Typhoon Committee Roving Seminar
Lao DPR, 4-6 Nov., 2015

Topic C: River and Urban Flood Forecasting and Mitigation

(C-1) River Flood Forecasting System Mitigation in Korea

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KICT KOREA INSTITUTE of CIVIL ENGINEERING and BUILDING TECHNOLOGY

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2 Flood Forecasting System

3 Flood Hazard Map & Inundation Information

4 Structural measures for Flood prevention

1 Introduction

Major 4 Rivers in South Korea

Han River

Geum River

Nakdong River

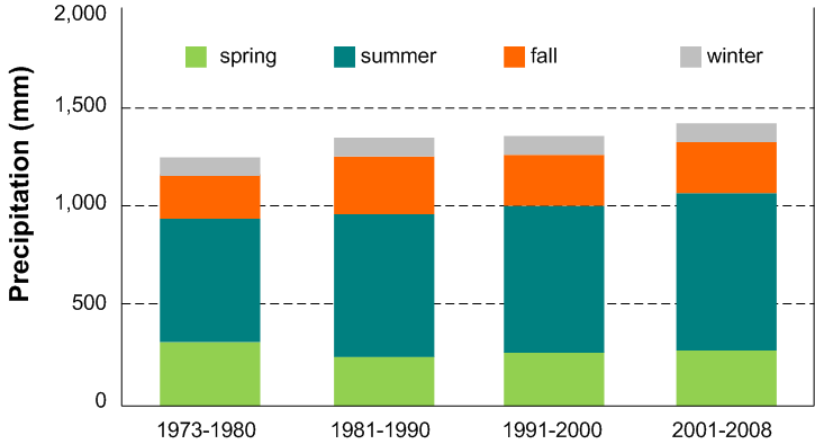
Yeongsan River

Geographical Characteristics

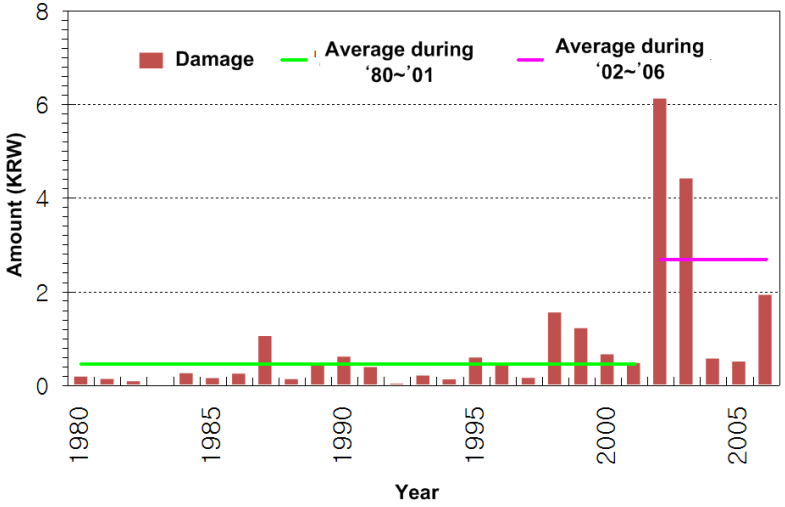
- About 70% of Korea is mountainous area
- Short and steep rivers
- Extreme flow variation in the year

Precipitation of Korea

- Annual precipitation
  - 1,341 mm (1.5 times of global average)
- Seasonal distribution
  - From June through August
    - 2/3 of annual precipitation



- Flood damage
  - Typhoon and heavy rainfall
    - Abnormal flood due to climate variation
    - 100.5 mm/hr, 870mm/day (2002, TY Rusa)
  - Amount of damage
    - 2.4 billion USD (’02 ~ ’06)



Historical Flood Damages

Imjin river basin flood (1999)

- Cause : Heavy rainfall
- Period : 31 Jul. ~ 3 Aug.
- Rain fall : 784.2 mm
- Death : 19 people
- Victims : 4,776 house/14,729 people
- Flood area : 26,103 ha

Gangwon-do region flood (2002)

- Cause : Typhoon Rusa
- Rain fall : 897.5 mm
- Death : 126 people
- Victims : 22,920 house/72,660 people
- Property : 2.2 billion USD

Historical Flood Damages

Nakdong river basin flood (2003)

- Cause : Typhoon Maemi
- Rain fall : 471 mm
- Victims : 400 house/1,500 people
- Property : 4.2 billion USD
- Inundation due to several levee breaks in Nakdong river

Seoul flood(2011)

- Cause : Heavy rainfall
- Rain fall : 587 mm
- Death : 49 people
- Property : 100 million USD
- Overtopping/landslide

Countermeasures for flood damage prevention

- River improvement works(levee, dredging, widening of channel)
- Flood control facilities (dam, detention basin)
- Flood control capacity enhancement(floodway, floodwall, emergency spillway)

Structural

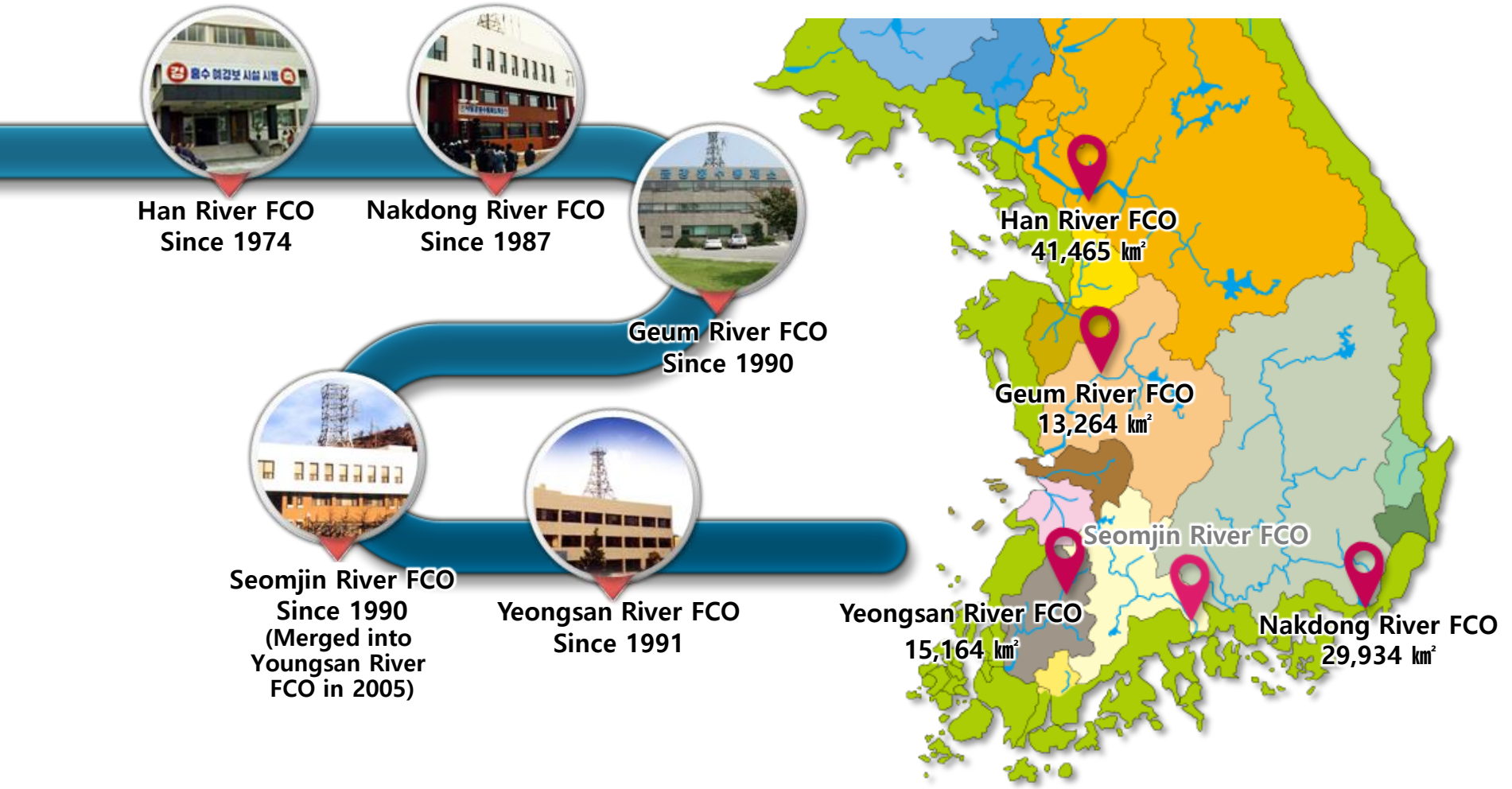
- Flood forecasting and warning system
- Land use and Floodplain management(hazard map)
- Flood insurance

Non-structural

Flood damage mitigation

2 Flood Forecasting System

FCO (Flood Control Offices) in Korea



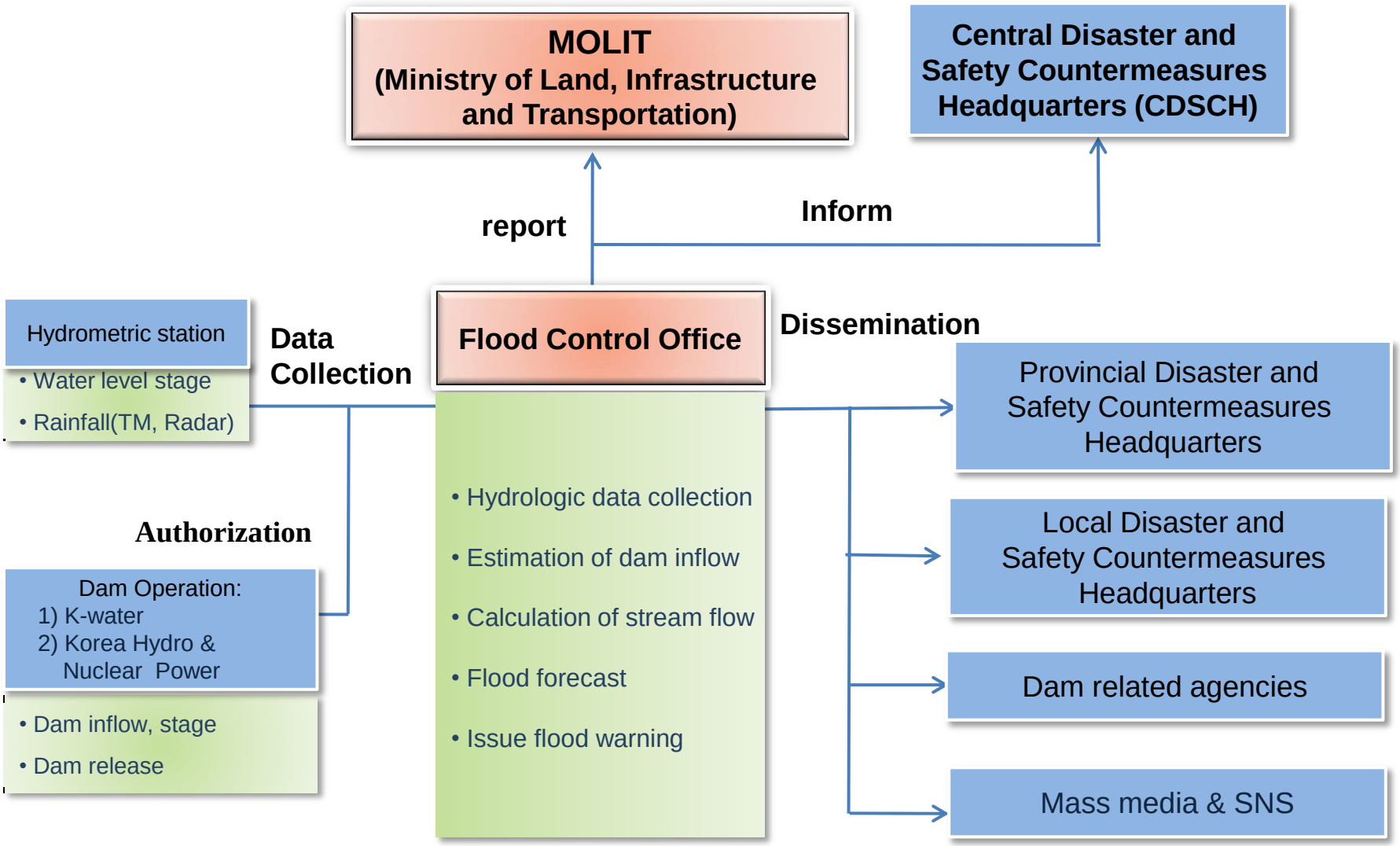
History of FFS(Flood Forecasting System) in Korea

1968	• The Han River was selected as a pilot river basin for automated flood forecast system at the 1st Typhoon Committee Conference in Dec. 1968.
1974	• Han River FCO was established and flood forecasting, warning system got started.
1987	• Nakdong River FCO was established.
1990	• Geum and Sumjin River FCO
1991	• Yeongsan River FCO (Sumjin River FCO was merged into Yeongsan River in 2005)

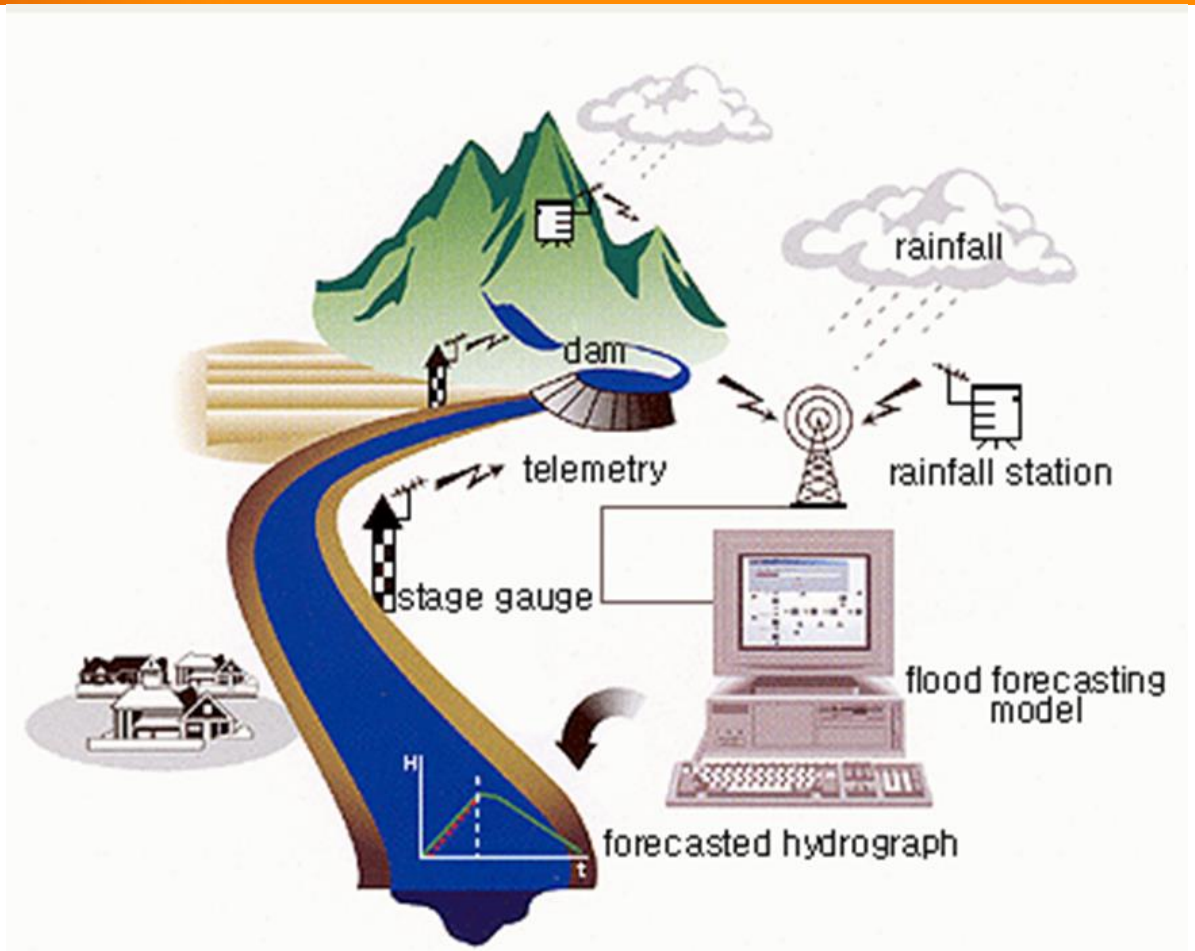
History of FFS(Flood Forecasting System) in Korea

1993~ 1997	• Development of FFS for Seven Major Medium Rivers
2000	• Installation of the first Rainfall Radar at Imjin River
2002~ 2004	• Setting up Rainfall Radar Master Plan for Flood Forecasting • Development of Tributary FFS in Urban Area
2005	• Formation of River Information Center in Han River
2009~ 2016	• Installation of Six S-band Dual-Pol Rainfall Radars • Development of Flash Flood Forecasting System

National Framework for Flood Management

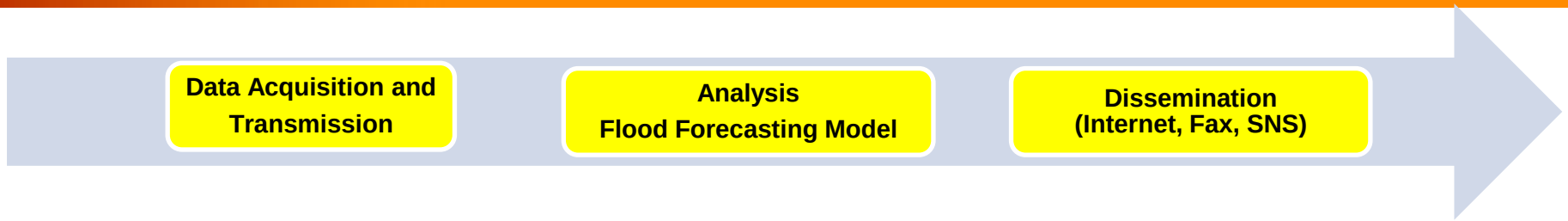


Process of Flood Forecast



- Concept of Flood Forecast -

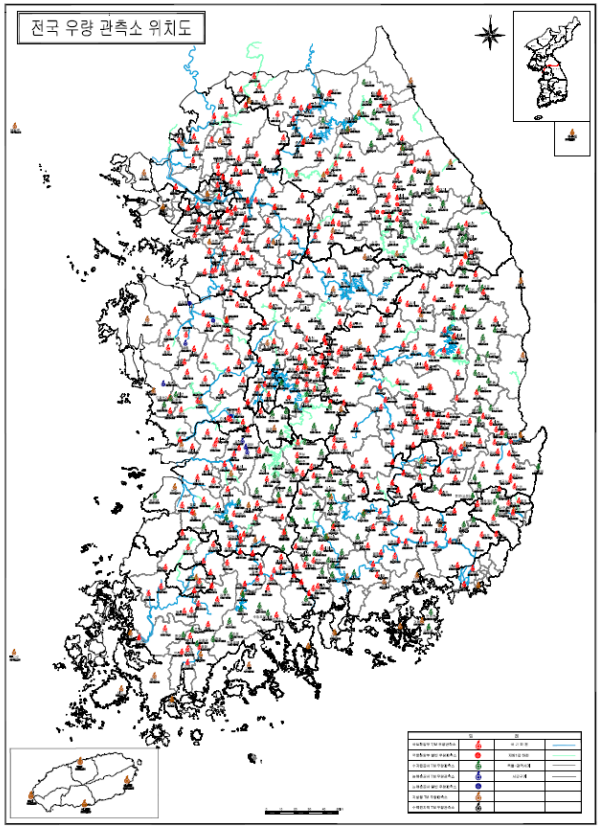
Process of Flood Forecast



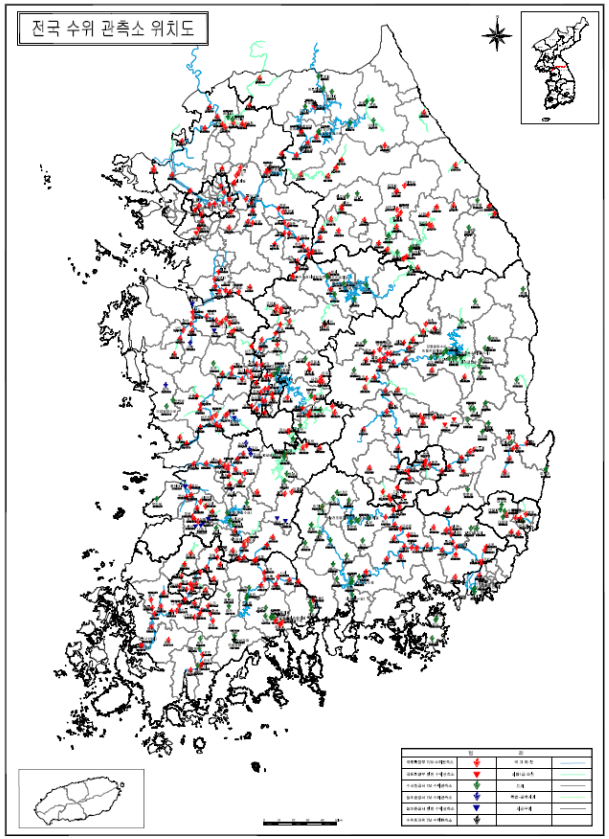
Observation	Flood Forecast	Flood Warning	Flood Forecast Dissemination
Rainfall, Water Level	Flood Flow & Peak time	Issue Flood Watch	Central Disaster and Safety Countermeasures Headquarters
Radar Rainfall	Control Dam Release	Issue Flood Warning	Mass media
Dam Inflow, Release and Level			SNS and River information Display System

Telemetering Rainfall and Water Level Stations

Rainfall stations (599)



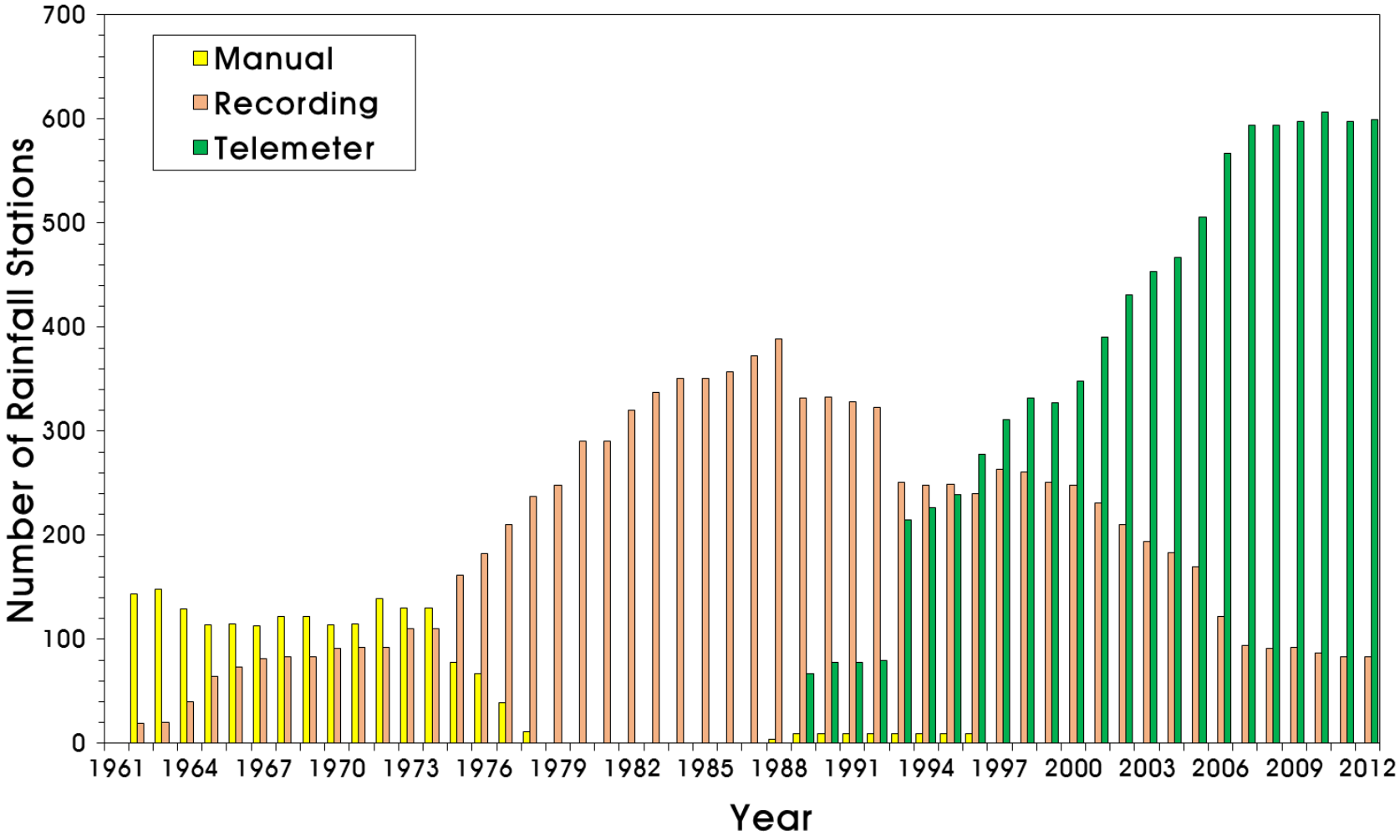
Water level stations (570)



- Rainfall stations : 99,720 km^2/599 stations ≈ 166 km^2/station
- Denser than WMO suggestion (10~20 km^2/station in urban area, 5,750 km^2/station in flatland area for TM measurement)

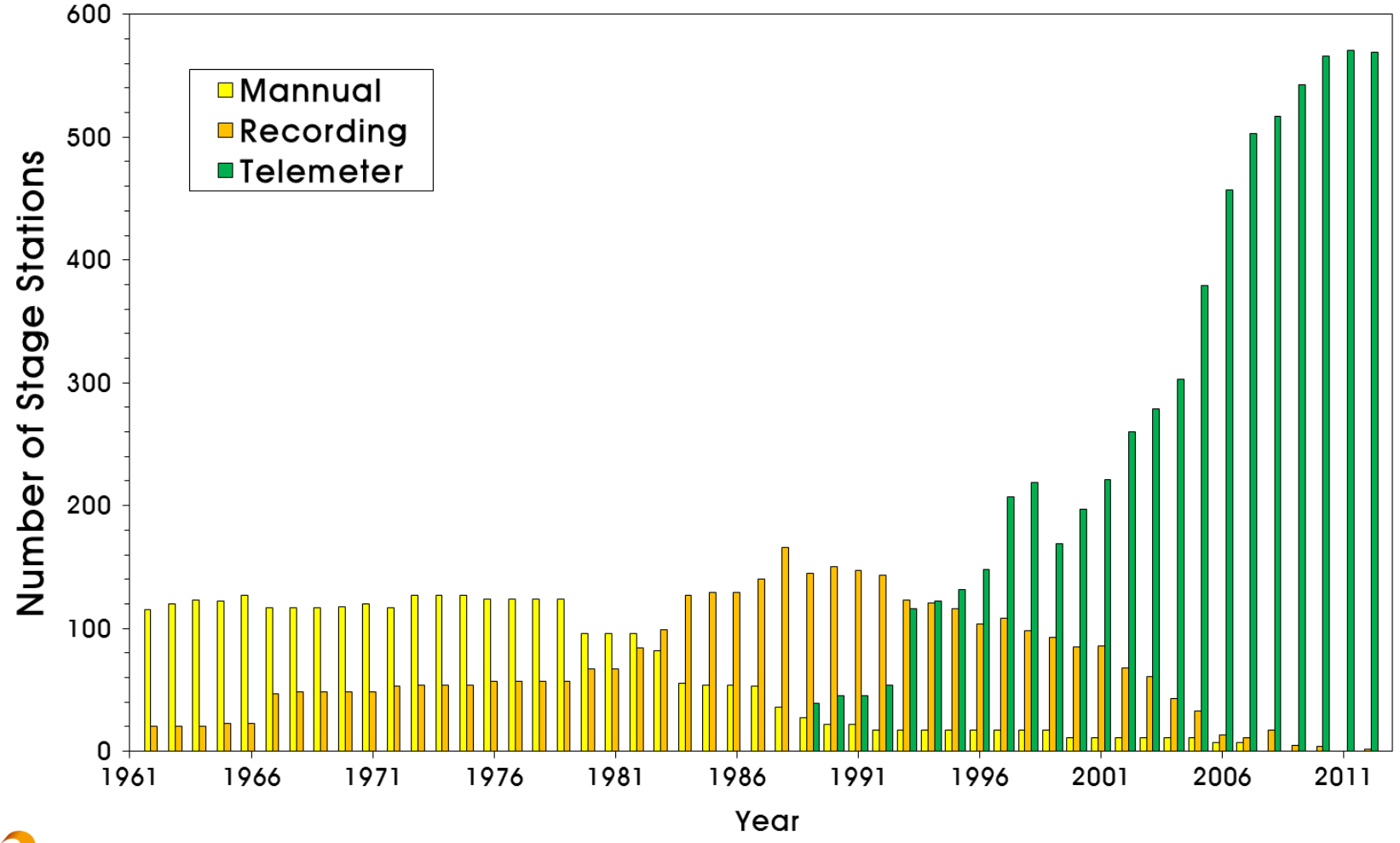
Telemetering Rainfall and Water Level Stations

Rainfall stations (599)

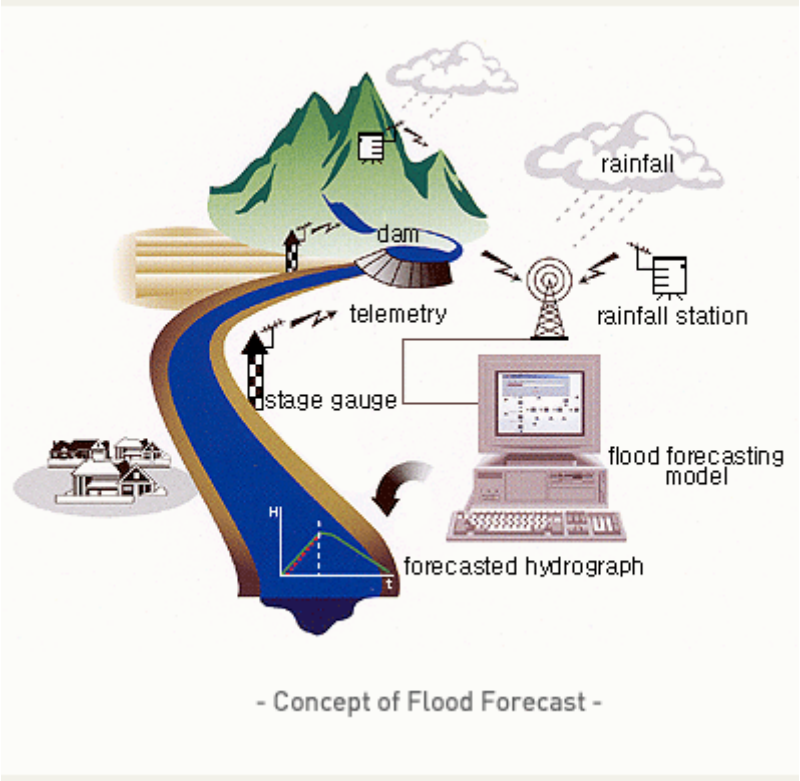


Telemetering Rainfall and Water Level Stations

Water stage stations (571)



Flood Forecasting Model



- Concept of Flood Forecast -

Meteorological and Hydrological data

Flood Forecasting Model

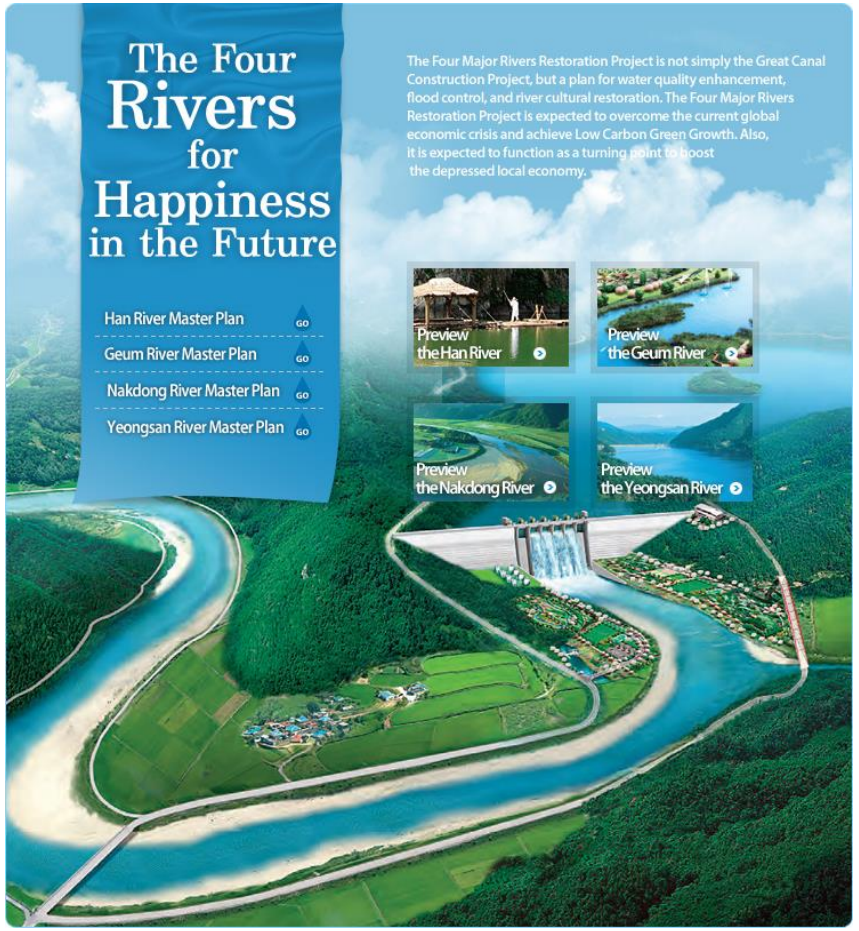
Hydrologic Model

Hydraulic Model

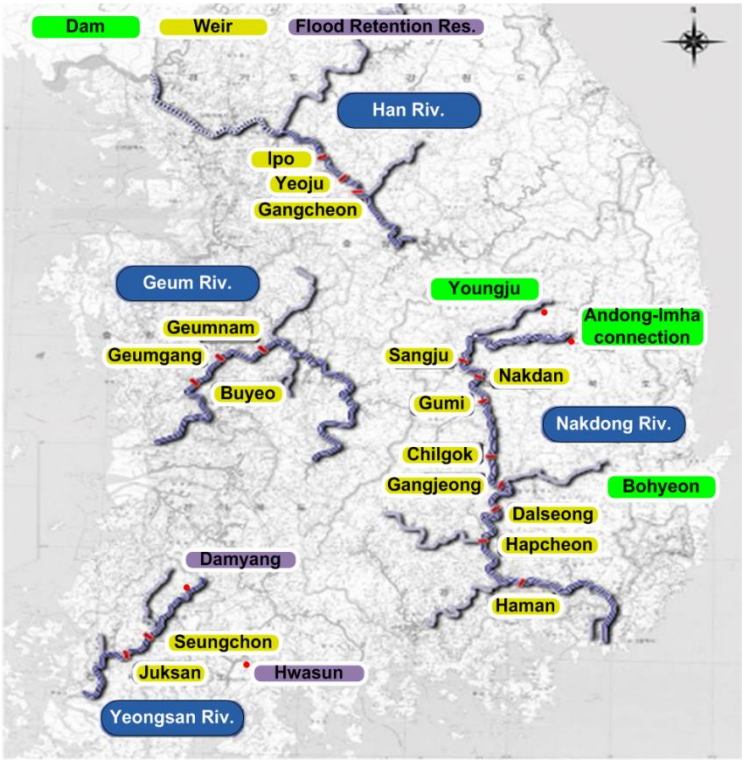
Flood Forecasting & Warning Issue

The Four Major Rivers Restoration Project (4MRRP): 2008~2013

- Vision and Objectives



The Four Major Rivers Restoration Project (4MRRP): 2008~2013



Dredging	Weir	Levee Reinforcement	New Dam	Flood Retention Res.
460 mil. m^3	16	620 km	2	2

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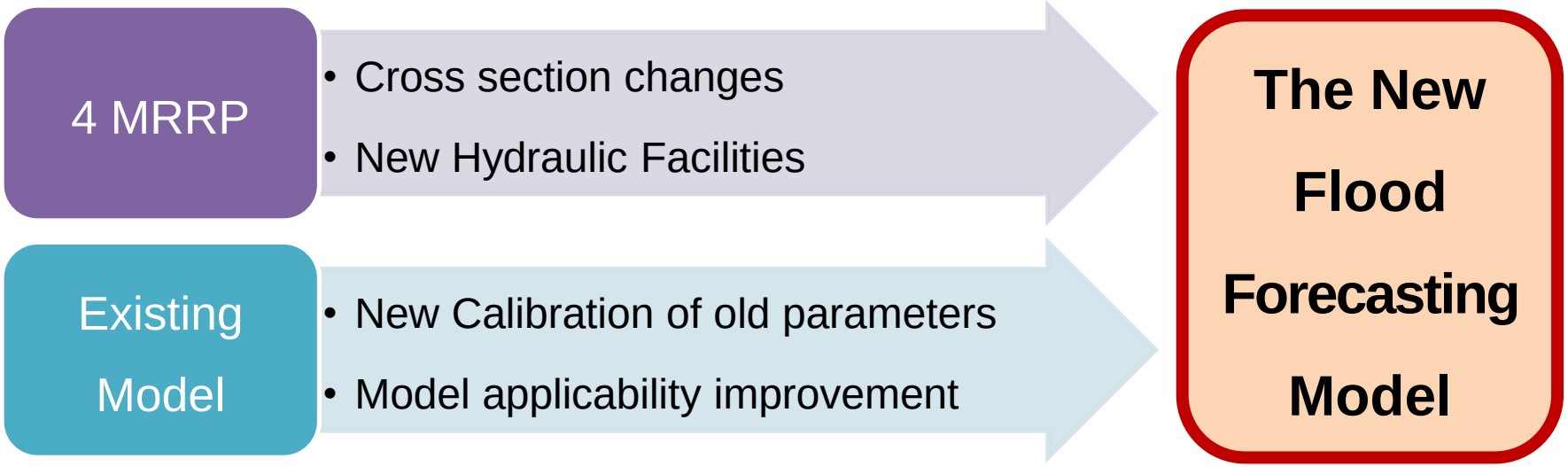
Flood Forecasting Model Modification



Hydrologic model

- Adjustment of basin area and channel length
- New technique for effective rainfall assessment
- Modification of parameters for basin, channel and reservoir routing

Hydraulic model

- Modification of cross section data for Han and Geum river models
- New hydraulic model for Nakdong and Yeongsan and Sumjin river models
- Numerical model improvement and development to reflect new facilities

Flood Forecasting Model

Hydrologic model				
River	Han	Nakdong	Geum	Yeongsan
Basin Area (km^2)	27,652	23,384	9,912	3,468
No. of Basin	236	192	78	32
No. of Channel	275	280	268	69
Hydraulic model				
River	Han	Nakdong	Geum	Yeongsan
Channel length (main stream)	316 km	332 km	130 km	143 km
Cross Section	1,695	1,387	462	651
Branch	11	7	1	2

Hydrologic Model

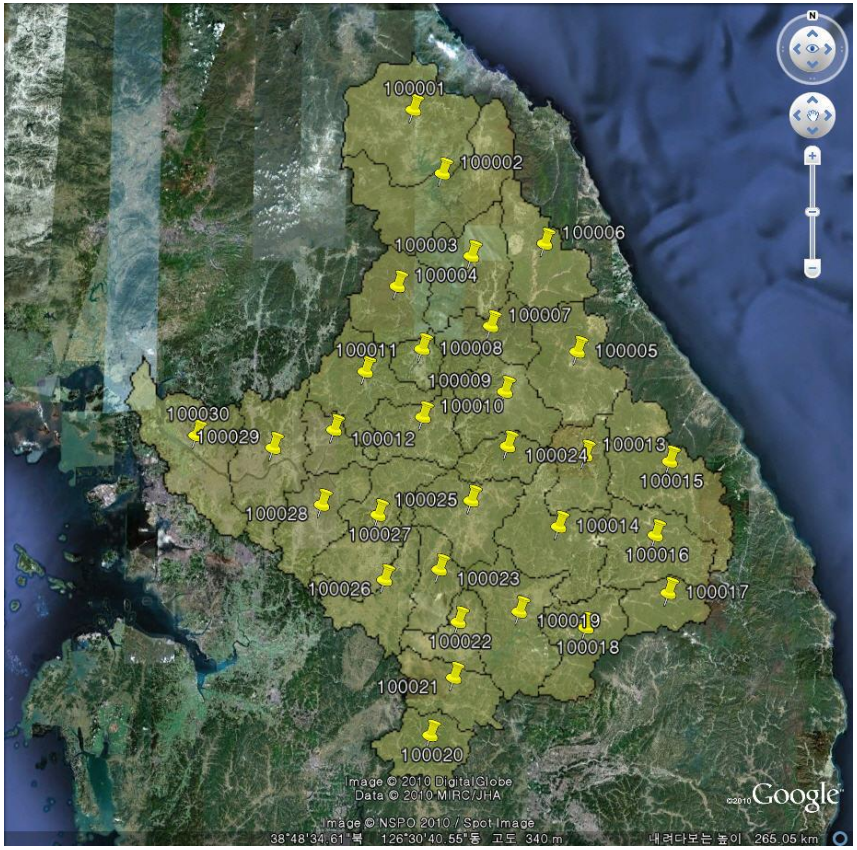
- Adjustment of basin area and channel length
  - Storage function method
    - Basin area : 10 ~ 3,000 km^2
    - Channel length : 10 ~ 200 km
  - Adjusted area and length
    - Maximum area : 300 km^2
    - Maximum length : 30 km
  - Geological and hydrological homogeneity for subbasins

Average Basin area (km^2)		
River	Previous	Present
Han	921.7	117.2
Nakdong	205.1	122.4
Geum	145.8	127.1
Yeongsan	150.8	108.4

No. of Divided Channel		
River	Previous	Present
Han	23	275
Nakdong	84	280
Geum	60	168
Yeongsan	22	69

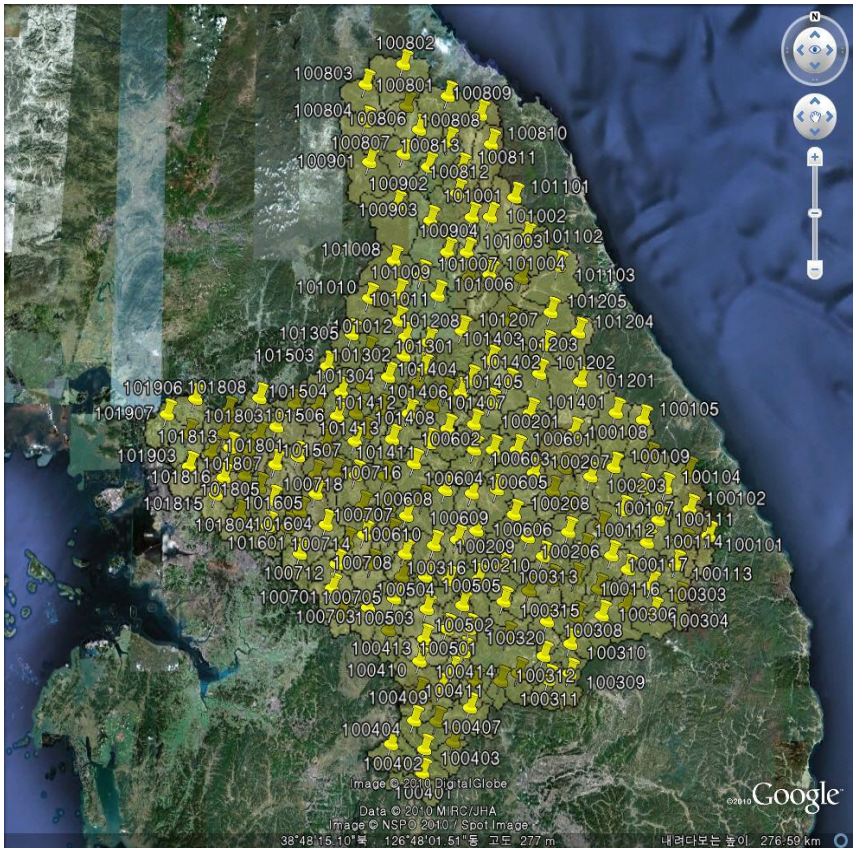
Hydrologic Model (Han river)

Previous (~2011)



• 30 basins/27,562 km^2

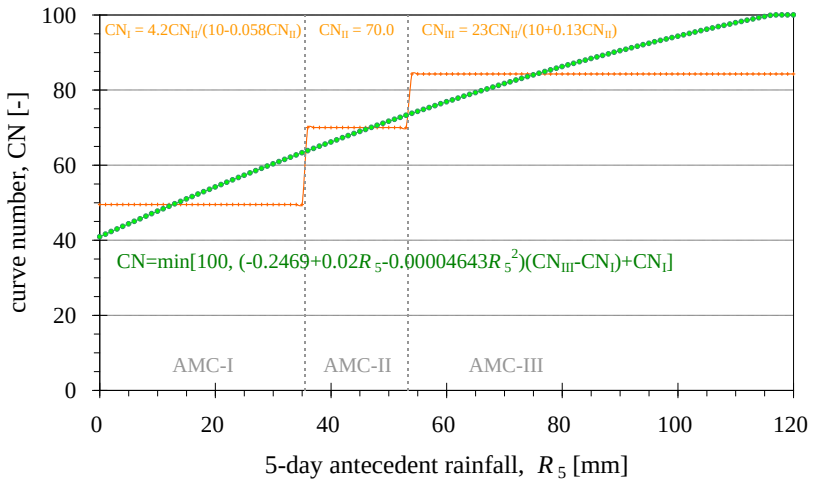
Present (2012)

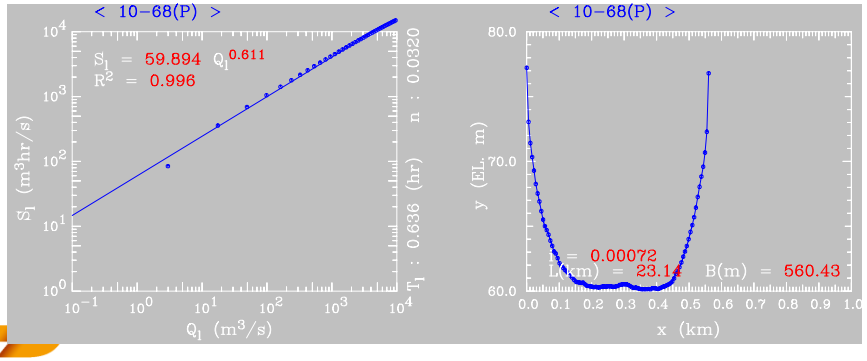


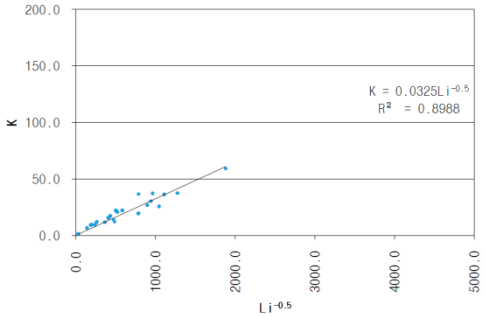
• 236 basins/27,562 km^2

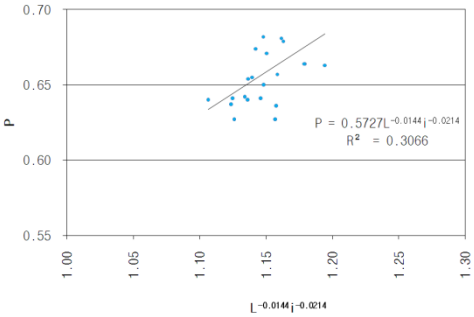
Hydrologic Model

- Effective rainfall
  - SCS method
    - CN (runoff curve number)
    - Previous : step wise value
    - Present : continuous function
  - Addition of Green-Ampt model
- Parameter assessment
  - Hydrologic models
    - Storage function, muskingum and Unit hydrograph methods
  - Geological data assessment
  - Optimal value for each method



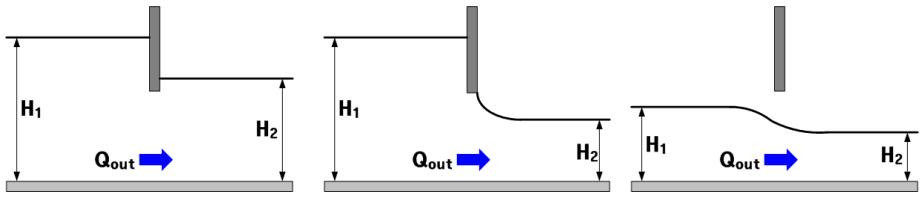






Hydraulic Model

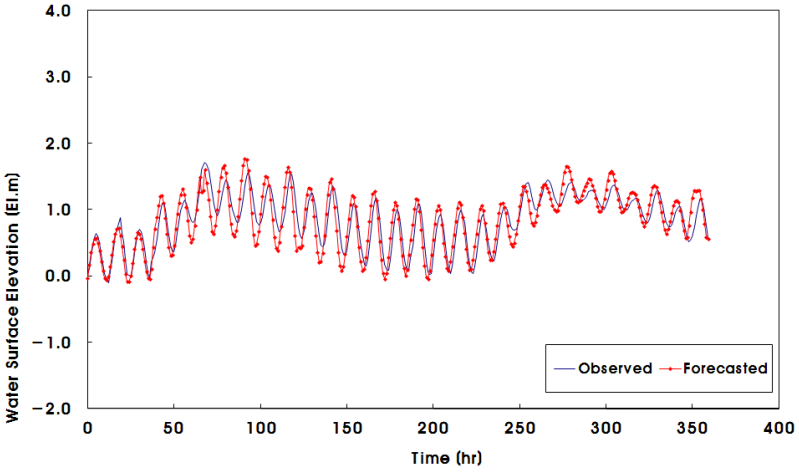
- Improvement of FLDWAV model
- Previous model
  - Only orifice flow
  - Not stable for 4MRRP structures
- Modified model
  - Weir flow equations added
  - Appropriate equations for various flow conditions

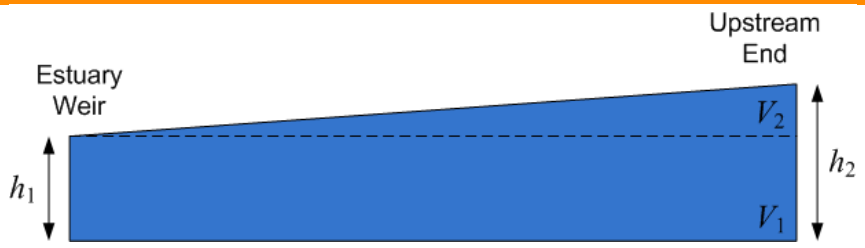


Orifice **Partially Orifice** **Weir**

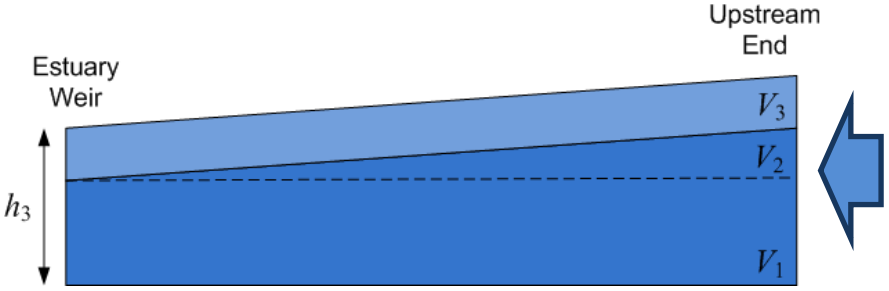
Hydraulic Model

- Downstream BC forecasting
  - 3 estuarine barrages
    - Nakdong, Geum and Yeongsan rivers
  - Reservoir routing needed
  - Unified model developed

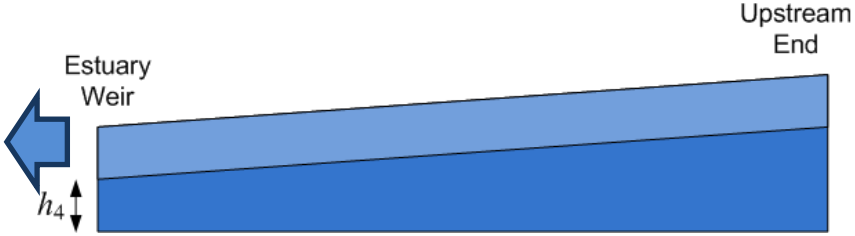




$$V_{initial} = V_1 + V_2 = F(h_1)$$



$$V_{mid} = V_1 + V_2 + V_3 = Q_{in}\Delta t + V_{initial}$$



$$V_{final} = V_{mid} - Q_{in}\Delta t$$

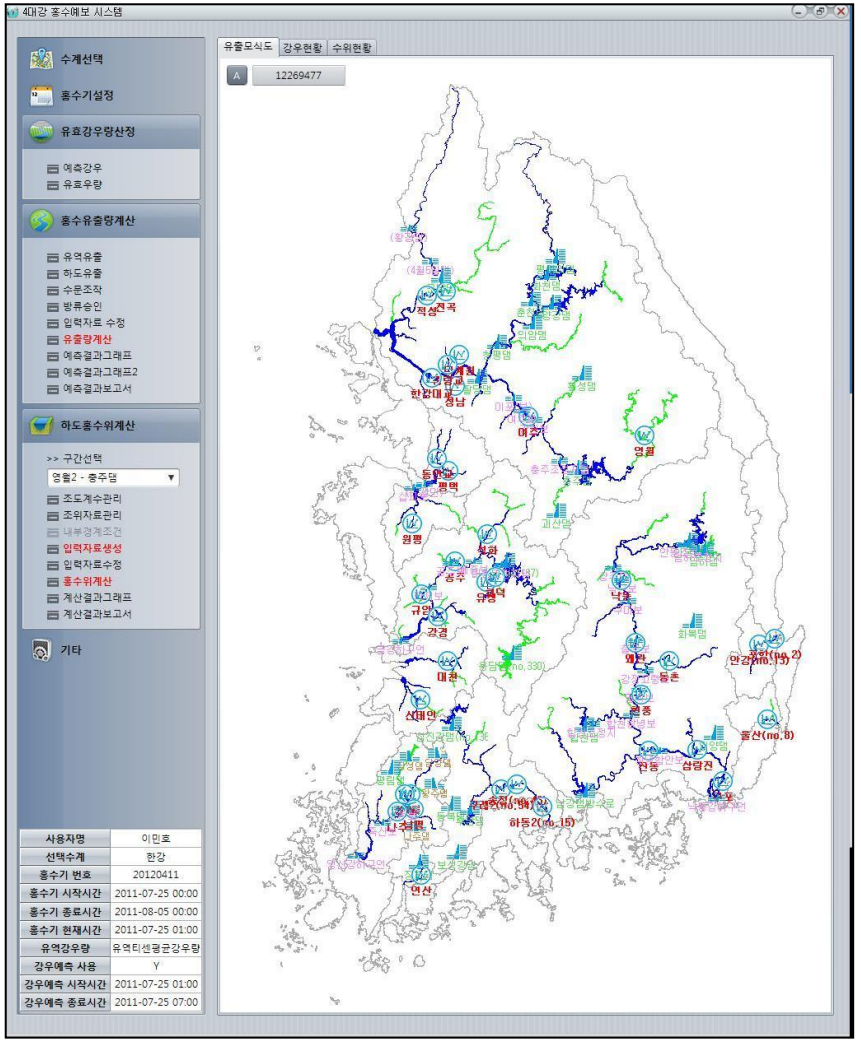
Hydraulic Model

- Flood retention reservoir
  - Function in FLDWAV model
  - Han and Yeongsan river model

▪ Normal

▪ Flood

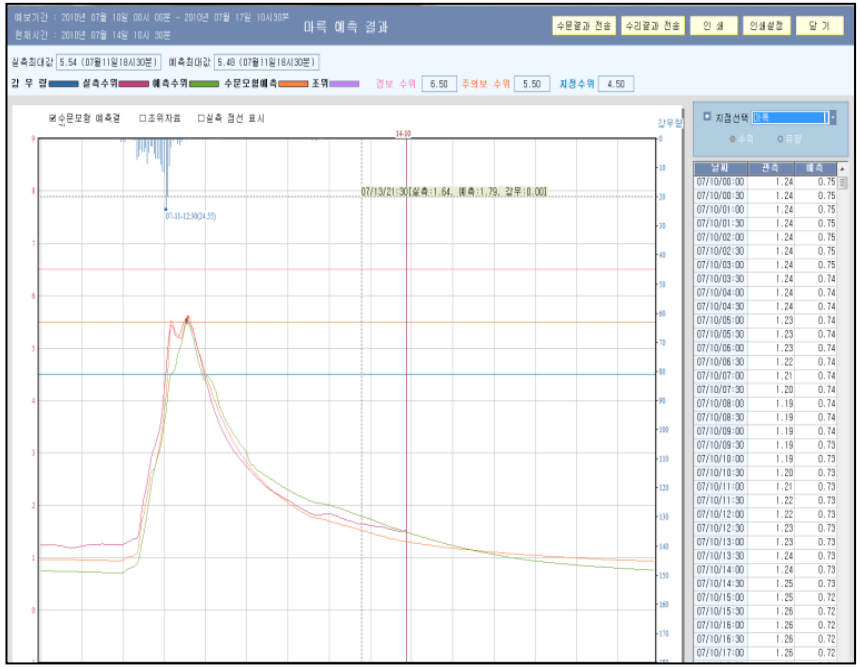
- Bifurcation
  - Ara canal and west Nakdong river
  - Controlled by gates
  - Applying negative lateral flow



Flood Forecasting Results

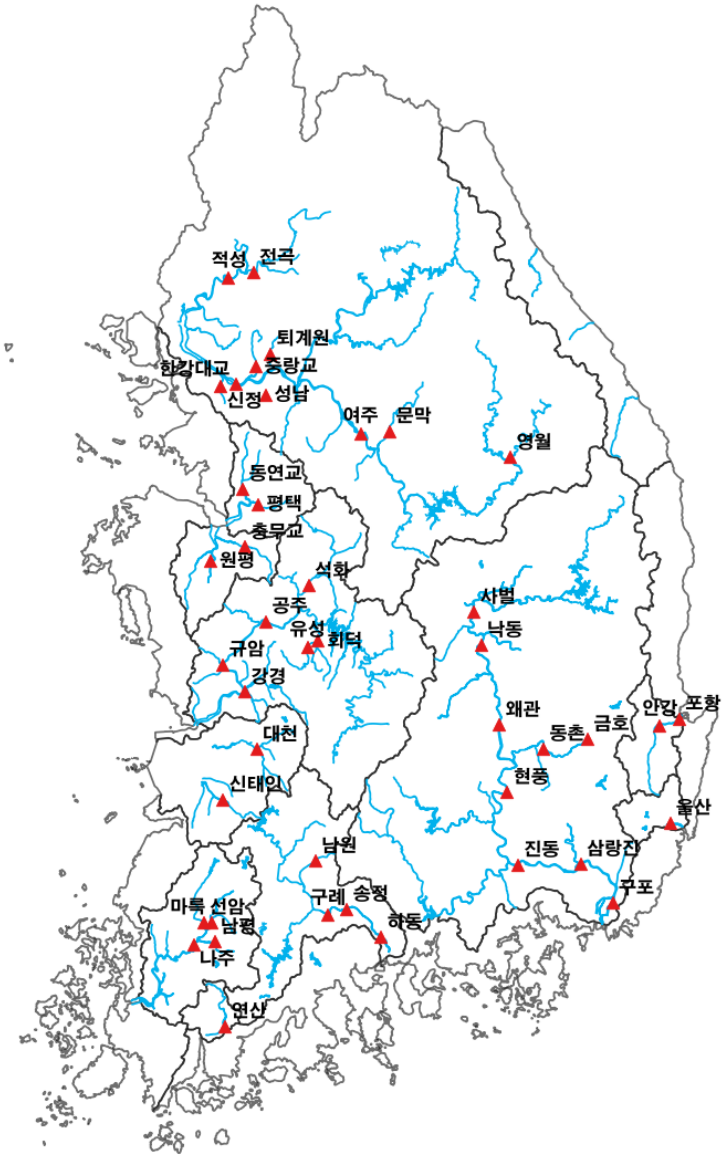
- Flood forecasting and model verification
  - Over 50 times during 2010-2012
  - Very reasonable and accurate results, appropriate flood warning issues

Forecasting result (Mokgye, Han river)



Forecasting result (Mareuk, Yeongsan river)

43 Flood Warning Stations



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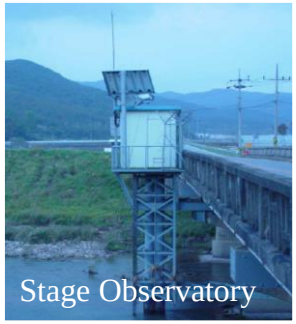
Hydrologic Observation in Han river Basin

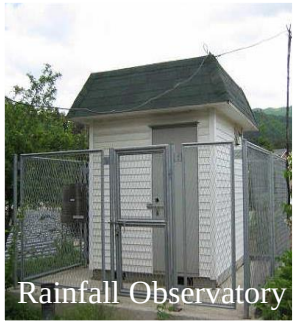
Major river basin within HRFCO

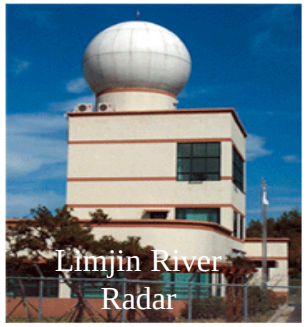
Division	Area(km^2)	Length(km)
Total	Korea 38,554 South Korea 28,738	11,937
Han River	Korea 35,770 South Korea 25,954	10,586
Limjin River	Korea 8,138 South Korea 3,186	
Ansung River	1,656	938
Others	1,128	413

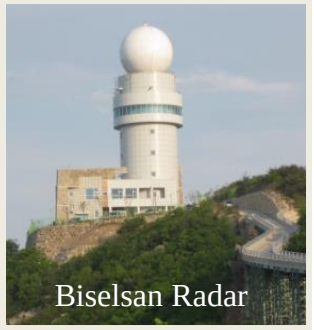
Operation of Hydrological Observatory

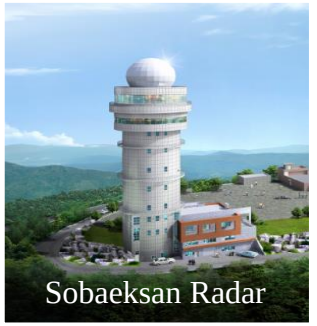
Water Level	Rainfall	Radar
124	147	3


Stage Observatory


Rainfall Observatory


Limjin River Radar


Biselsan Radar


Sobaeksan Radar

Data Collection for Flood Analysis

홍수예보 종합상황

2012년 07월 18일 14시 50분 ~ 2012년 07월 30일 14시 50분 검색

주요예보지점 수위 - 홍수예보주요지점 수위를 30분단위로 제공(검색기간 끝시간 기준)

하천	예보지점	홍수 주의보·경보 발령 및 해제	발령 및 해제 시간	제방고 (좌)	제방고 (우)	경보	주의보	현재 수위	14:20	13:50	13:20	12:50
한강	한강대교	-		16.06	16.56	10.50	8.50	0.71▲	0.68	0.69	0.69	0.67
한강	여주	-		14.60	14.59	8.00	6.00	0.72▲	0.70	0.69	0.69	0.70
한강	영월	-		14.02	13.77	8.00	6.00	0.78 -	0.78	0.78	0.78	0.78
한강	잠수교	-		-	-	-	-	2.88▲	2.82	2.83	2.83	2.81
안성천	평택	-		11.79	11.05	7.00	6.00	2.32 -	2.32	2.32	2.32	2.31
안성천	동연교	-		13.04	13.10	8.50	7.50	2.67 -	2.67	2.67	2.67	2.67
임진강	전곡	-		11.20	11.20	9.50	7.50	0.53 -	0.53	0.53	0.52	0.50
임진강	적성	-		14.47	14.47	11.50	9.50	0.32▲	0.31	0.30	0.30	0.29
한강	중랑교	-		9.21	9.13	6.50	5.00	0.85 -	0.85	0.84	0.82	0.76
한강	성남	-		10.86	10.83	7.00	5.50	1.98 -	1.98	1.98	1.98	1.98
한강	퇴계원	-		6.39	5.80	3.00	2.00	-0.19▲	-0.20	-0.21	-0.21	-0.21

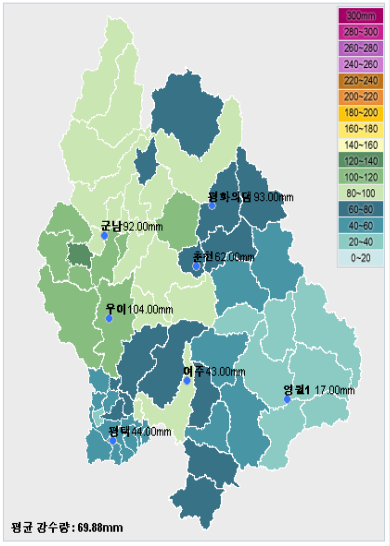
댐자료 - 댐의 수문현황을 제공(검색기간 끝시간 기준)

댐관측소	계획홍수위 (EL.m)	제한수위 (EL.m)	수위 (EL.m)	저수율 (%)	유입량 (m³/s)	총방류량 (m³/s)	수문방류량 (m³/s)	발전방류량 (m³/s)
평화의댐	221.50	191.00	166.09	0.16	31.00	30.00	0.00	0.00
화천댐	183.00	175.00	165.82	53.74	180.00	180.00	0.00	180.00
춘천댐	104.90	102.00	101.73	87.79	244.40	210.00	0.00	210.00
소양강댐	198.00	190.30	173.13	49.27	210.00	221.00	0.00	220.00
의암댐	73.36	70.50	69.94	70.95	209.00	319.10	0.00	319.10
청평댐	52.00	50.00	49.76	86.46	339.40	517.40	0.00	517.40
충주댐	145.01	138.00	133.34	59.47	332.00	329.00	0.00	329.00
괴산댐	136.93	134.00	133.57	78.76	0.00	0.00	0.00	0.00
충주조정지댐	67.30	-	64.11	87.37	269.00	123.00	0.00	123.00
횡성댐	180.00	178.20	172.50	57.55	2.00	2.00	0.00	1.00
팔당댐	27.00	25.00	25.27	96.61	867.60	767.60	0.00	767.60
군남댐	40.00	23.00	23.82	2.22	102.00	98.00	98.00	0.00

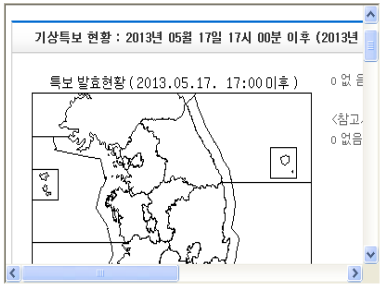
보자료 - 보의 수문현황을 제공(검색기간 끝시간 기준)

보관측소	계획홍수위 (EL.m)	관리수위 (EL.m)	상류수위 (EL.m)	하류수위 (EL.m)	저수율 (%)	유입량 (m³/s)	방류량 (m³/s)
강천보	45.57	38.00	37.92	33.34	97.47	255.00	383.00
여주보	40.64	33.00	33.07	28.35	102.39	269.00	204.00
이포보	36.24	28.00	27.83	25.30	92.17	249.00	92.00

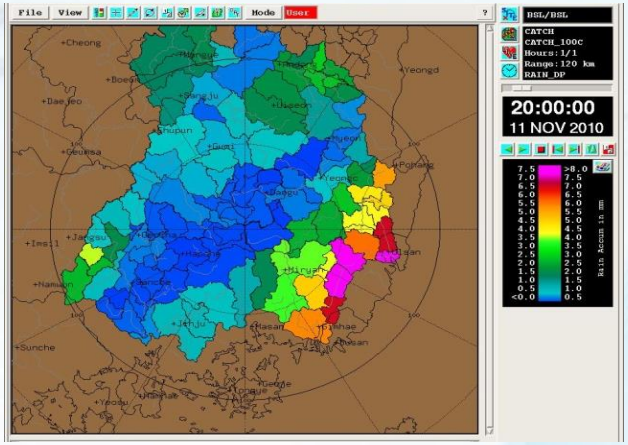
강수량자료 검색기간동안 평균누가강수량



기상 특보 상황 - 현재 기상특보 현황(기상청 자료제공)



Integrated Flood Monitoring
(Water Level, Rainfall, Dam, Weir, Weather report)



Mean Areal Precipitation by Rain Radar

CCTV River Monitoring
(Hangangdaegyo)

Data Transmission in real time

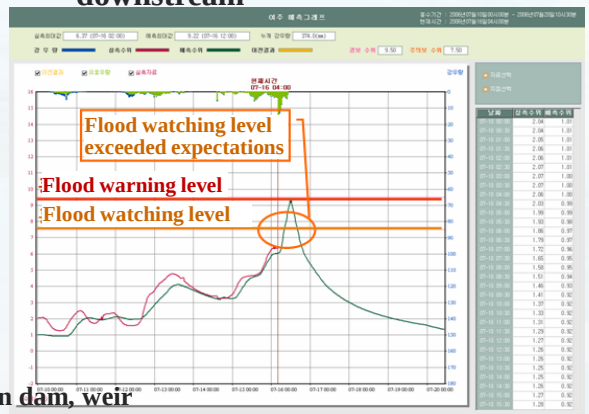
- Real time transmission of observation data every 10 minute
- Applying VHF, CDMA, Wireless communication, VSAT and etc
- Real time Monitoring by CCTV

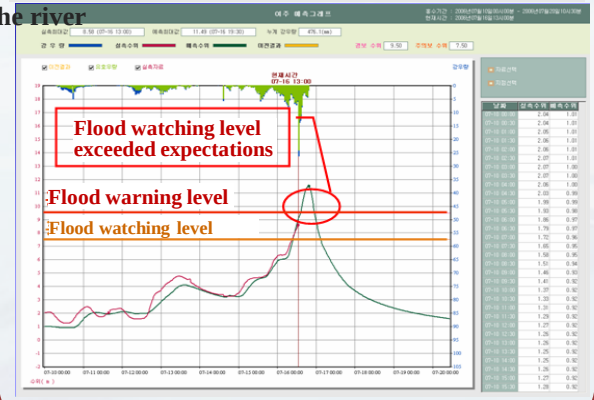
Flood Analysis and Prediction

- Flood Discharge and Water Level Prediction by observation data
- Flood Analysis by experts and advanced software system

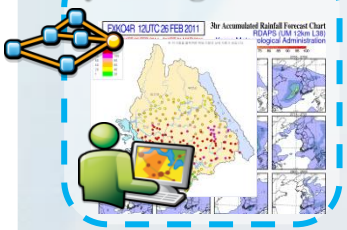
Flood Analysis

- Scenarios analysis
- Check the Dam & Weir Release
- Prediction of water level, flow in downstream





Collect hydrological data



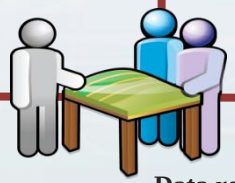
- Rainfall
- Water Level, Flood Discharge
- Predicted rainfall
- Dam inflow/release

Analyze data

- Quality Control
- Data Analysis

Scenarios review

- Consider rainfall forecast
- Reflection of release plan in dam, weir
- To consider the status of the river



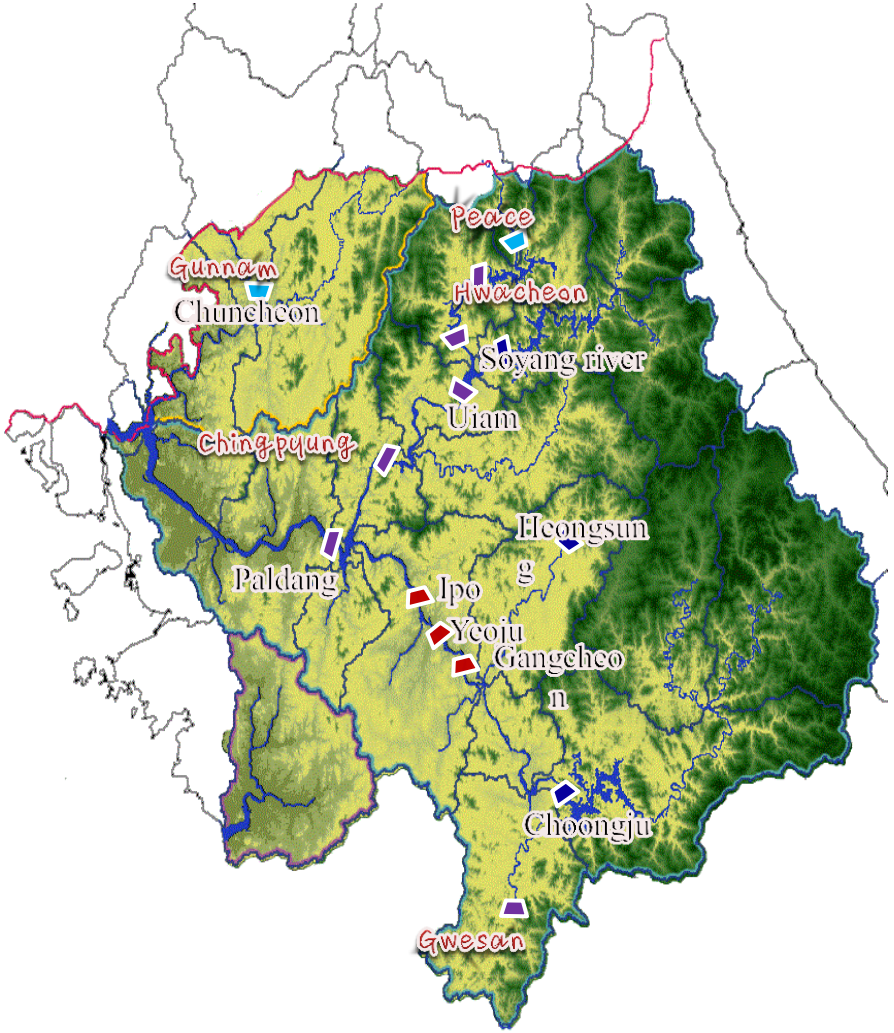
- Data review
- Scenario reset
- Recheck the status of the river

Integrated Dam operation in Han River Basin

River Basin Dam Operation Council

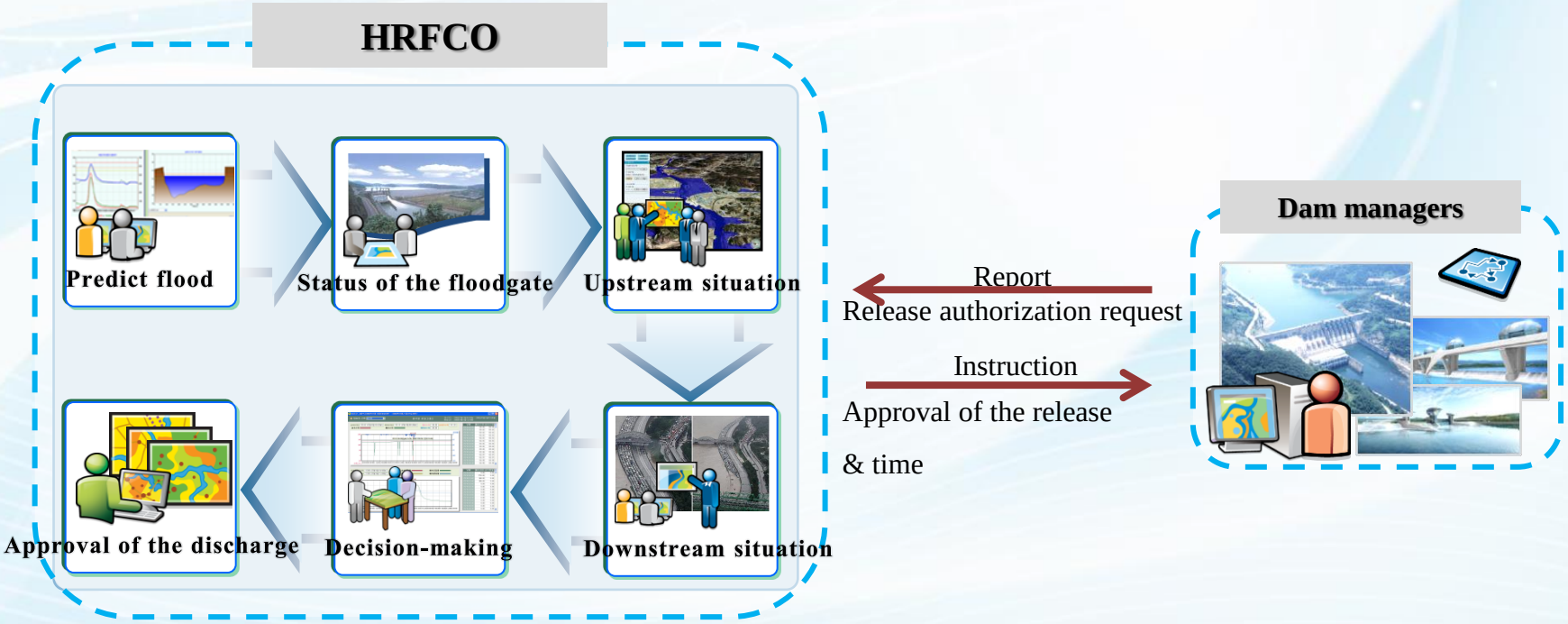
- Multipurpose Dam(3)
  - Soyang river, Chungju, Heongsung
- Hydroelectric Dam(6)
  - Hwacheon, Chuncheon, Uiam, Cheongpyu
- Flood control Dam(2)
  - Peace, Gunnam

- Multifunctioning Weir(3)
  - Gangcheon, Yeoju, Ipo
- Agricultural Reservoir(16)



Dam operation by flood analysis

- **Control Release of Dams and Weirs by the consideration of weather conditions**
  - **Comprehensive review of rainfall in the upstream and the water level in the downstream**
  - **Preliminary release review and action to control flood**
  - **Release review, action and authorization of multipurpose dams of K-water, hydro-electric dam of Korea Hydro & Nuclear Power**



Dam operation by flood analysis

Flood control by regulation of dams and weirs

- (Dam) Flood control
  * Soynag-river, Chungju, Hwacheon, Hoengsung
- (Weir) Floodgate operation
  * Gangcheon, Yeoju, Ipo

Measures to ensure the flood control capacity

- ✓ Maintain restricted dam level during flood season(6.21~9.20)
- ✓ Preparatory release for the flood defense

Flood Watch & Warning Issue

- **Flood Watch & Warning Issue by Flood Forecasting Results and Weather Prediction**

Flood Warning Criteria

Flood forecasting criteria

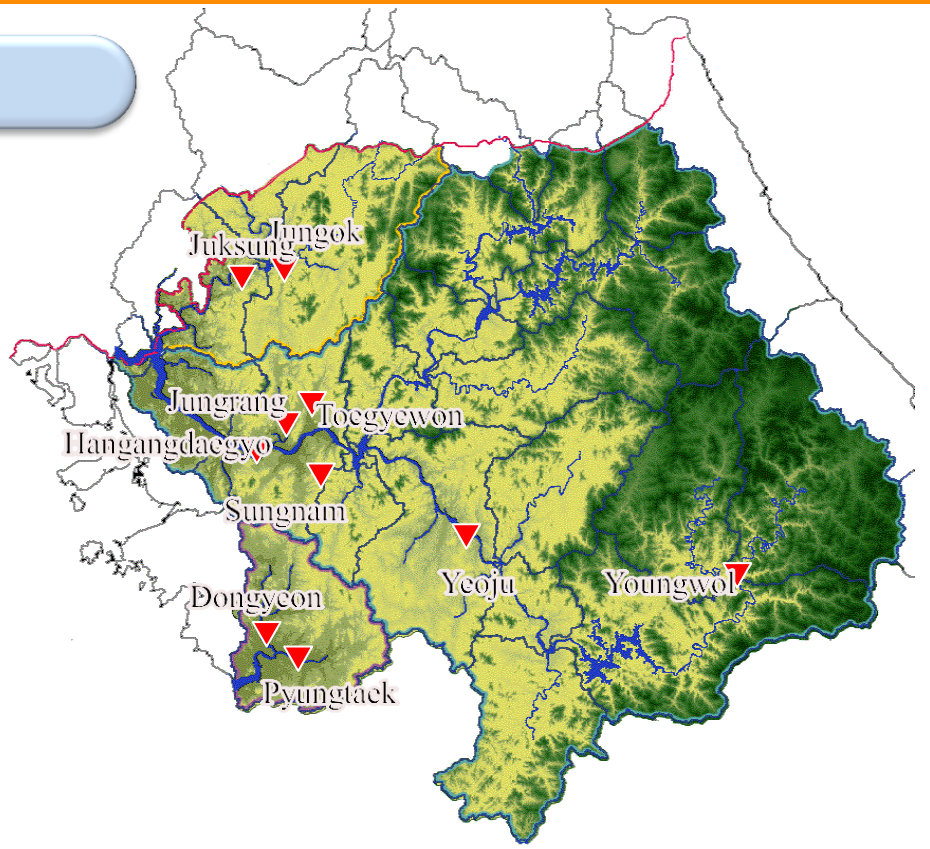
Flood forecasting criteria

- Flood Watch

  Reaching at 50% of Design Floods for River Improvement Work

- Flood Waring

  Reaching at 70% of Design Floods



Flood forecasting station

water system	Han river(the main stream)			Han river(major branch)			Limjin river		Ansung river	
Forecast station	Hangangdaegyo	Yeoju	Youngwol	Jungrang	Sungnam	Toegyewon	Juksung	Jungok	Pyungtaek	Dongyeon
Watch water level(m)	8.5	6.0	6.0	5.0	5.5	2.0	9.5	7.5	6.0	7.5
Warning water level(m)	10.5	8.0	8.0	6.5	7.0	3.0	11.5	9.5	7.0	8.5

Dissemination of Flood Forecast

Protect the lives and properties of the people from flood

1 Flood Prediction

- Data Collection
  (rainfall, water level, dam, weather, etc)
- Real time transmission
- Flood prediction
  (water level, flood discharge)
- Examine dam discharge
- Examine flood forecasting water level

2 Flood Control

- Control dam & weir

(Dam) Operation of Restrict water level

- Storage upper flow during flood
- Consider downstream effect during discharge
- (Weir) Operation floodgate

- Issue Flood Forecasting

3 Dissemination

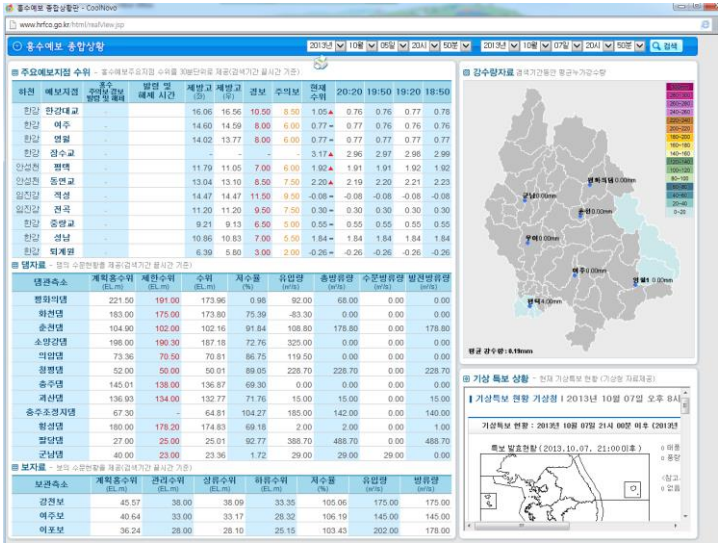
- Dissemination
  - Web, SNS, Fax, phone
  - Central Disaster and Safety Countermeasures Headquarters, Local Disaster and Safety Countermeasures Headquarters, company, Police Agency
- Provide flood information
  - Road, Railway and etc
  - Waterfront area

Dissemination of Flood Forecast

Dissemination toward the general public

- **Dissemination to the general public using Han River Flood Control Office Webpage and related system**

Electrical transmission(SNS)



Comprehensive Flood Management Systems (Han River Flood Control Office)
http://www.hrfco.go.kr/html/realView.jsp

River Information Display System

Dissemination of Flood Forecast

Provision of various flood information concerning road, railway and park

Operation of river information dsiplay system

Flood information

Directly sending to the flood prevention staff s

2012

4 times flood forecast issue
25 Flood Preparation Water Level exceed
345 Dam Discharge approval
51,890 SNS

Issue flood forecasting

Approval of the discharge(dam, weir)

Stream stage
- **River facility, road, railway**
- **Weir(the upper limit stage)**
- **Pump station**

Strengthening flood information service toward public

- Central department (Blue House, MOLIT, Ministry of Defence, etc)
- Local government agency(Seoul, Gyeonggi, Chungcheong, etc)
- Seoul Metropolitan Police Agency, etc
- K-water, Korea Hydro & Nuclear Power, related organizations, etc
- **Total more than 1,100 people received**

Dissemination of Flood Forecast

Extension of alarm of road water level control in main road of Seoul

(Dissemination to the police station)

- Road management in flood season

HRFCO

Situation notice

The municipality, Police Office (Road management agency)

Main road

Electronic Display

Overall control of inundated road

Dissemination of control situation

Provision of predicted water level for the road control

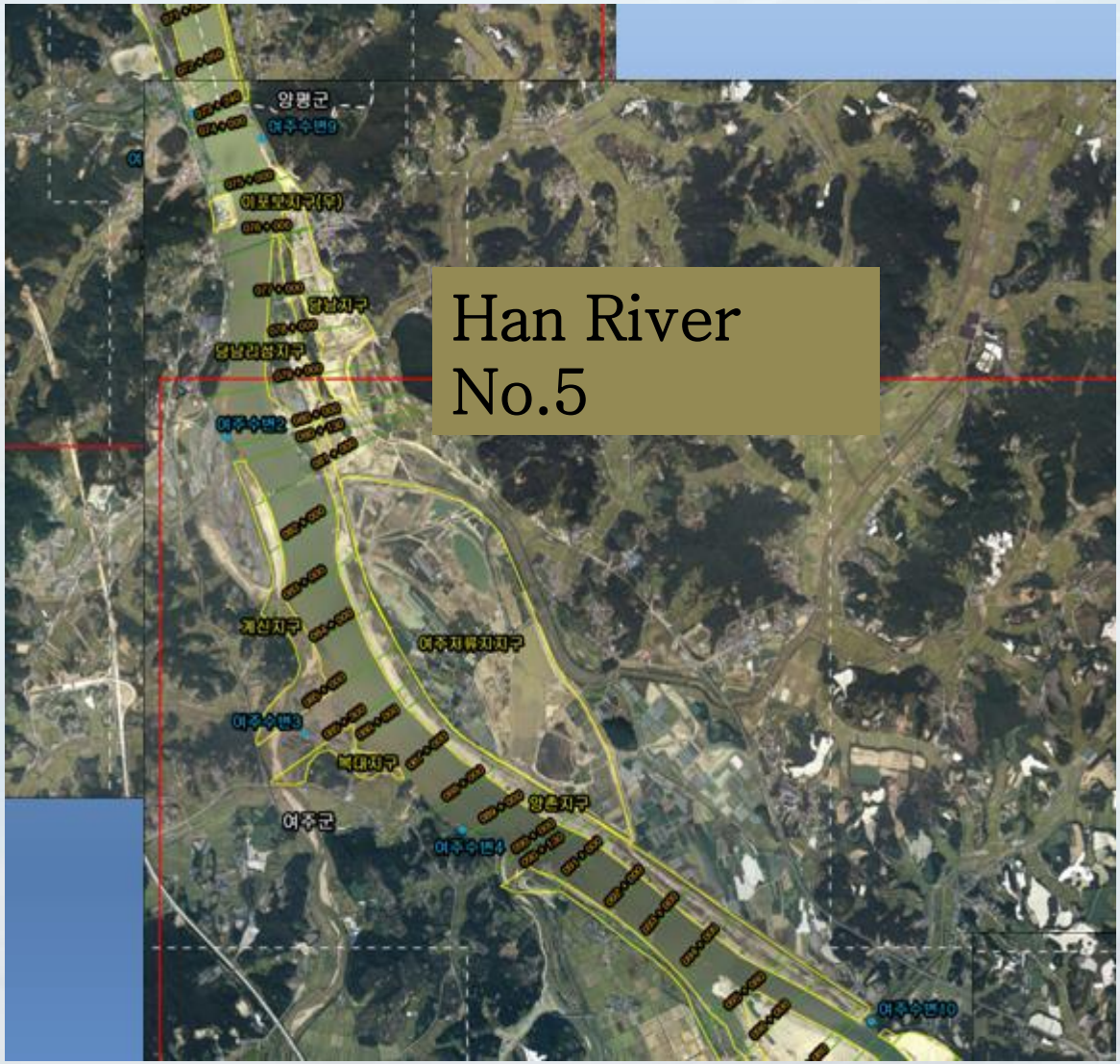
Instruction

Report

Facility management agency Jurisdiction police station

Patrol vulnerable areas, Road management

Provide inundation information along Water Front Area



Stage observatory

- (Data) Ipo, Yeoju, Gangcheon
- (Application) MOLIT

Water-friendly leisure facilities

- (Data) Camp
- (Application) Yeoju

Military training ground

- (Data) Baeksuk division, Auto camp
- (Application) Ministry of Defense

Yeoju detention pond

- (Data) ecological park
- (Application) K-water

Issued Flood Warning

- Watch flood level : Water level which is equivalent to 50 % flow of design flood
- Warning flood level : Water level which is equivalent to 70 % flow of design flood

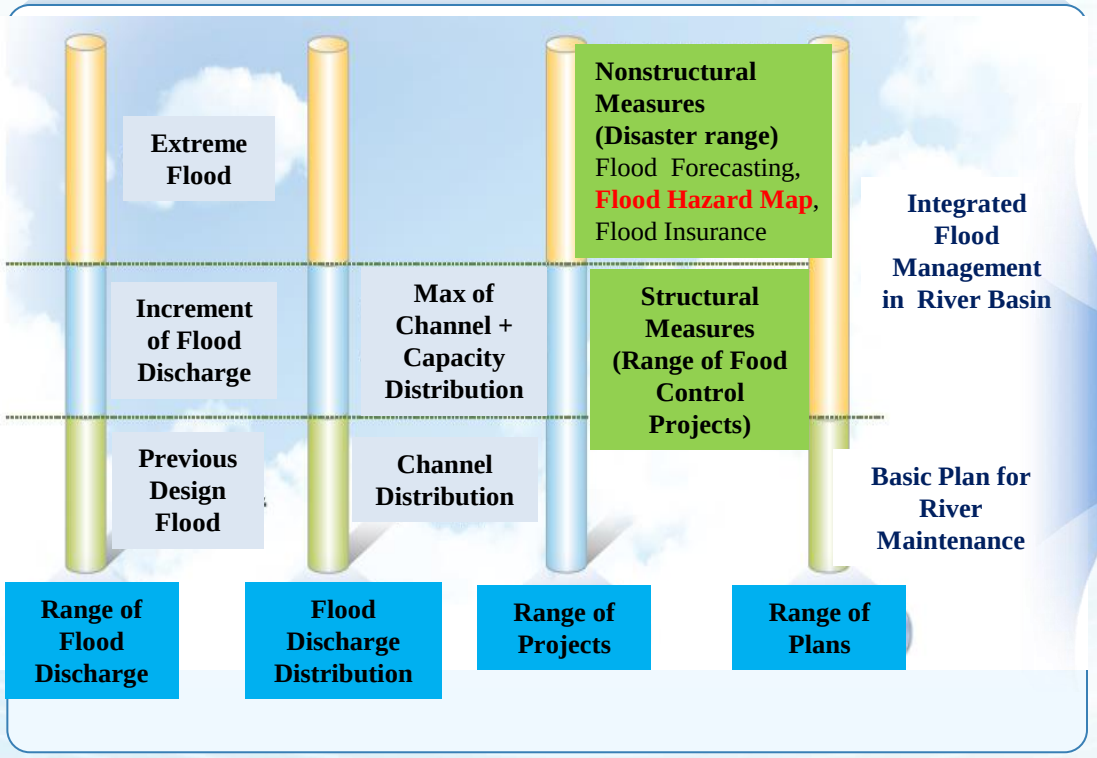
		'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11~'13
Han River FCO	Watch	6	5	-	2	-	9	-	3	6	1	18
	Warning	1	3	-	-	-	2	-	-	1	-	3
Nakdong River FCO	Watch	-	15	11	8	2	14	2	-	-	-	13
	Warning	-	12	6	1	1	1	-	-	-	-	5
Geum River FCO	Watch	-	4	7	1	2	2	-	-	2	-	6
	Warning	-	2	1	-	-	1	-	-	1	-	2
Yeongsan FCO	Watch	-	9	1	2	1	1	4	-	10	12	15
	Warning	-	4	-	3	2	-	1	-	3	3	4

3

Flood Hazard Map & Inundation Information

Flood hazard map

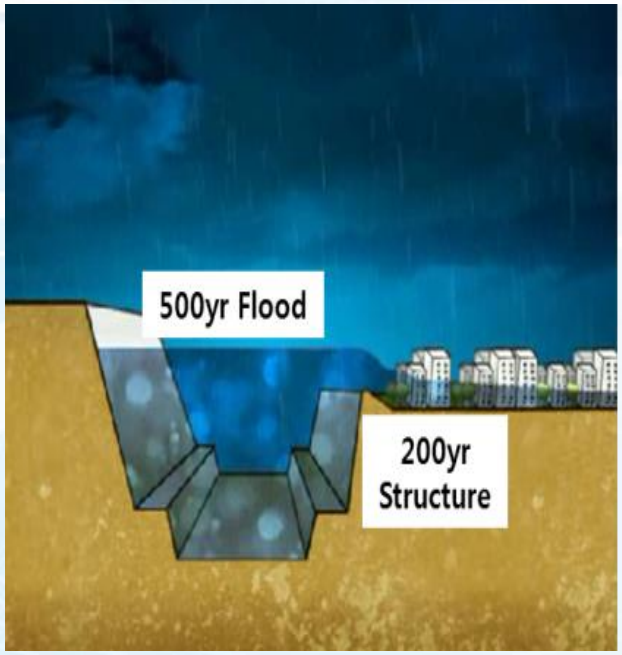
- Map and Digital map presented inundation depth and inundation area expected to flood occurs
- Information provided basic range of flood damage and inundated area
- To minimize the causalities, property damage by inundation

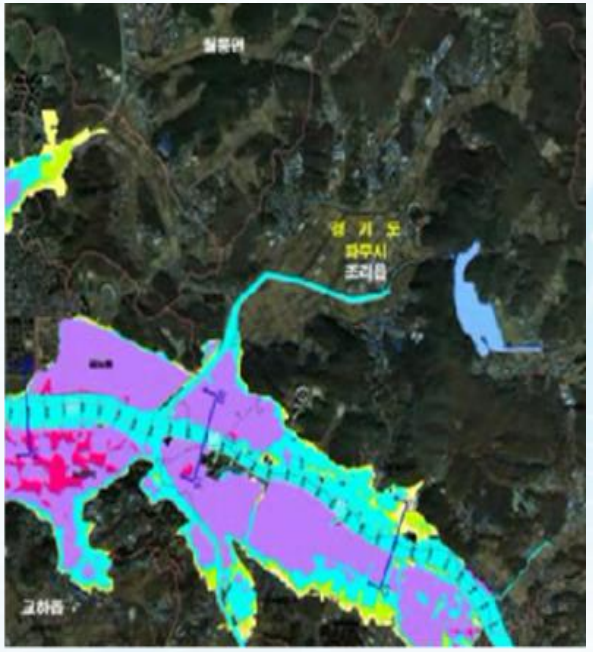


Minimize the flood damage as part of the non-structural Flood mitigation

Flood hazard map

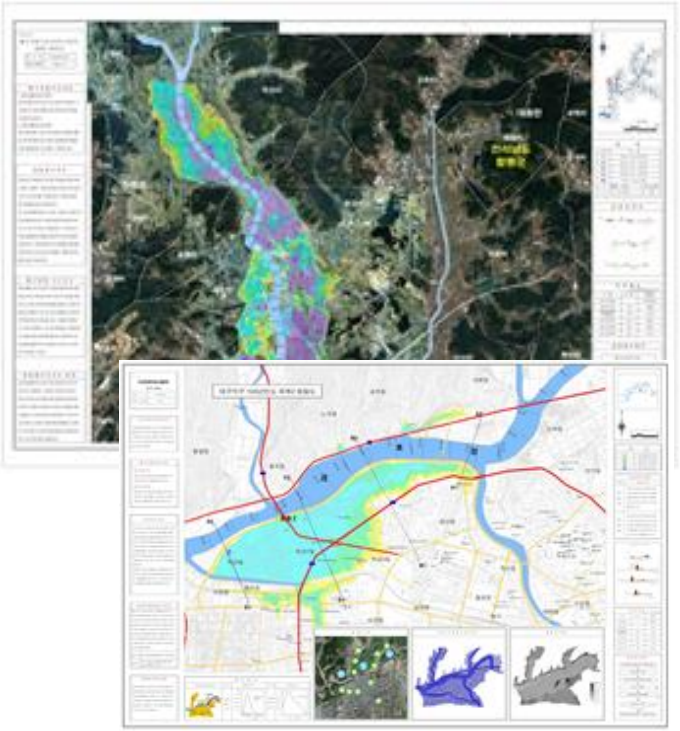
Concept of Flood Hazard Map



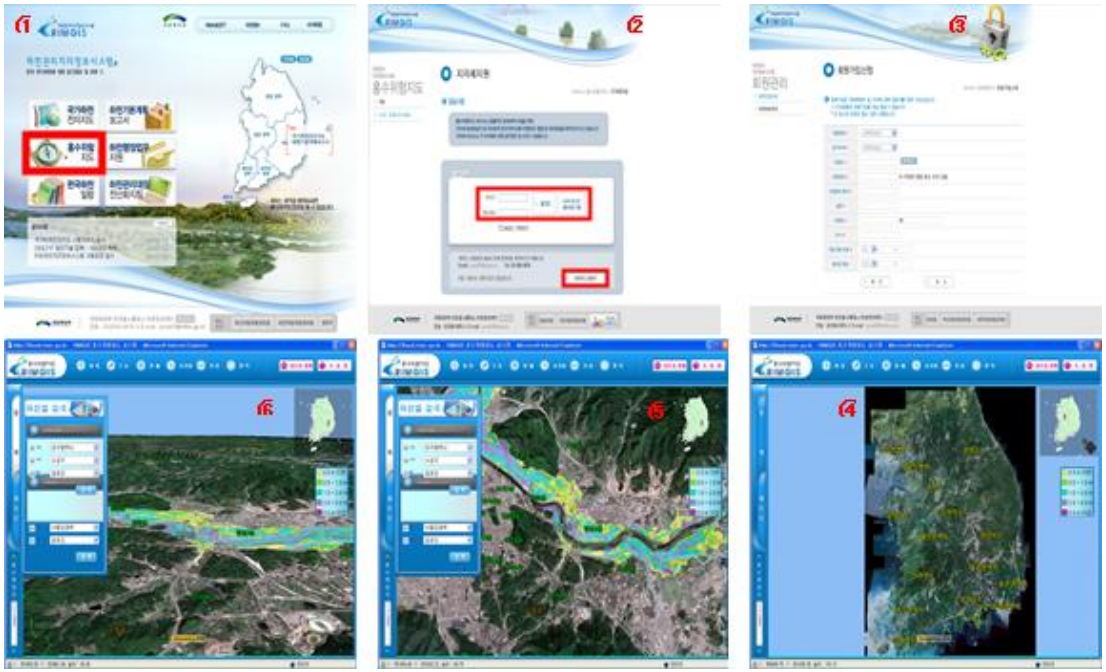


Flood hazard map

- To implement forecast and early warning for flooding inundation in vulnerable areas
- Casualties and property damages can be reduced by using the map
- It is applied to make a flood insurance, and basic data for emergency response planning



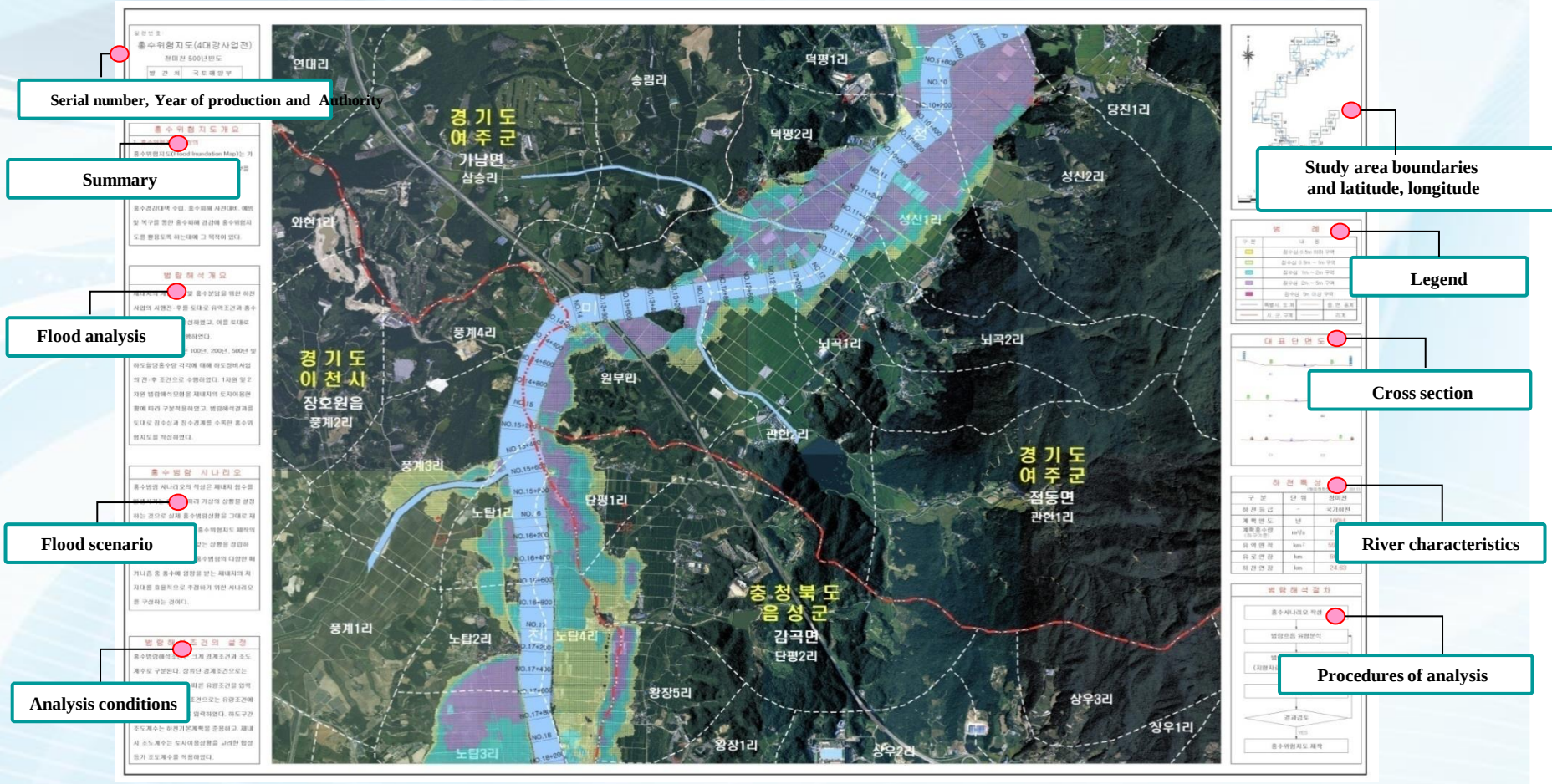
Flood Hazard Map (paper-type map)



Online-system of the Flood Hazard Map (digital map)
(RIMGIS, http://www.river.go.kr)

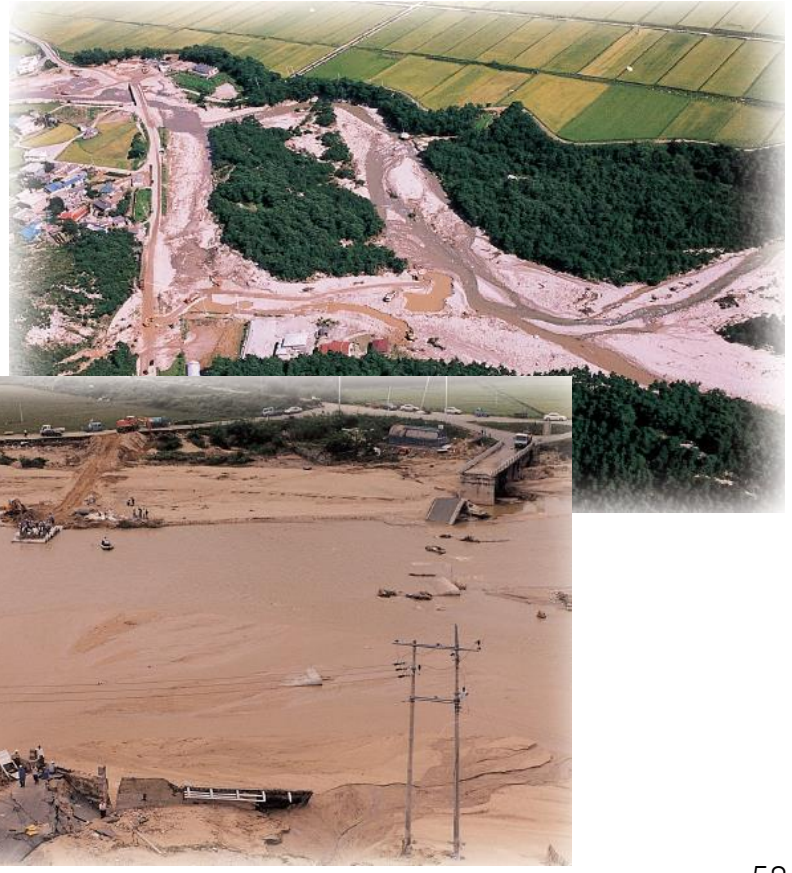
Flood hazard map

- **National stream (2,332 km) Production projected in 2015**
  - 72% (1,674 km) production schedule in 2013



Inundation Information for Flooded Area by Extreme Flood

- WAMIS(Water Management Information System supply past inundation information (date, rainfall type, etc.) http://wamis.go.kr
- Publish the annual Disaster Report (including flood damage cost, causalities, inundated area, pictures, etc.)



4 Structural Measures for Flood Prevention

1. Introduction

Structural Countermeasures

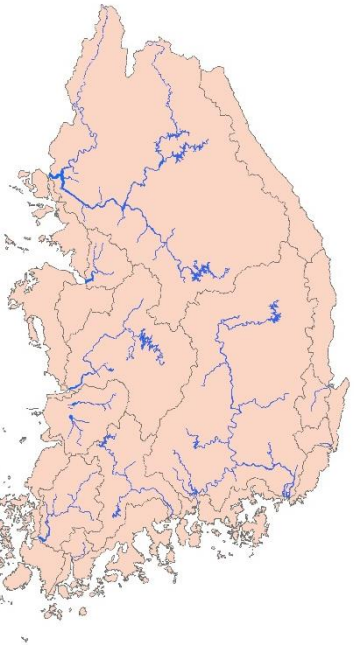
- Structural Countermeasures such as detention basins, levees, reservoirs(dams) and weirs are used to prevent flood.

2. River Improvement Works (RIW)

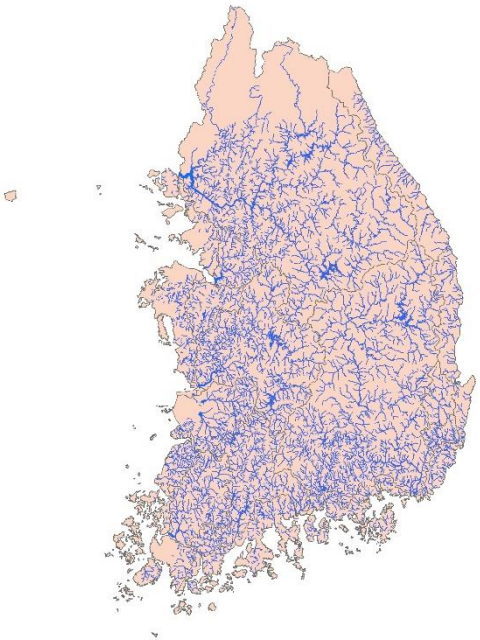
Rivers in Korea

Status

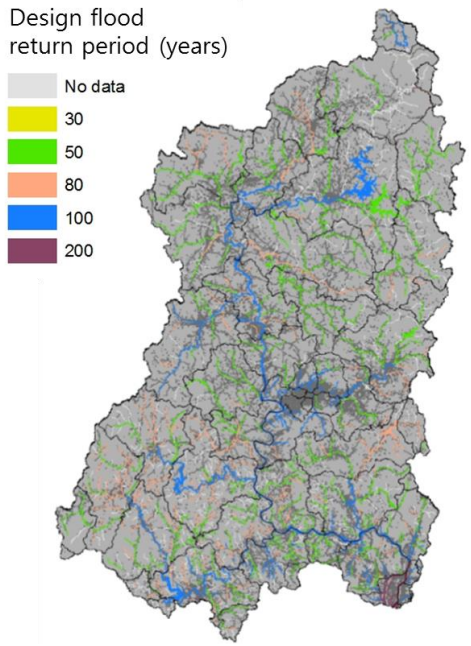
Classification	Number	Length(km)	RIW(km)	Ratio(%)
National River	62	2,998	2,972	99.13
Regional River	3,775	26,843	20,581	76.67



National River



National & Regional River

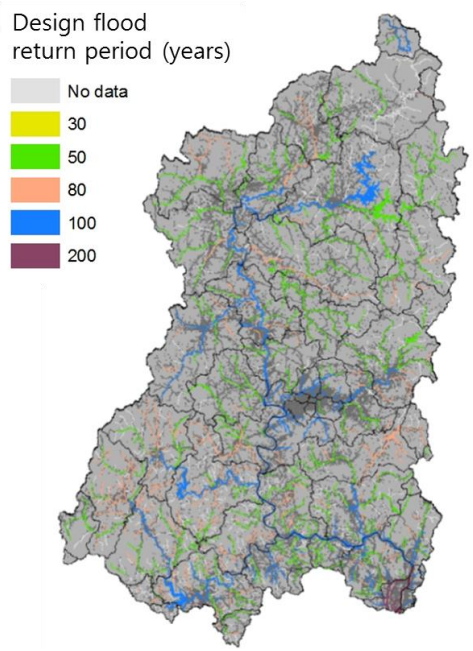


Nakdong River

2. River Improvement Works (RIW)

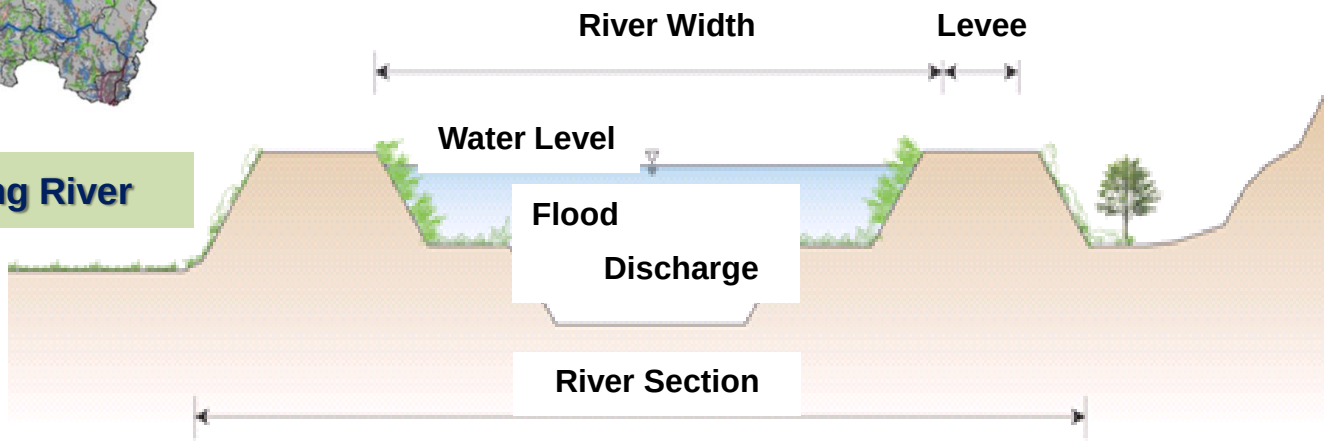
Outlines of RIW's Plan

- **Determination of Design Flood, Water Level, Width, Levee, etc.**



Nakdong River

- Hydrological & Hydraulic Analysis
- Determination Design Flood, Water Level, River Width, and so on
- Levee Reinforcement



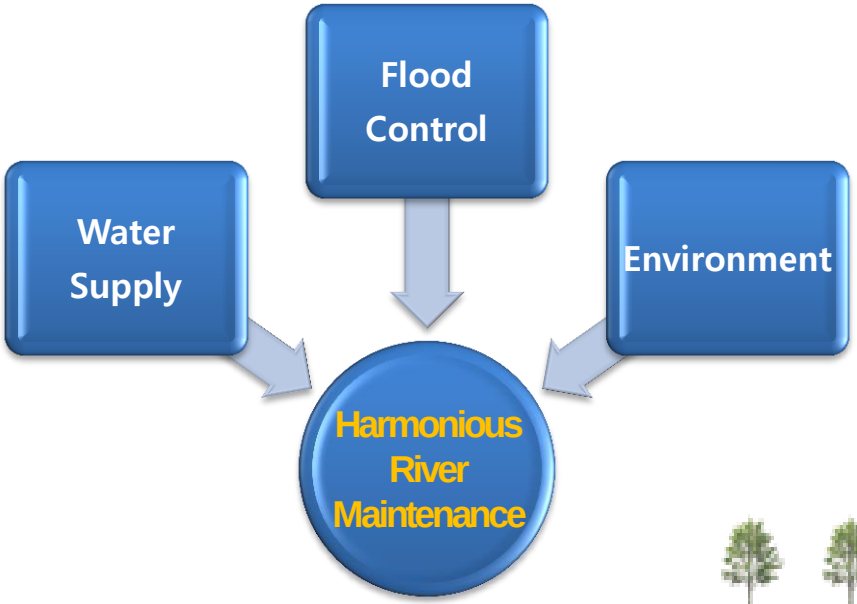
Design Frequency :

30~200yr

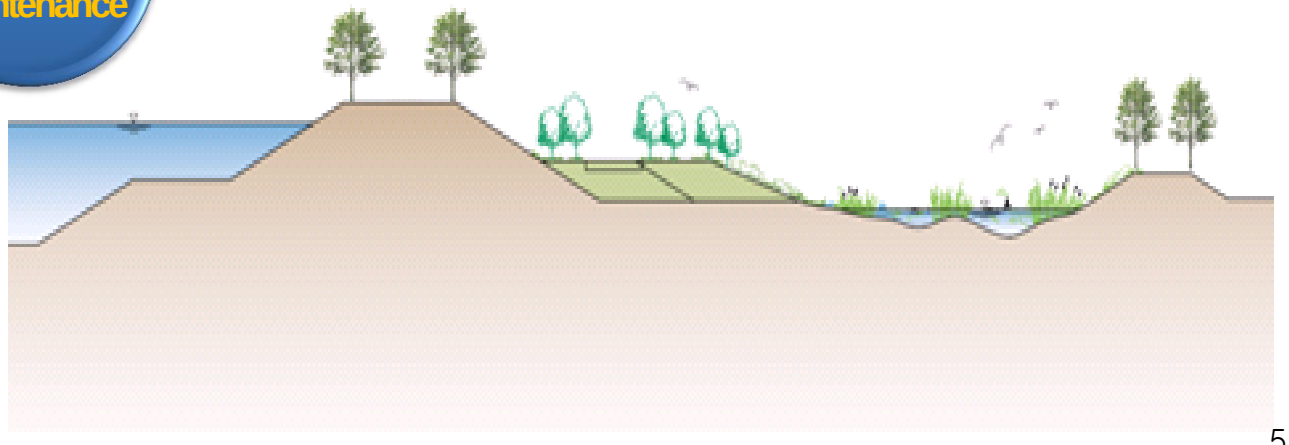
2. River Improvement Works (RIW)

Outlines of RIW's Plan

- **Considering Flood Control, Water Supply, Environment**



- Comprehensive Investigation
- Governance including Resident
- Natural River Engineering
- Restoration & Preservation Area



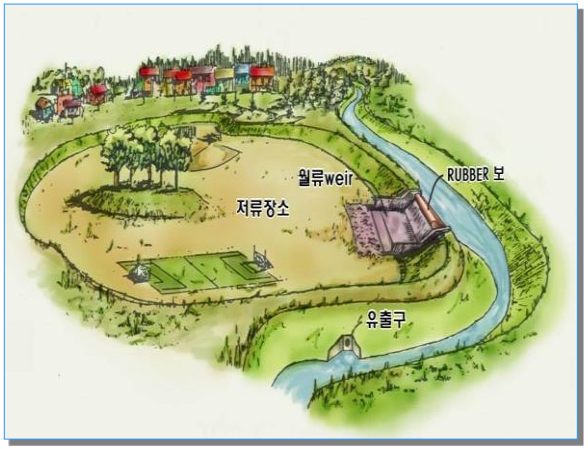
2. River Improvement Works (RIW)

RIW's Planning Procedures

1	• Field Survey and Primary Data Collection • Investigation and Review Related Plan
2	• River Surveying • Setting Basic Direction
3	• Cause Analysis of Flood Damage • Flood Analysis(Hydrological/Hydraulic) • Planning of Water Supply and Environment
4	• Determination of Design Flood • Flood Control Economic and effectiveness Analysis • Determination of River Improvement Work Facilities
5	• Consultation with Related Agencies • Deliberation Committee • Making Report and Computerization Data

2. River Improvement Works (RIW)

Flood Control Facilities in River



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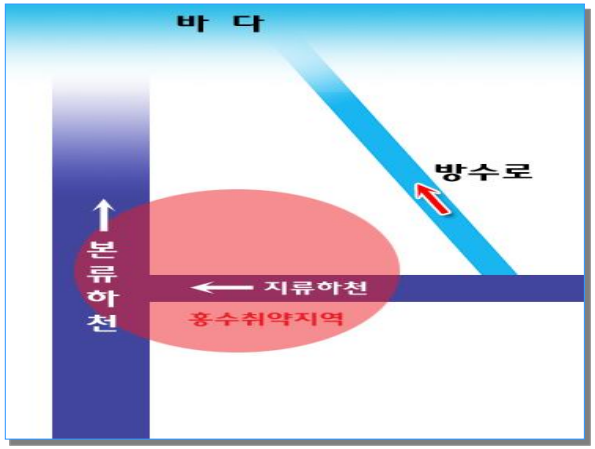
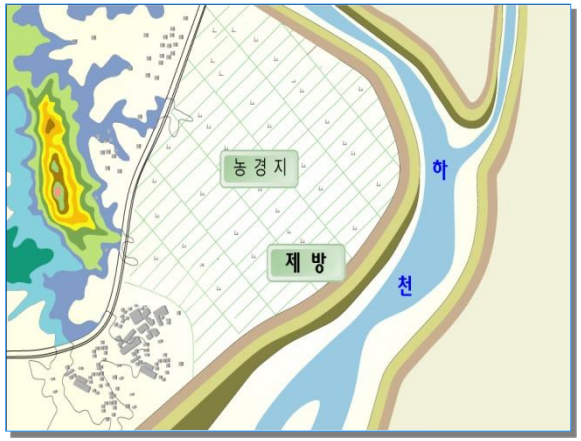
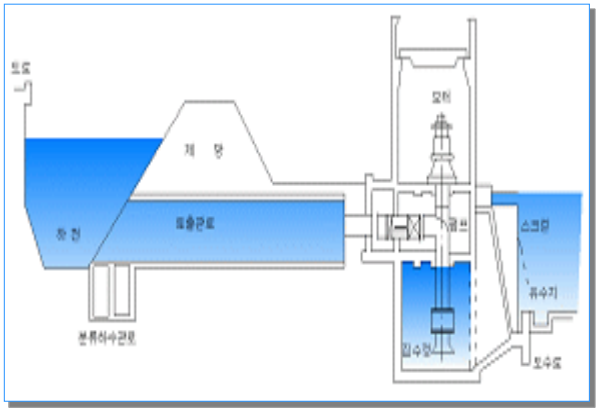


<Diversion Channel>

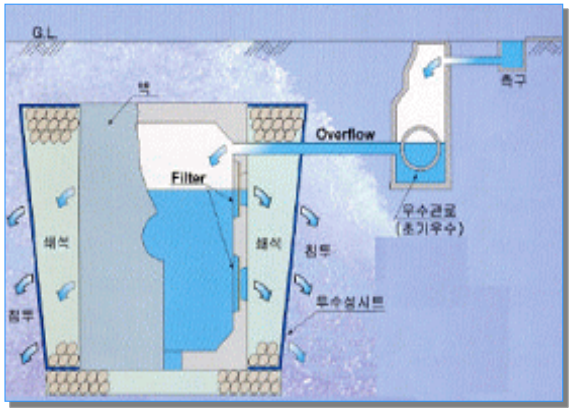


<Levee Reinforcement>

<Detention Dam>



<Pump Station>

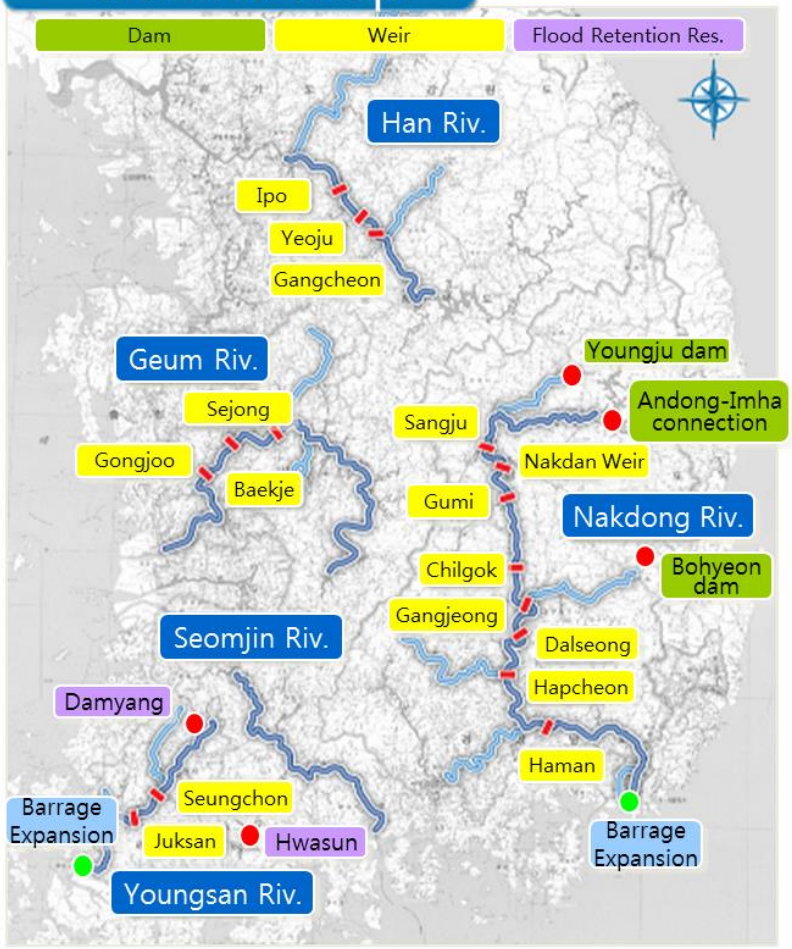


<Runoff Reducing Facilities>

3. 4 Major Rivers Restoration Project

Outline of 4MRRP

Outline Map

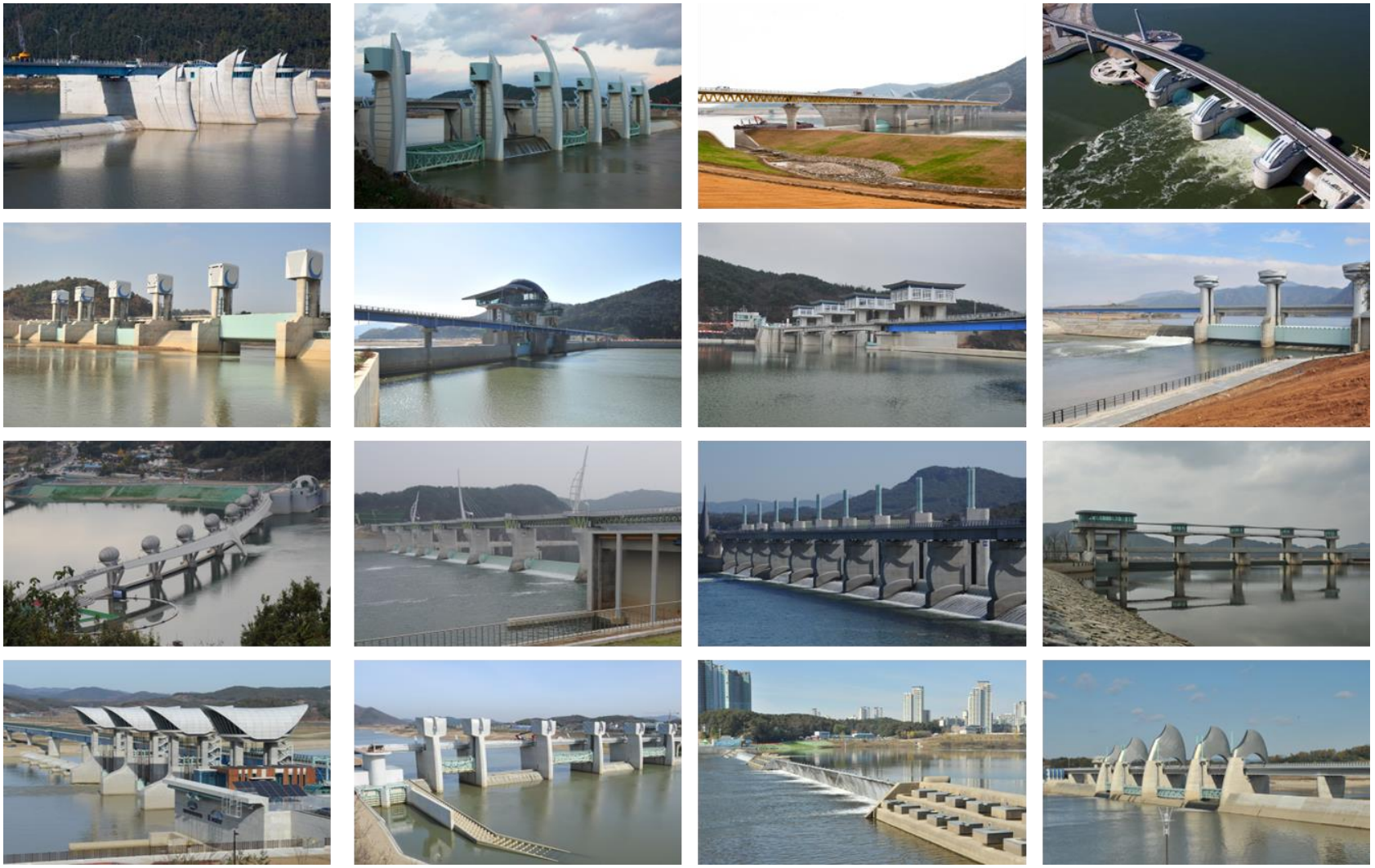


Main Projects

- Dredging : 450 million m^3
- Multi-purpose Weir : 16
- Hydro-power Plant: 16
- Levee Reinforcement : 784 km
- Dam : 3 / Barrage Expansion : 2
- Flood Detention Basin, Washland : 5
- Embanking Agri. Res. : 93
- Riverside Eco-Park : 130 km^2
- Bike path : 1,657km
- Treatment Facilities(WQ) : 1,281

3. 4 Major Rivers Restoration Project

16 Multi-purpose Weirs



3. 4 Major Rivers Restoration Project

Project Scopes & Expected Effects

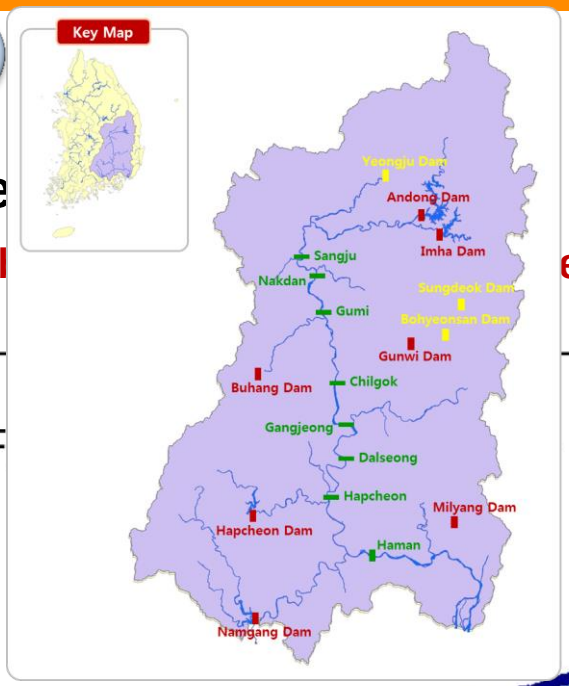
Flood Control	Dredging: 450 million ㎥, Flood Control & Water Retention including Dams: 8 Reinforcing old Levees: 784 km	→ Decreasing Flood Water Level (0.4 - 4m)
Water Security	Weir Construction: 16 Elevation of Reservoir Banks : 93	→ Security water resources of 1.1 billion ㎥
Water Quality Improvement	Environmental Facilities: 1,281 Farmland Removal : 156.8 ㎢	→ Water Quality Grade III (BOD 6mg/L) → II (BOD 3mg/L)
Ecological Restoration	Ecological Wetlands: 39 Preserving natural wildlife habitat Fishway construction : 23 sites	→ Improving Natural Ecology & Promote Eco-tourism
Waterfront Development	Constructing bicycle roads: 1,657km Landscape View Points: 36	→ Improving people's quality of life
Green Energy	Small Hydro Power Plant : 16 Gross Generation : 271 M Kwh/yr	→ Equivalent to electricity used by 250,000 people

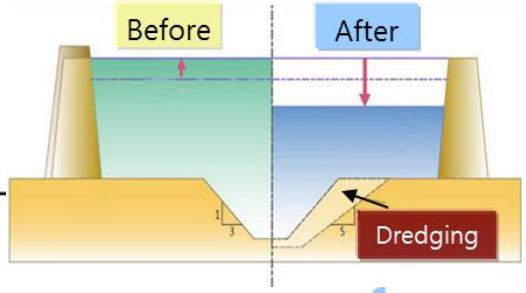
3. 4 Major Rivers Restoration Project

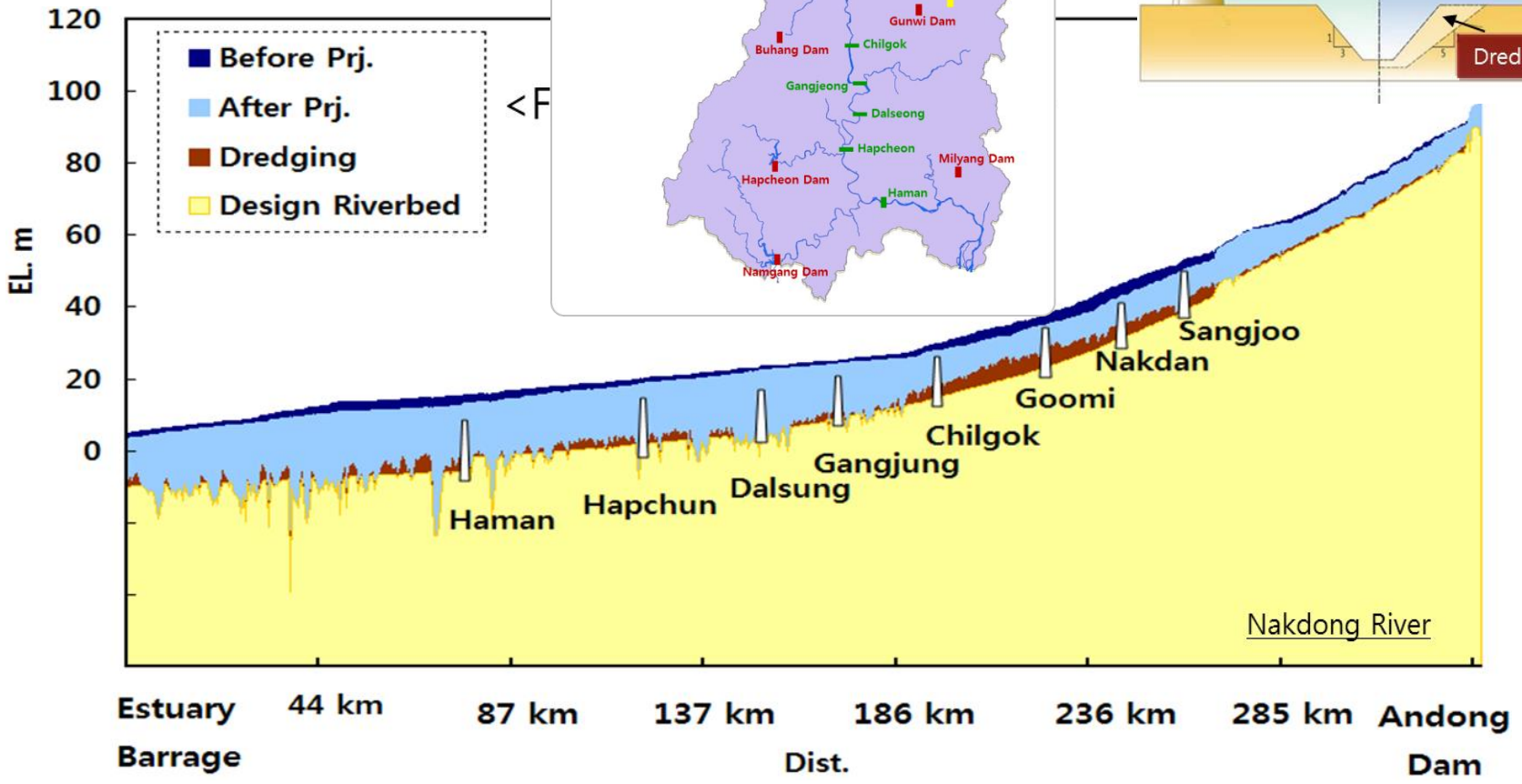
River Topography

- **Riverbed changes due**

  (Mild slope of levee & river-l **e)**





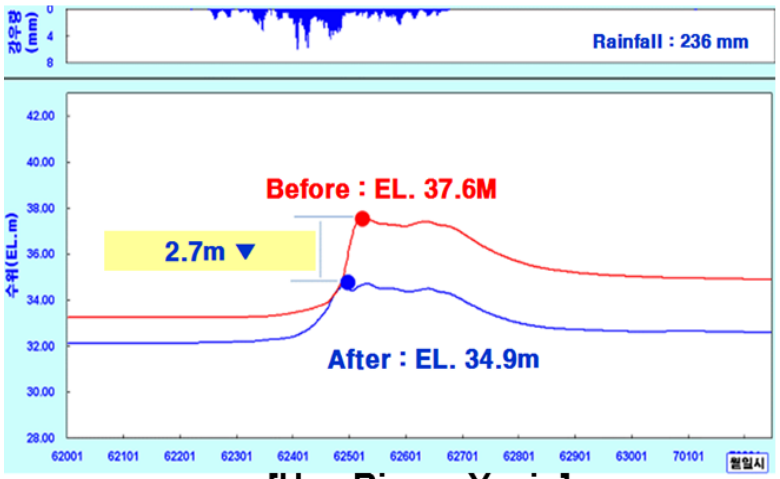


3. 4 Major Rivers Restoration Project

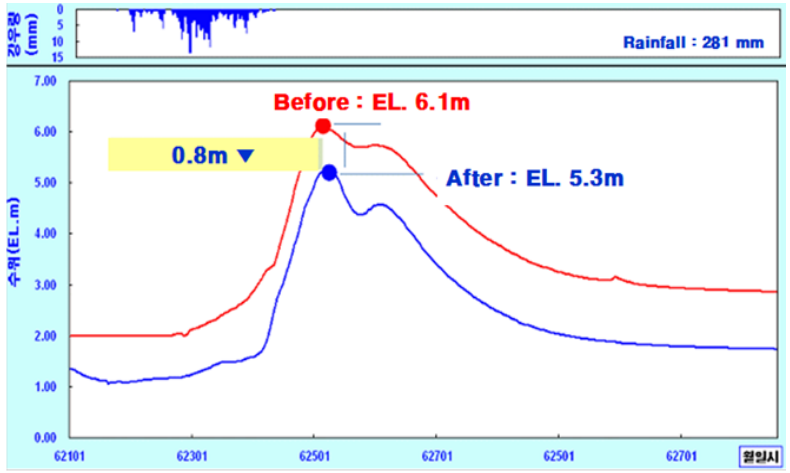
Effects of Riverbed Dredging

- **Significantly decreasing flood water level in main channels of 4 major rivers and its tributaries**

	Han	Nakdong	Geum	Yeongsan
Mainstream	Yeoju	Sangju	Baekje	Naju
	2.70m	3.78m	0.80m	2.13m
Tributary	Seom	Hwang	Miho	Hwangryong
	0.5m	1.3m	0.5m	0.6m



[Han River - Yeoju]



[Geum River - Baekje]

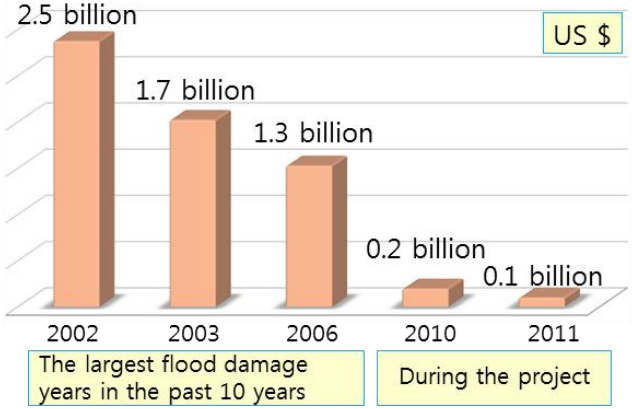
3. 4 Major Rivers Restoration Project

Effects of Riverbed Dredging

- **Record-breaking rain during the rainy season (June 20~July 17, 2011)**
  (Rainfall of over 640mm for 20days)
- **But, dereasing flood water level by dredging (avg. 3.0m ▼)**

- Han Riv. 2.6m ▼
- Nakdong Riv. 3.8m ▼
- Geum Riv. 3.4m ▼
- Yeongsan Riv. 2.1m ▼

The flood damage dramatically drops by 90%



3. 4 Major Rivers Restoration Project

Pictures of Flood Damage Mitigation

Changwon City

Before ('06. 7, 203mm)

After ('11.7, 312mm)

Daegu City

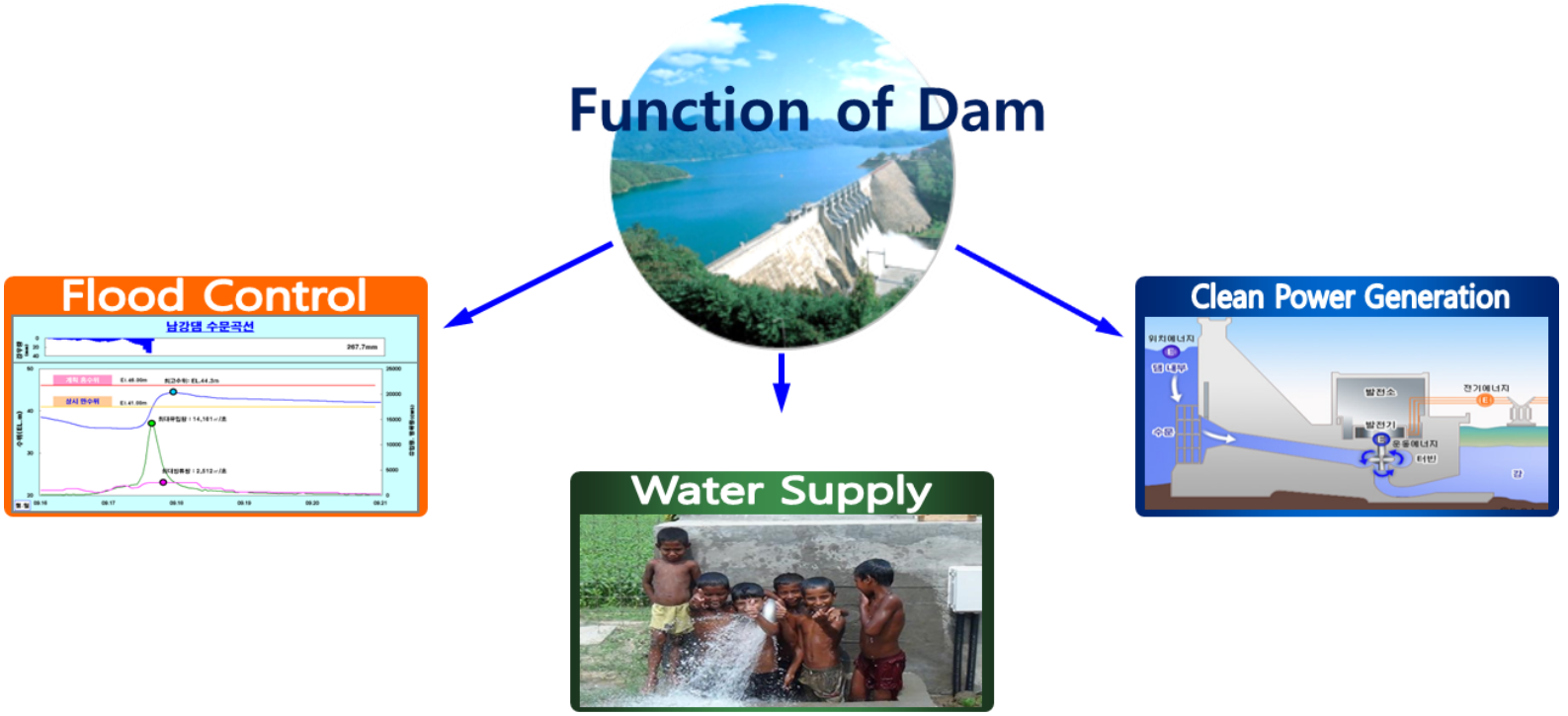
Before ('06. 7, 277mm)

After ('11.7, 290mm)

4. Dam Operation for Flood Control

Basic Concept

- **Purpose of dam(reservoir) operation is to increase public benefit and remove or mitigate flood damage ....**



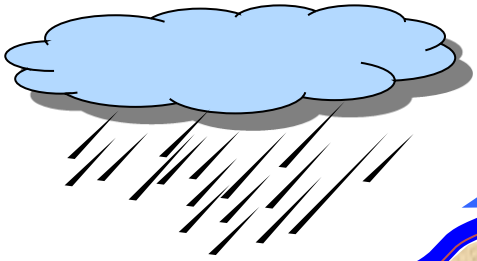
* Flood control take precedence over other functions in flood season

4. Dam Operation for Flood Control

Flood Control by Dam

- **Without Dam**

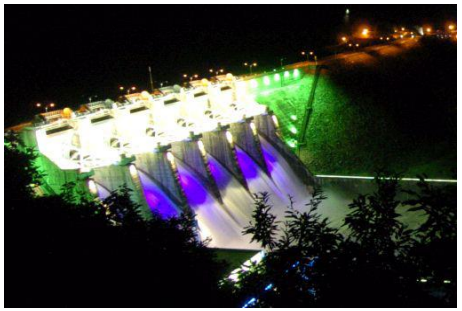
Flood damage in summer season concentrated on rains, water shortage in other season



4. Dam Operation for Flood Control

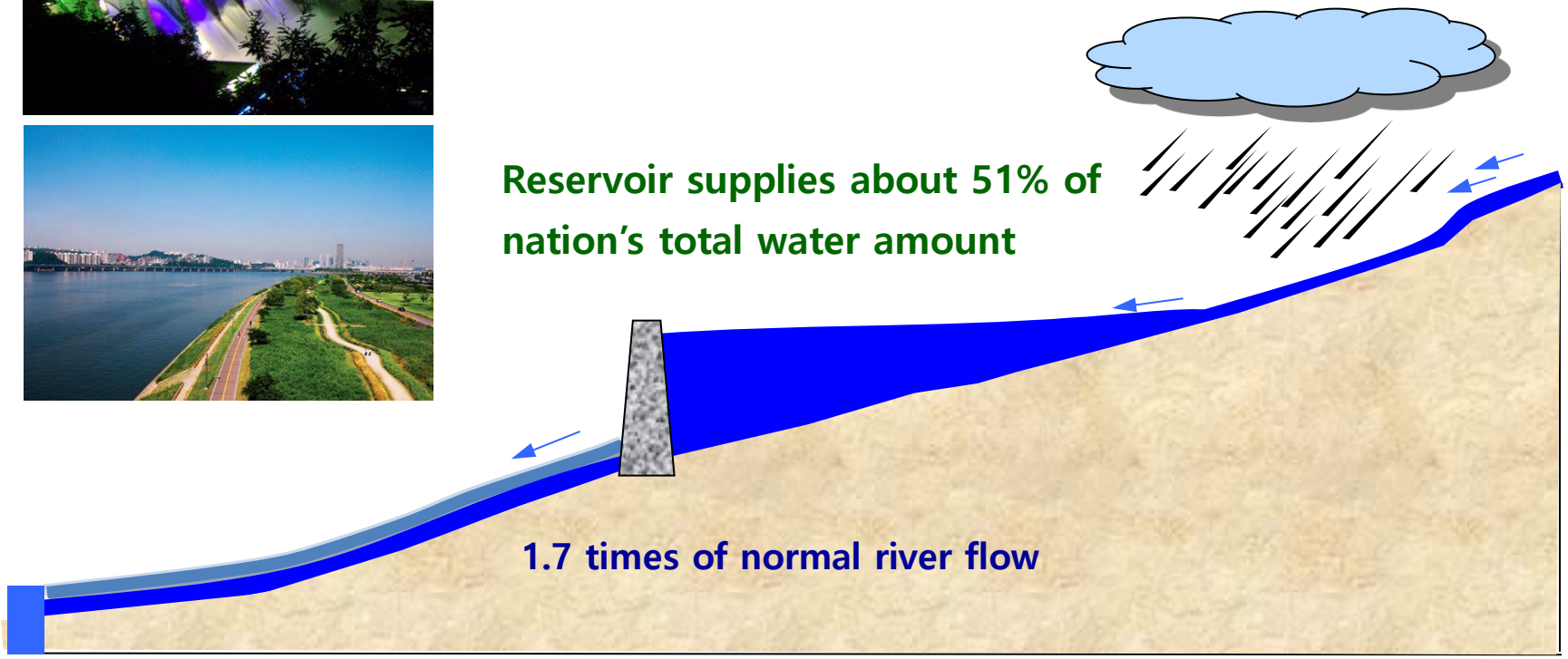
Flood Control by Dam

- **With Dam**



In flood season, Reservoirs control flood and protect downstream.

Water stored in Reservoirs is supplied in dry season.

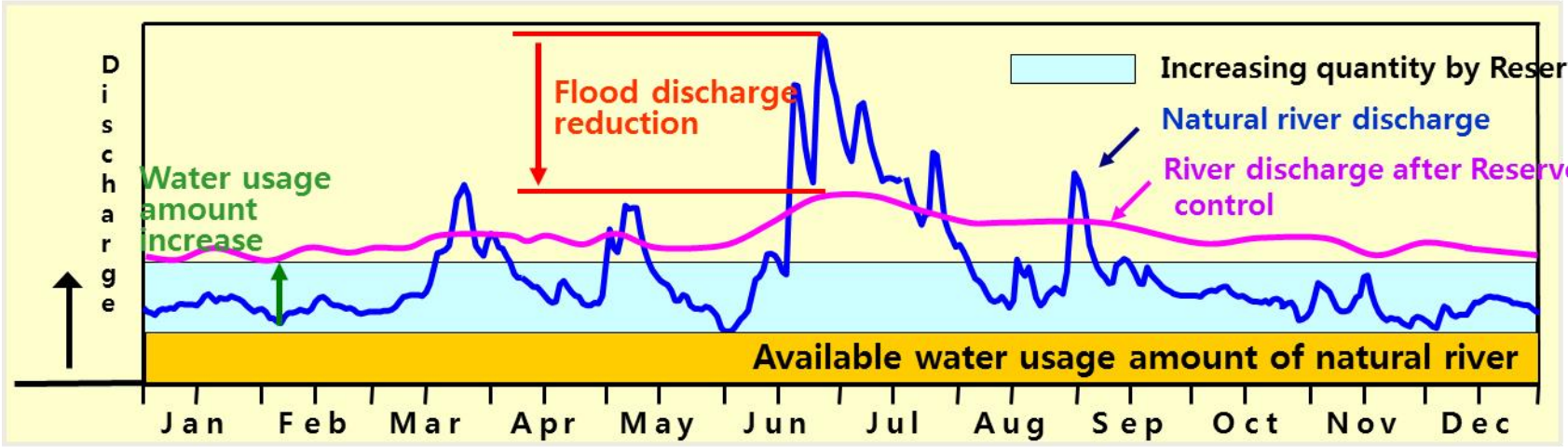


4. Dam Operation for Flood Control

Flood Control by Dam

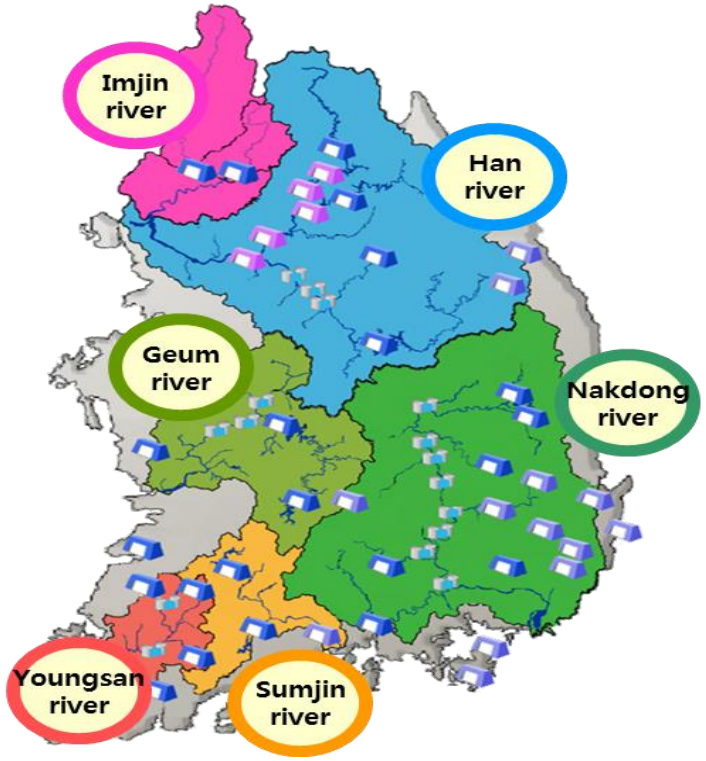
When river discharge is abundant

When river discharge is inadequate



4. Dam Operation for Flood Control

Dams in Korea



Dams in Korea

Toatal 17,750

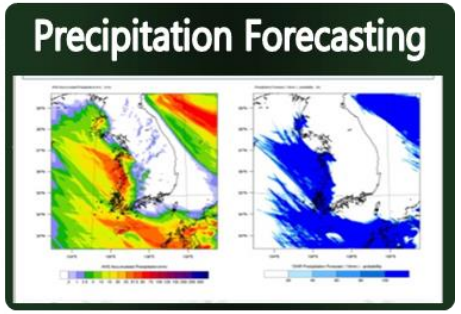
Multi-purpose	17
Municipal & industrial	54
Hydropower	12
Agricultural	17,649
Flood control	2

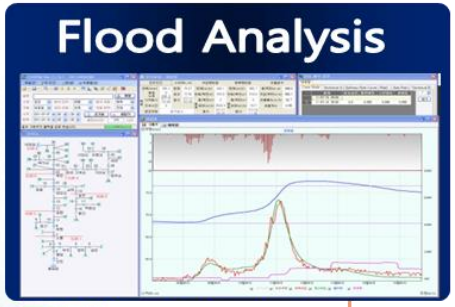
Water Supply (Dam)	Flood Control Capacity	Hydro Power Generation	Water Supply System Capacity
18.8 B㎥/yr	5.2 B㎥	1,750MW	37.2 M㎥/day

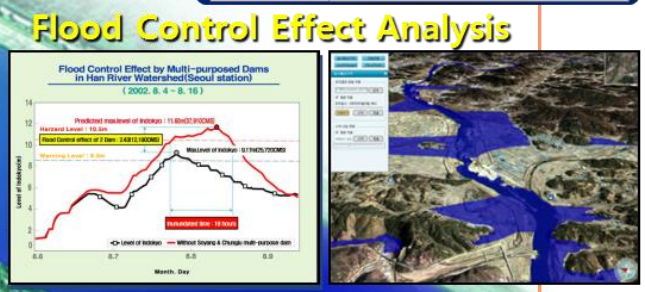
4. Dam Operation for Flood Control

Dam Operation Procedures

- Precipitation Forecast
  Observed Hydrological Data
- Flood Analysis
- Reservoir Simulation (Combined)
- Channel Routing
- Decision Making
- Gate Open/ Warning

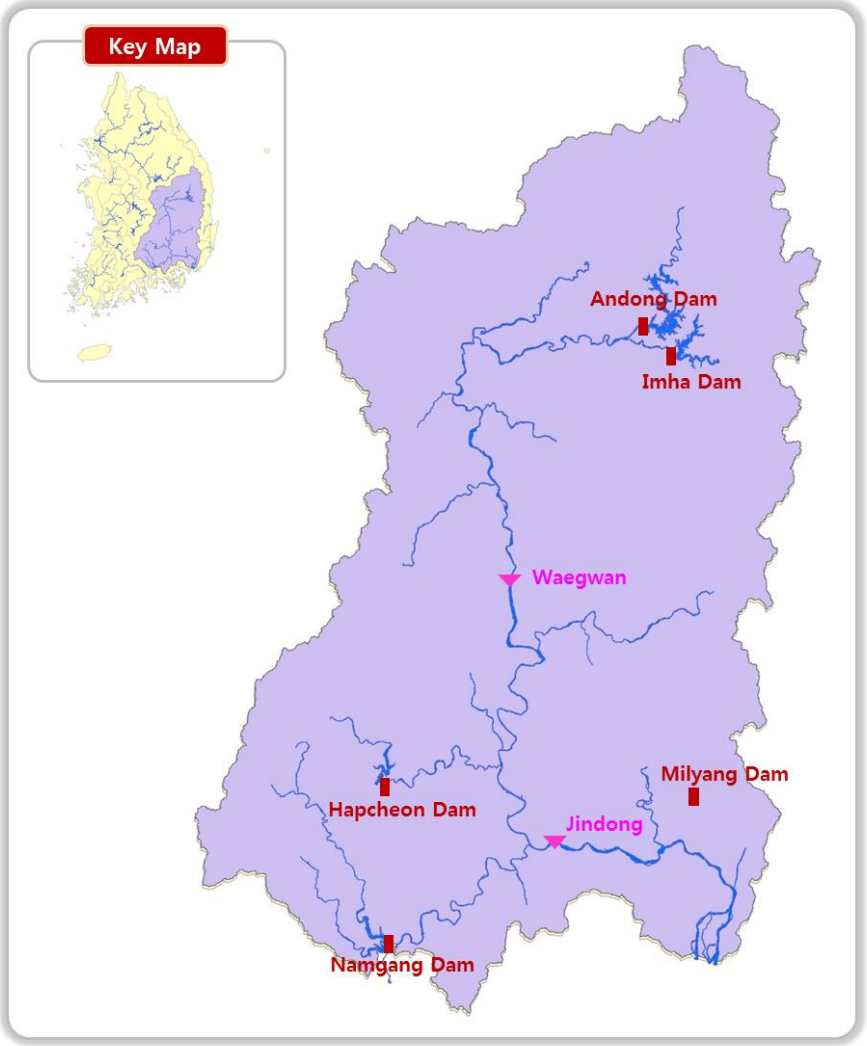


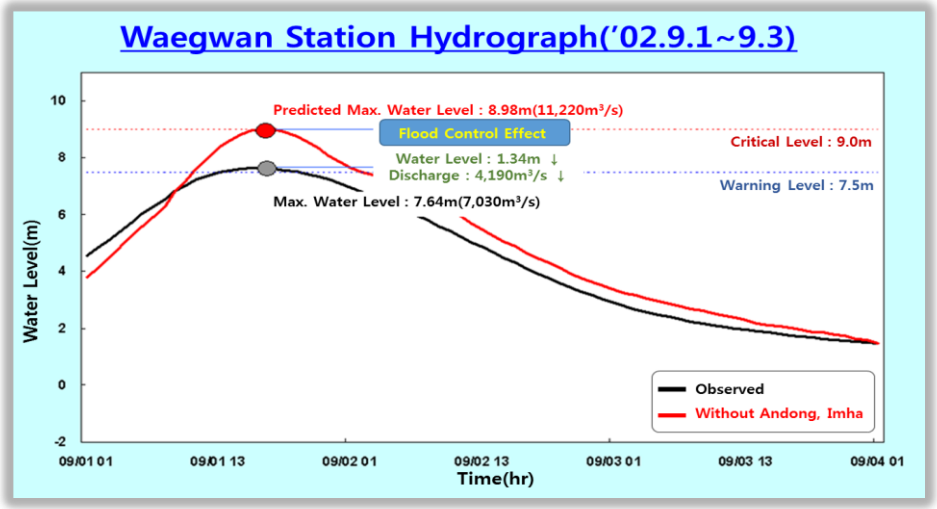


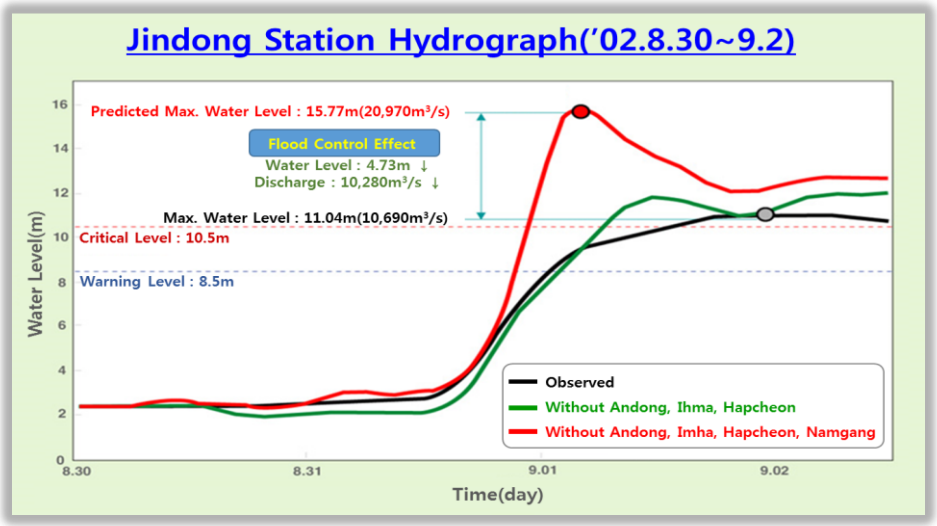


4. Dam Operation for Flood Control

Case 1 ('02 Typhoon 'RUSA')





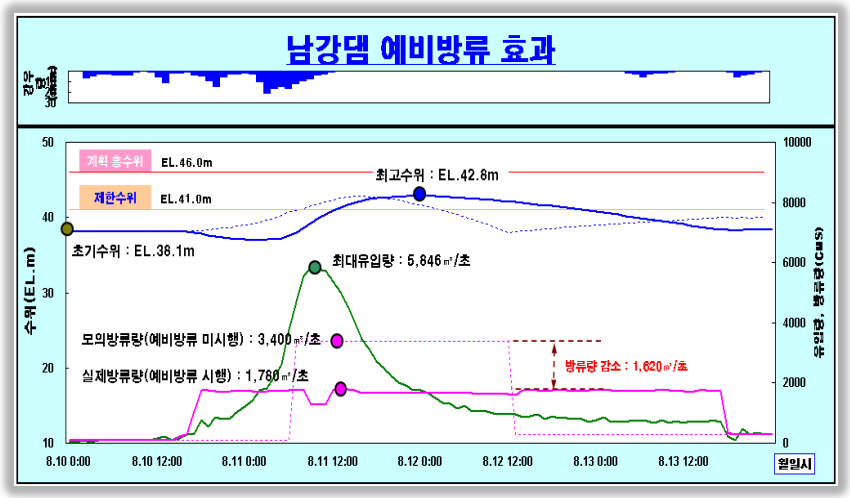


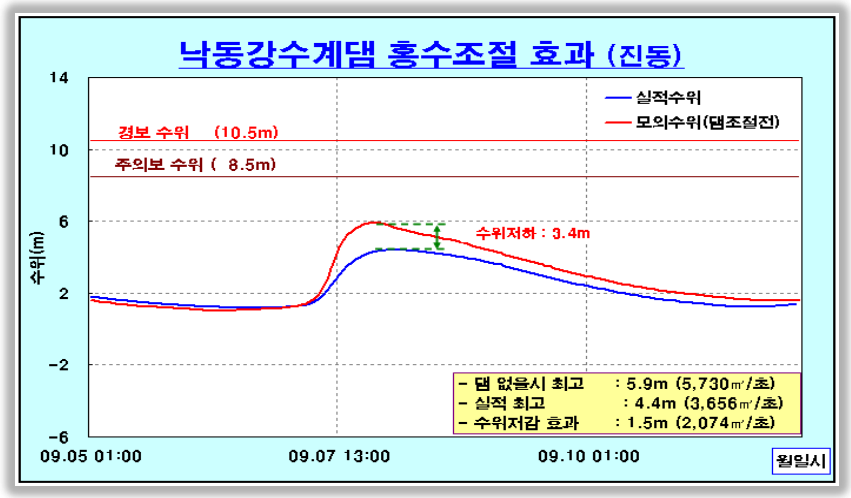
4. Dam Operation for Flood Control

Case 2 (’10 Typhoon ‘DIANMU’)

Flood Damage Mitigation by Pre-Release & Connected Operation

River	Station	Water Level	Discharge	Note
Han	Hangang Br.	1.4m ↓	4,024m^3/s ↓	Heavy Rainfall
Nakdong	Jindong	3.4m ↓	5,847m^3/s ↓	Typhoon ‘DIANMU’
Geum	Gongju	1.1m ↓	747m^3/s ↓	Typhoon ‘DIANMU’
Seomjin	Gurye	1.8m ↓	3,112m^3/s ↓	Typhoon ‘DIANMU’



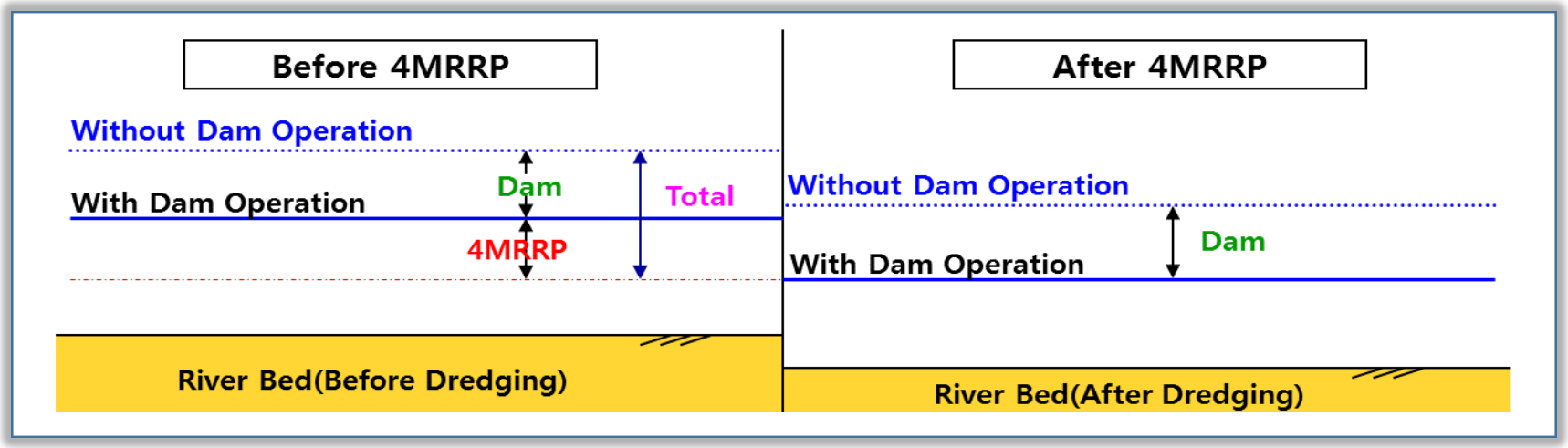


4. Dam Operation for Flood Control

Case 3 (’12 Typhoon ‘SANBA’)

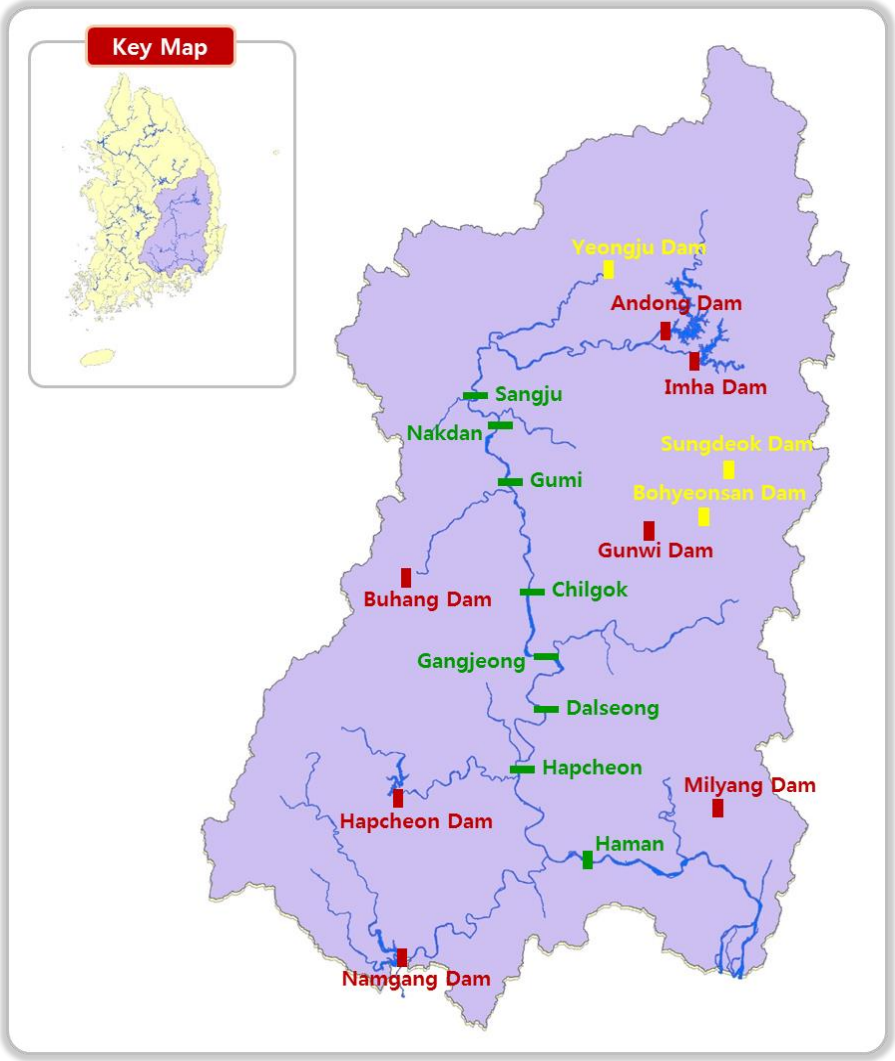
Flood Damage Mitigation by Dam Operation & 4MRRP

River	Station	Dam Operation	4MRRP	Total	Note
Han	Yeoju	1.3m ↓	3.1m ↓	4.4m ↓	Typhoon ‘TEMBIN’
Nakdong	Jindong	3.0m ↓	3.3m ↓	6.3m ↓	Typhoon ‘SANBA’
Geum	Geumnam	5.1m ↓	1.1m ↓	6.2m ↓	Typhoon ‘SANBA’
Seomjin	Gurye	1.6m ↓	-	1.6m ↓	Typhoon ‘TEMBIN’

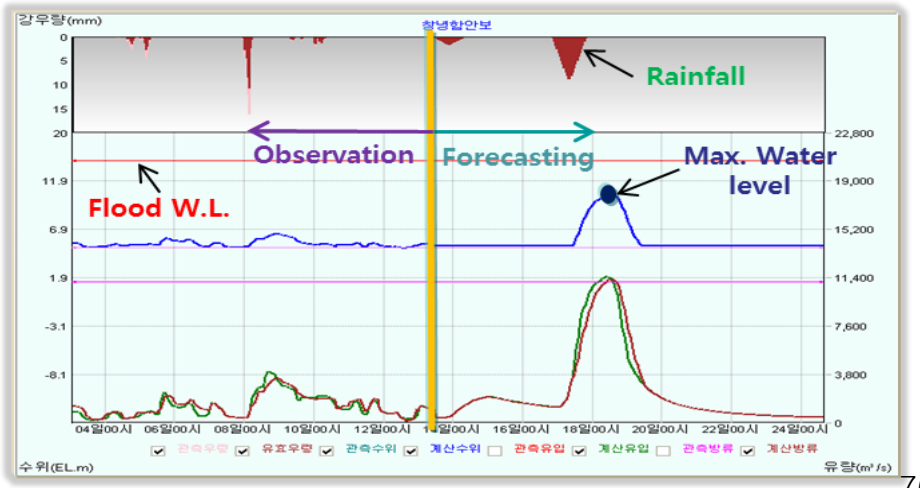


4. Dam Operation for Flood Control

Case 3 (’12 Typhoon ‘SANBA’)



Division	Andong	Imha	Hapcheon	Namgang	Milyang
Rainfall (mm)	95	110	243	270	374
Inflow (mil. ㎥)	105	140	175	585	30
Outflow (mil. ㎥)	12	68	32	569	25
Max. Inflow (㎥/sec)	1,129	1,967	3,861	14,233	895
Max. Outflow (㎥/sec)	130	304	104	2,515	538
Flood Control Rate (%)	88.5	84.5	97.3	82.3	39.9



4. Dam Operation for Flood Control

Case 3 ('12 Typhoon 'SANBA')

Specifications of Namgang Dam

Namgang Dam		
Classification	Unit	Specification
Area	㎢	2,285
Height	m	34
Length	m	1126
Storage	10^6 ㎥	309

Classification	Unit	Value
Effective Storage	10^6 ㎥	300
Flood Control Capacity	10^6 ㎥	270

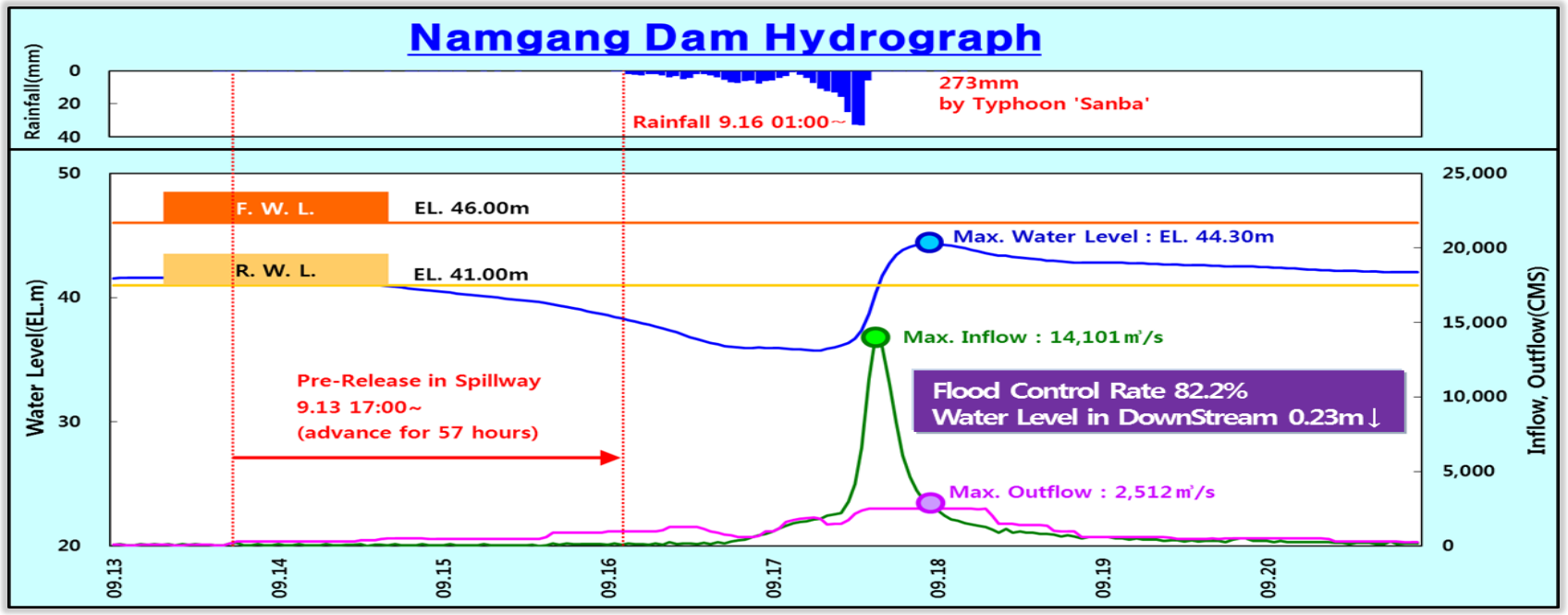
4. Dam Operation for Flood Control

Case 3 ('12 Typhoon 'SANBA')

- **Inflow into Namgang Dam Exceeding Design(200yr)**
  - ※ Max. Inflow 14,100㎥/s(Design 10,400㎥/s)
- **Increasing Flood Control Capacity due to Pre-release(Rainfall Forecast)**

→ **Outflow from Namgang Dam under Design**

- ※ Max. Outflow 2,510㎥/s(Design 4,050㎥/s)



5. Emergency Spillway (ES)

Background of ES

- To prepare frequent heavy rain due to recent climate change, the standard of design flood has been changed from Frequency Flood(100/200yr) to Probable Maximum Flood(PMF).

- The amount of inflow into dam is much higher than design capacity when dams were initially constructed. As a result, flood control capacity enhancement is inevitable to guarantee the permanent safety of dams.

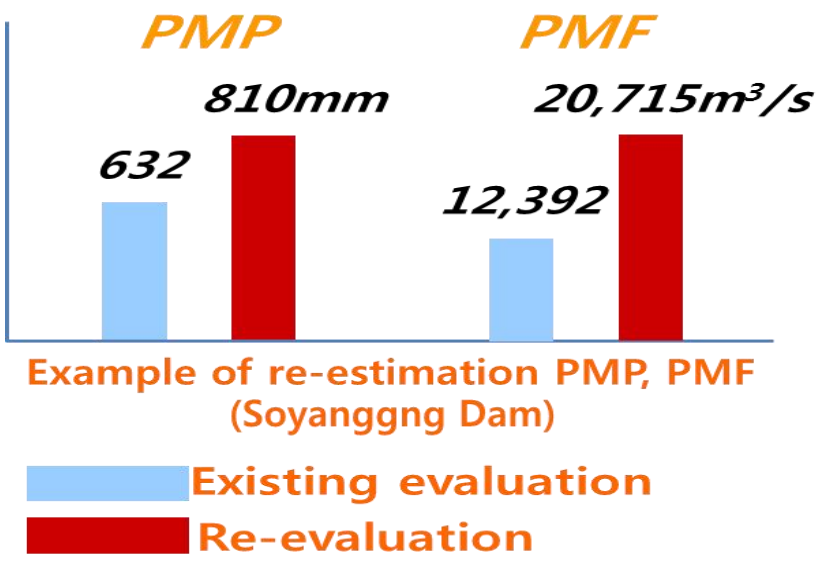
→ Hydrological Stability of Dams Must be Secured

5. Emergency Spillway (ES)

Measures of ES

- **Non-structural Measures**
  : Restricted Water Level Methods, Pre-release Methods, and so on

- **Structural Measure**
  : Dam Heightening, Watergate Installation, Emergency Spillway, Rubber Weir, Auxiliary Spillway, Spillway Expansion, and so on



Example of re-estimation PMP, PMF
(Soyanggng Dam)

Yeoncheon hydropower plant collapse

- Due to heavy rain(1996)
- 700mm in 3 days, daily max. 400mm

5. Emergency Spillway (ES)

Status of ES

- **24 Dams at Risk of Overflow according to Re-evaluation**

Classification	Completed(13)	Under Construction(6)	Planning(5)
Overflow (14)	Gwangdong, Yeongcheon, Sooeo, Yeoncho, Imha, Soyanggang, Daeam	Seomjingang, Daecheong, Andong, Unmoon, Pyeonghwa	Chungju, Namgang
Freeboard Shortage (10)	Dalbang, Goocheon, Hapcheon, Boryeong, Milyang, Booan	Juam	Seonam, Angye, Sayeon


(Auxiliary spillway)


(New spillway)

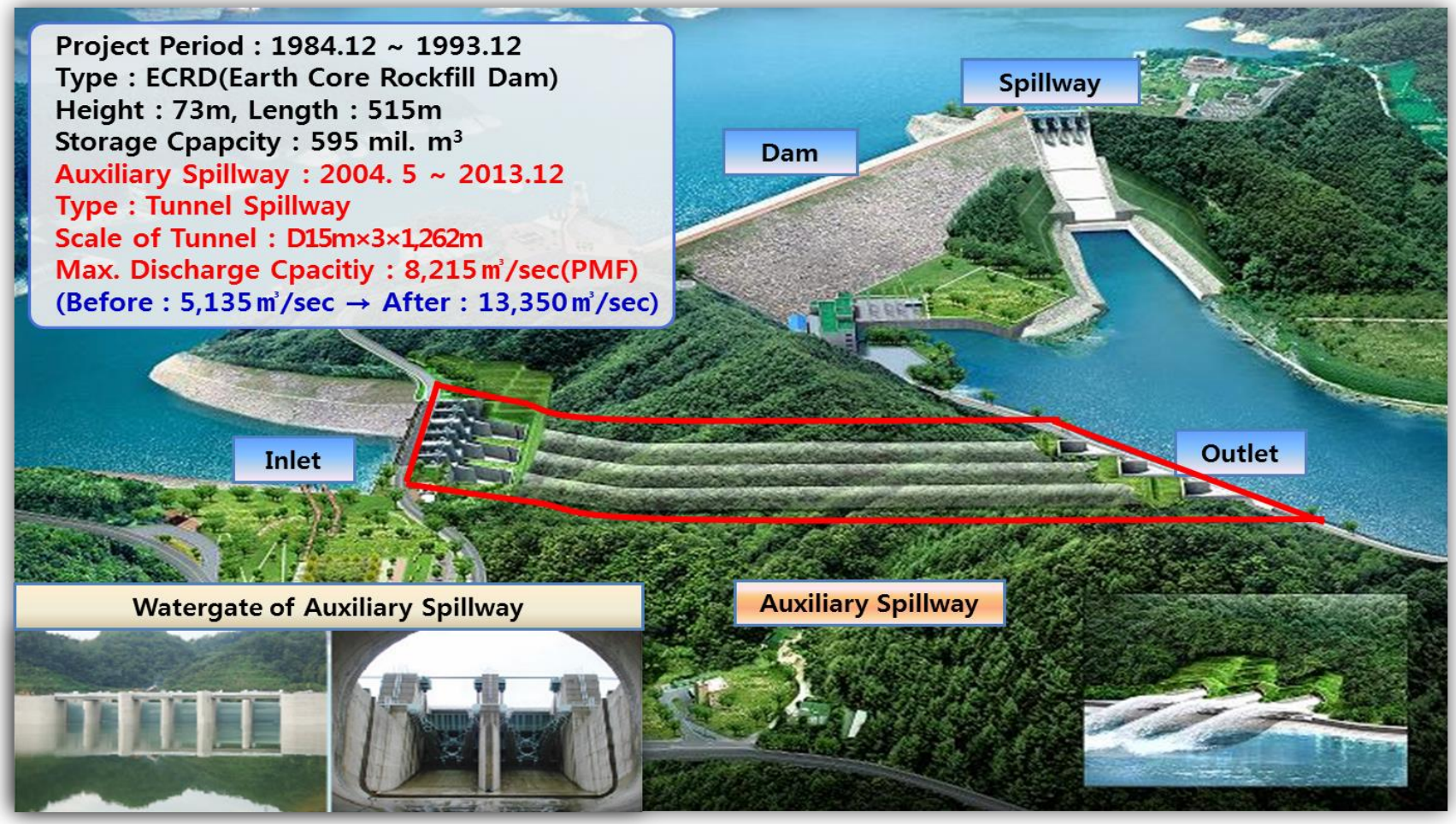

(Spillway expansion)


(Parapet wall)

5. Emergency Spillway (ES)

Examples of ES

Imha Dam



Thank You