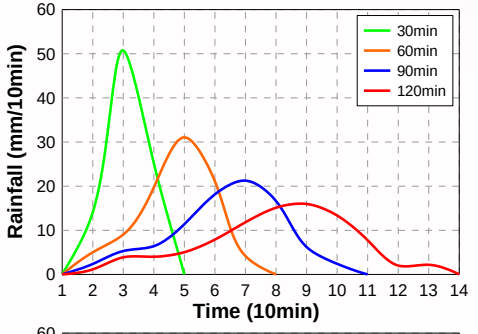
1D-2D COUPLED MODEL

Distribution(4)



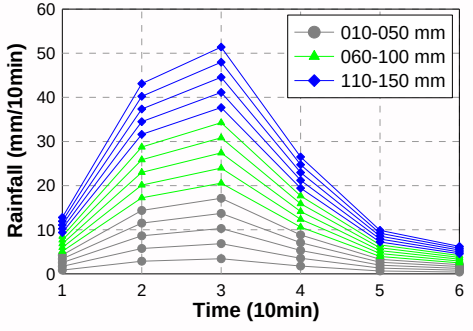
X

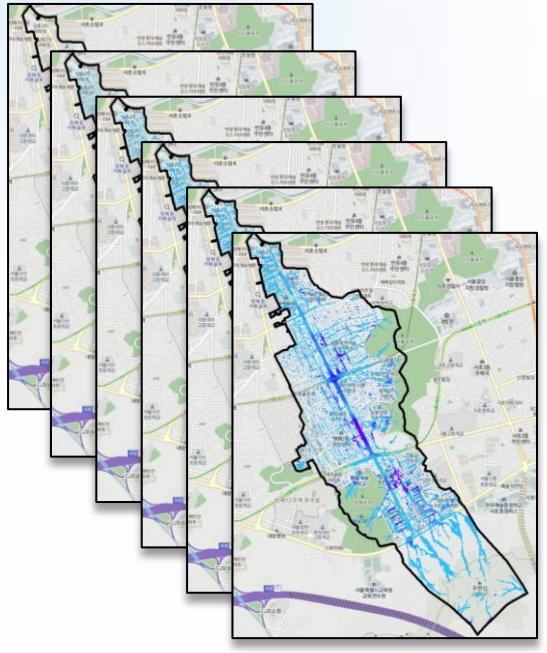
Duration(4)



X

Amount(4)

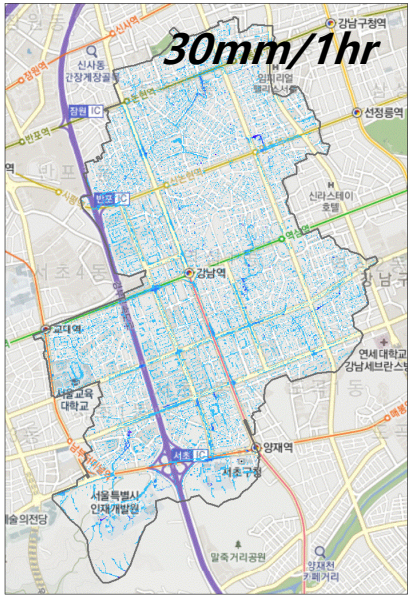


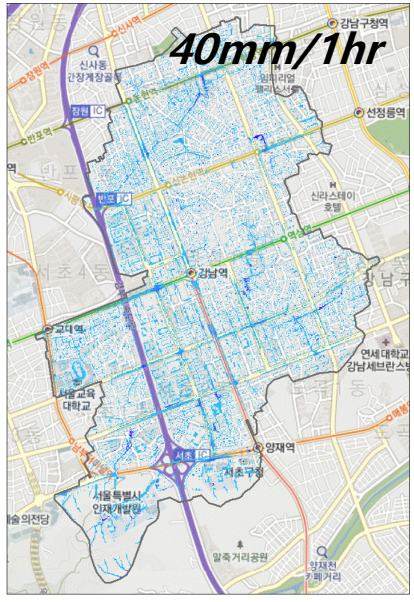


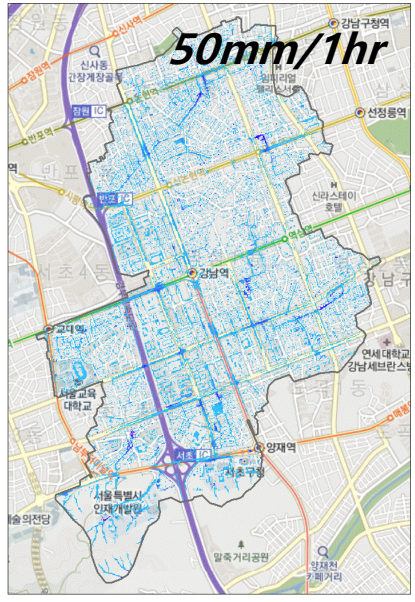
Investigate Vulnerable Area of Inundation

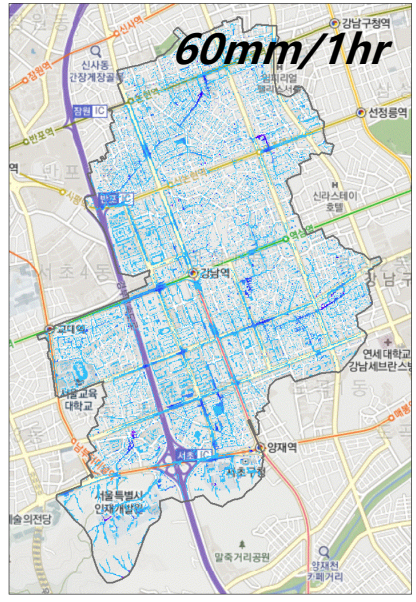
Inundation Prediction Using Radar QPF

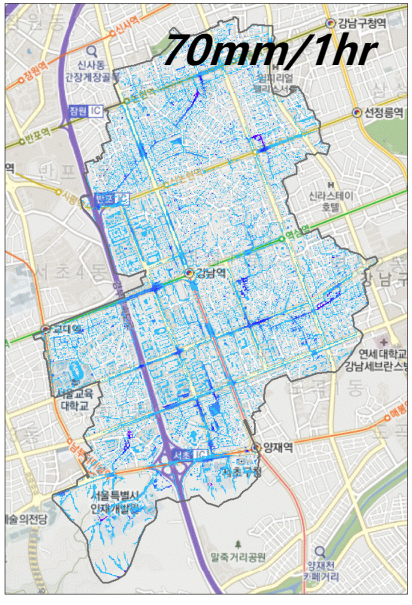
RESULTS OF FLOOD INUNDATION MAP (SCENARIO-BASED)

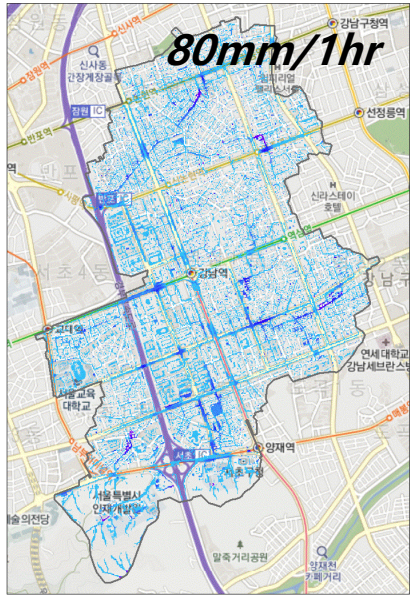


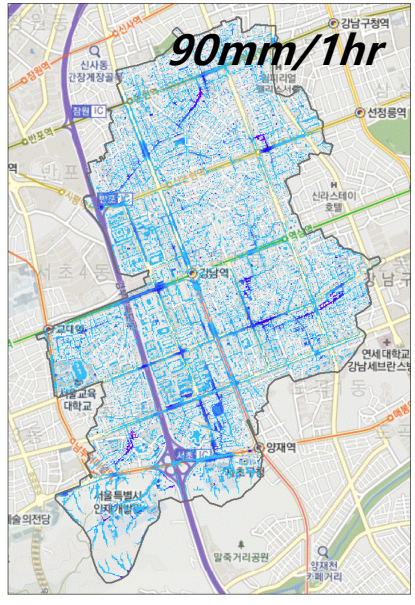


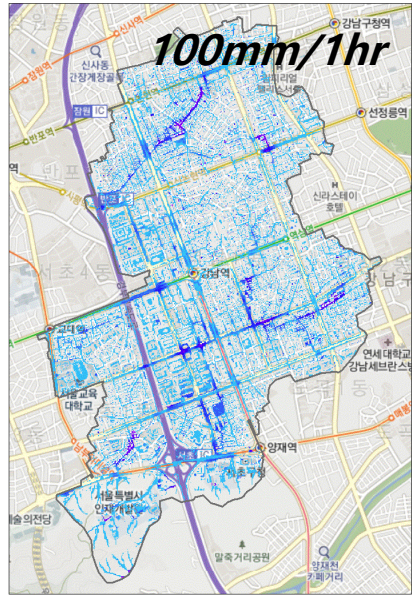










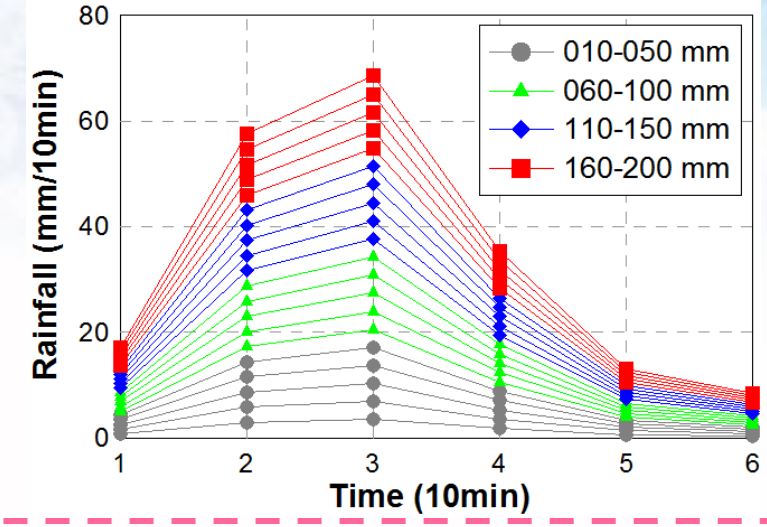


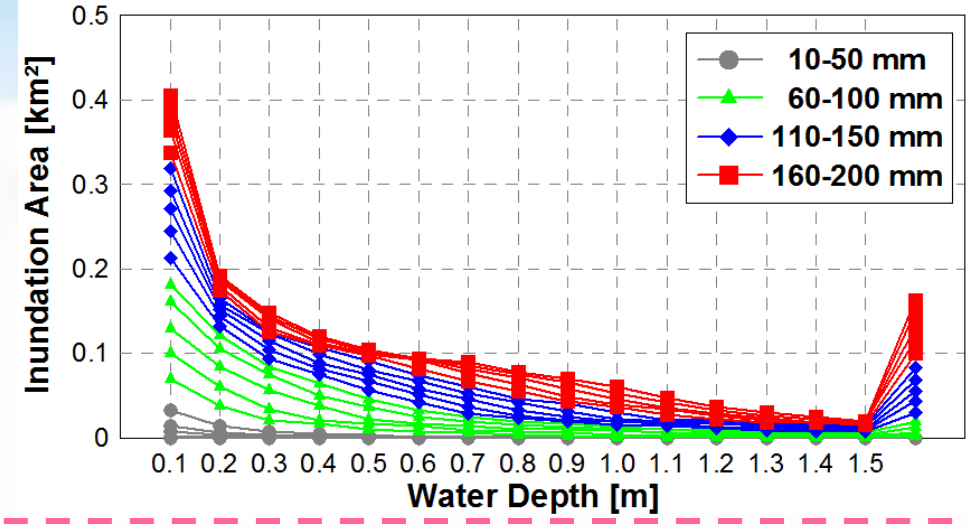
RESULTS OF RAINFALL-INUNDATION SCENARIO

Temporal Distribution of Rainfall

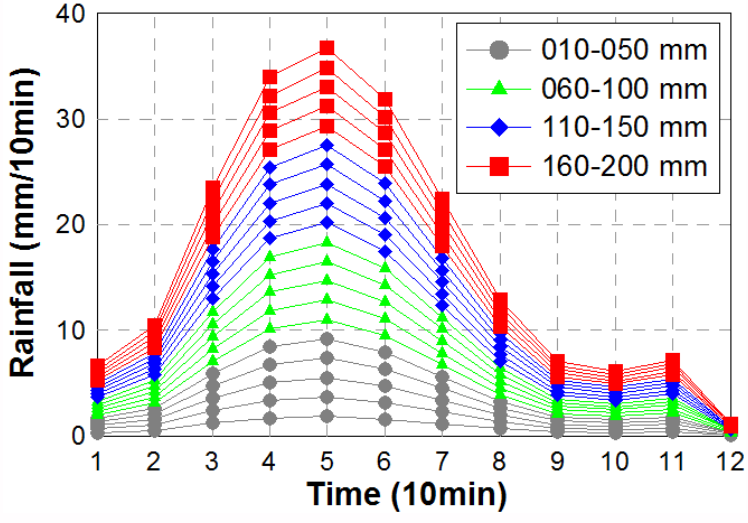
Rainfall-Inundation Area-Depth Relationship

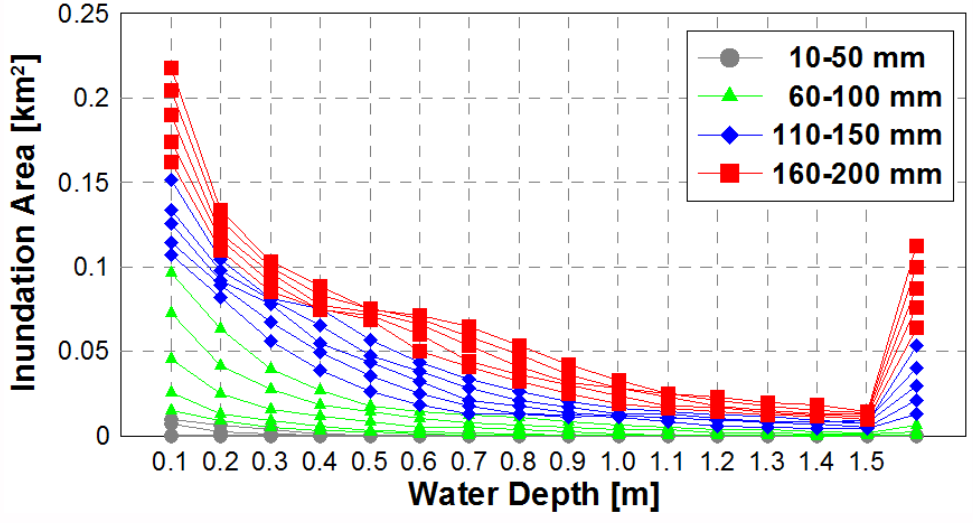
Rainfall Duration (60min)





Rainfall Duration (120min)






Thank you
for your
attention