Adaptation Practices of Urban Water Infrastructure Management

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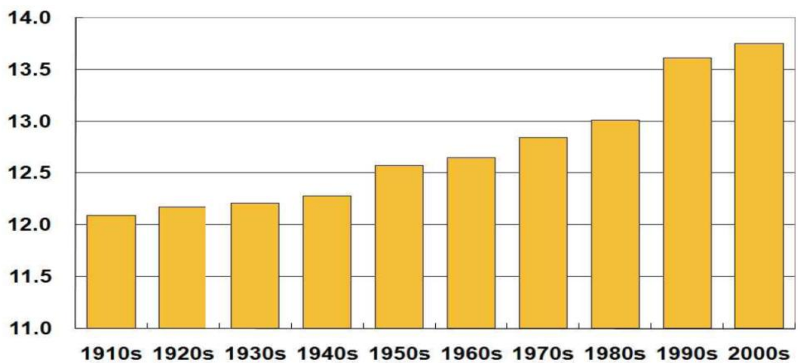
❖ Temperature change progress in Korea

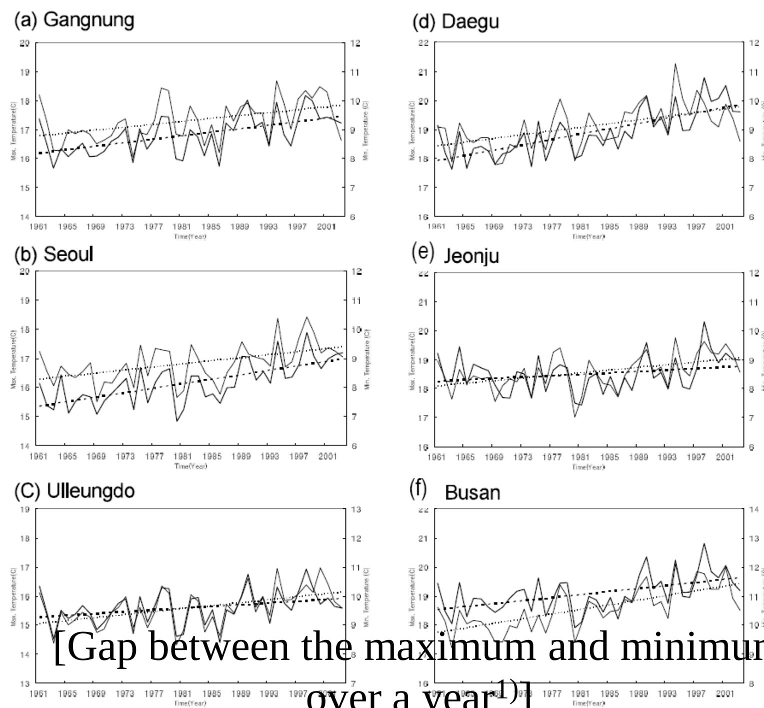


[Average temperature change[1)]]

- Average temperature in Korea has been increased
  - Approximately 1.7℃ for the last 100 years
  - 2~3 times higher than global mean temperature's
- Emergency of heat sources due to explosive economic and industrial development after the Korean War
  - 2 times faster in the late 20th century (development period) than the early 20th century

- Increasing the gap between the maximum and minimum of temperature over a year

  - Higher change rate in minimum temperature than maximum temperature

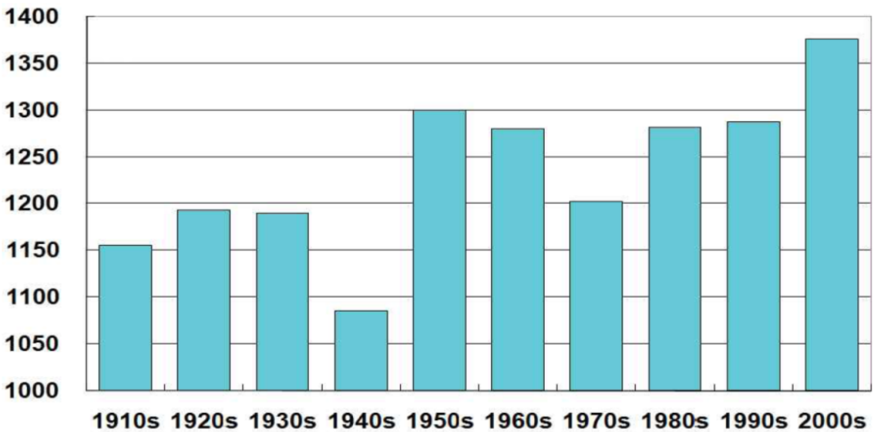


[Gap between the maximum and minimum over a year[1)]]

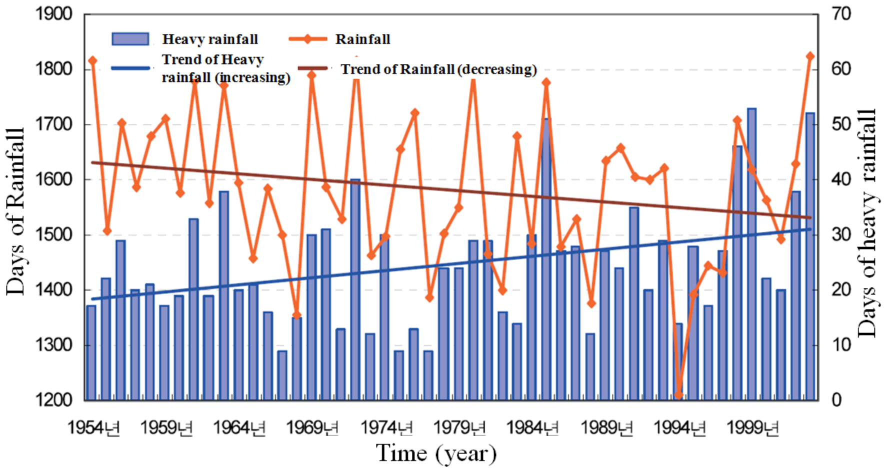
1) National Institute of Meteorological Research (2004; 2009)

Projections of Korean Climate Sensitivities

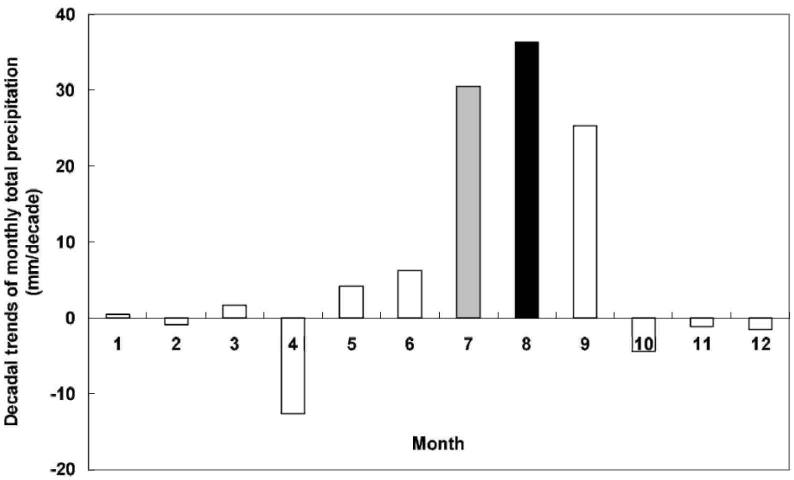
❖ Precipitation change progress in Korea



[Average rainfall change[1]]



[The change of days of rainfall and heavy rainfall[2]]



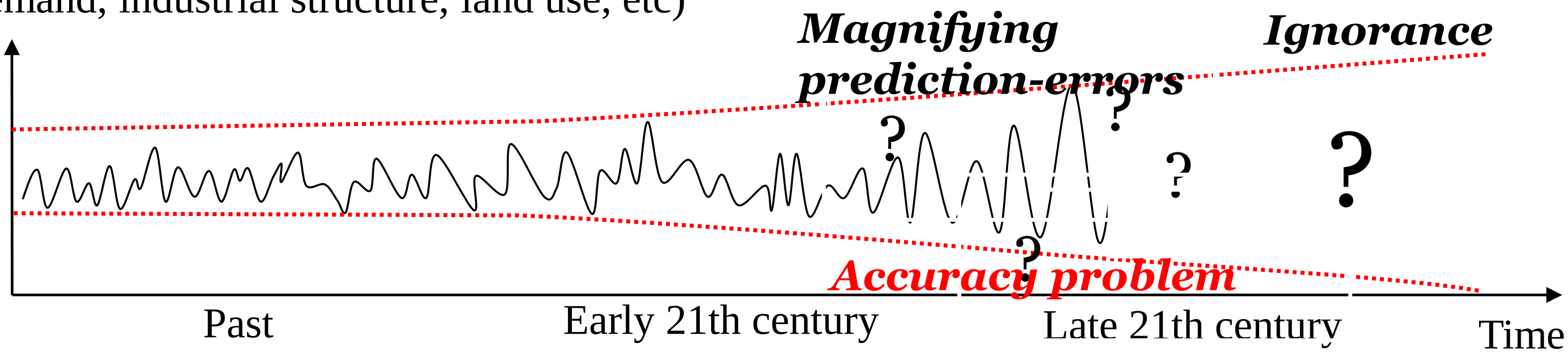
[The amount of rainfall per month[3]]

- Annual precipitation in Korea has been increased
  - Approximately 19% rise for the last 100 years
- Intensity and frequency of heavy rainfall are increasing
  - The amount of annual rainfall is increasing
  - The days of annual rainfall are decreasing
- Seasonal rainfall pattern change
  - Rainfall during summer season is increasing
  - Change from snowfall to rainfall in winter

1) National Institute of Meteorological Research (2004; 2009) 2) Choi et al. (2008)

➢ **HYDROLOGICAL/SOCIO-ECONOMICAL VARIABLES TO BE ADDRESSED**

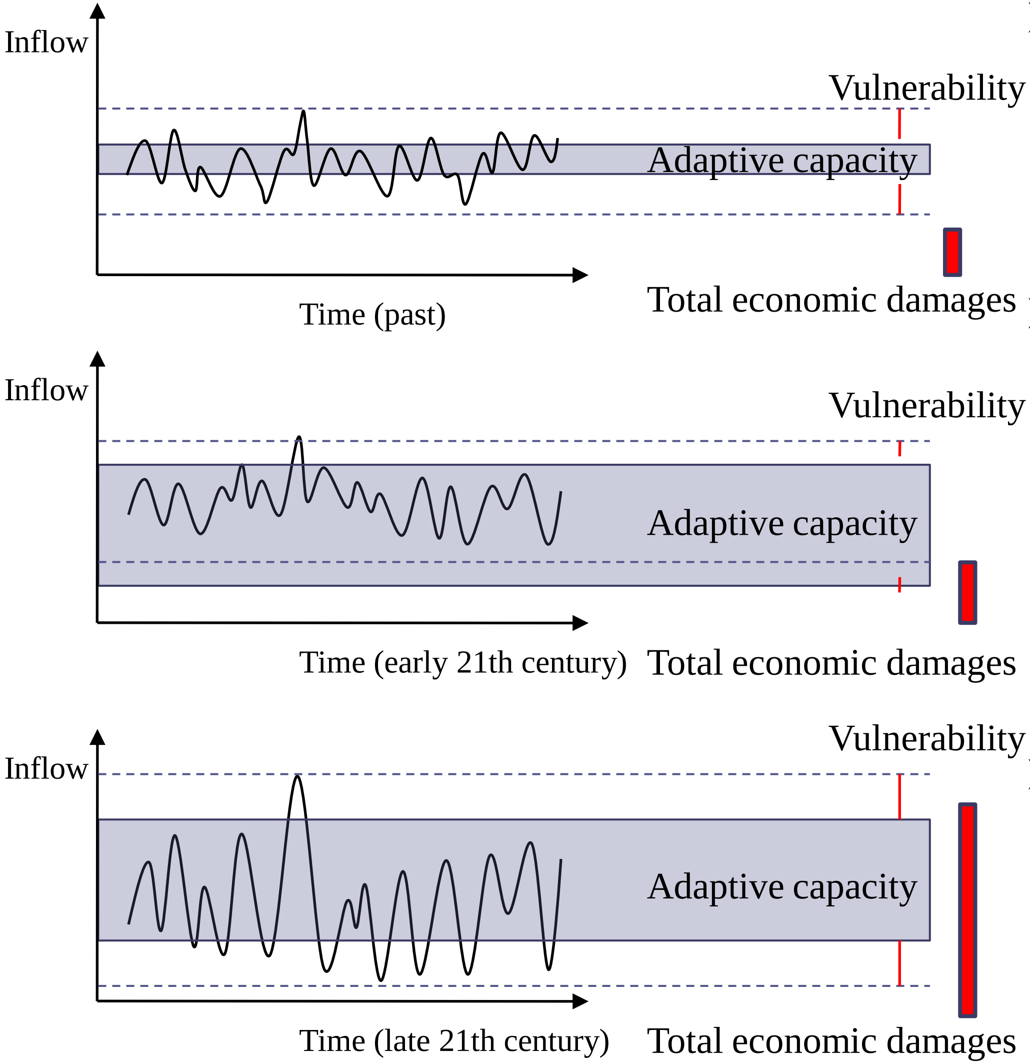
(including discharge, run-off, severity & frequency of flood, aquifer level, water quality deterioration, water demand, industrial structure, land use, etc)



➢ **DESIGN FACTORS THAT WATER ENGINEERS HANDLE**

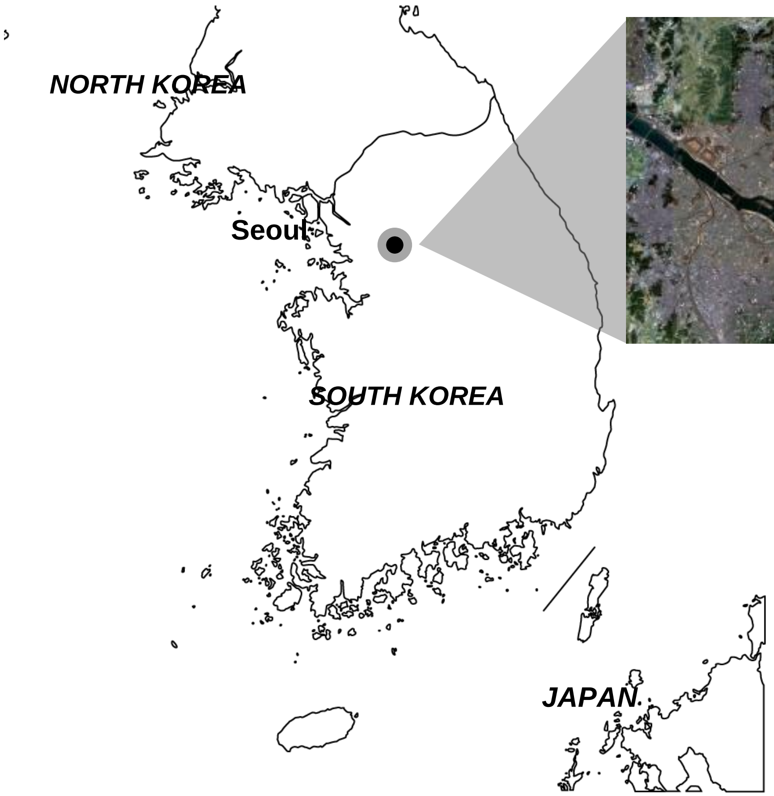
INFRASTRUCTURE	REQUIRED CAPACITY	DESIGN FACTOR	CRITERIA
Storage reservoir (dam)	**Storage capacity**	**Volume**	**Return period: 100 years, based on inflow**
Water supply facilities	**Pumping capacity Conveyance capacity Treatment capacity**	**Volume Diameter Flow rate**	**Daily maximum water use: based on estimates 10-20 years later**
Storm sewers (in the separate sewer system)	**Conveyance capacity**	**Diameter Flow rate**	**Return period: 5-10 years, based on rainfall**
Sewers (in the separate sewer system)	**Conveyance capacity**	**Diameter Flow rate**	**Hourly maximum waste water collection**
Combined sewer	**Conveyance capacity**	**Diameter Flow rate**	**Return period of rainfall + Hourly maximum waste water collection**
Drainage reservoir	**Storage capacity**	**Volume**	**Return period: 30-50 years, based on rainfall**
Drainage tank	**Storage capacity**	**Volume**	**Return period: 5-10 years, based on rainfall**

"The 21st cen. water resources management is seriously vulnerable to climate change."



- Past:
  - Considerable seasonal fluctuation
  - Small adaptive capacity (lack of infra.)
  - Seriously damaged whenever hydrological events were extreme
- Until the late 20th century
  - Adaptive capacity: incremented, mostly by raising storage capacity or discharge capacity
  - Vulnerability: shrunk so much
  - Climate change: beginning to increase the fluctuation more, often facing unexpected climatic or hydrologic events
- Mid- or late 21th century
  - Climate change: very likely to increase frequency and severity of extreme events unprecedentedly
  - Adaptive capacity: the existing practices is said to be inadequate to deal with climate change
  - Vulnerability: serious damages projected unless adaptive capacity is added further

CASE 1: URBAN FLOOD - JULY, 2011 (1/3)



- Seoul, the capital in Korea
  - 605.41 km^2 of the total area
  - Population of over 10 million people
  - A number of large streams including Han river, Cheong-gyecheon, and Jungnangcheon

CASE 1: URBAN FLOOD - JULY, 2011 (2/3)

- Extensive heavy rainfall at the end of July
  - Daily intensity: about 300 mm (return period of 10 years) over the Seoul
  - Hourly intensity: 140-160 mm during 3 hrs in two districts (Gangnam & Seochou):
  - Short of drainage capabilities
  - Drainage channels jammed by sediment and waste
- Occurrence of terrible urban floods and landslides
- Total damage: estimated to be about 300 mil. USD

  - Casualties : 39 persons

THE KOREA ECONOMIC DAILY (27, Jul, 2011)

THE YONHAP NEWS (27, Jul, 2011)

THE NEW DAILY (27, Jul, 2011)

CASE 1: URBAN FLOOD - JULY, 2011 (3/3)

➢ THE CONVENTIONAL PRACTICE

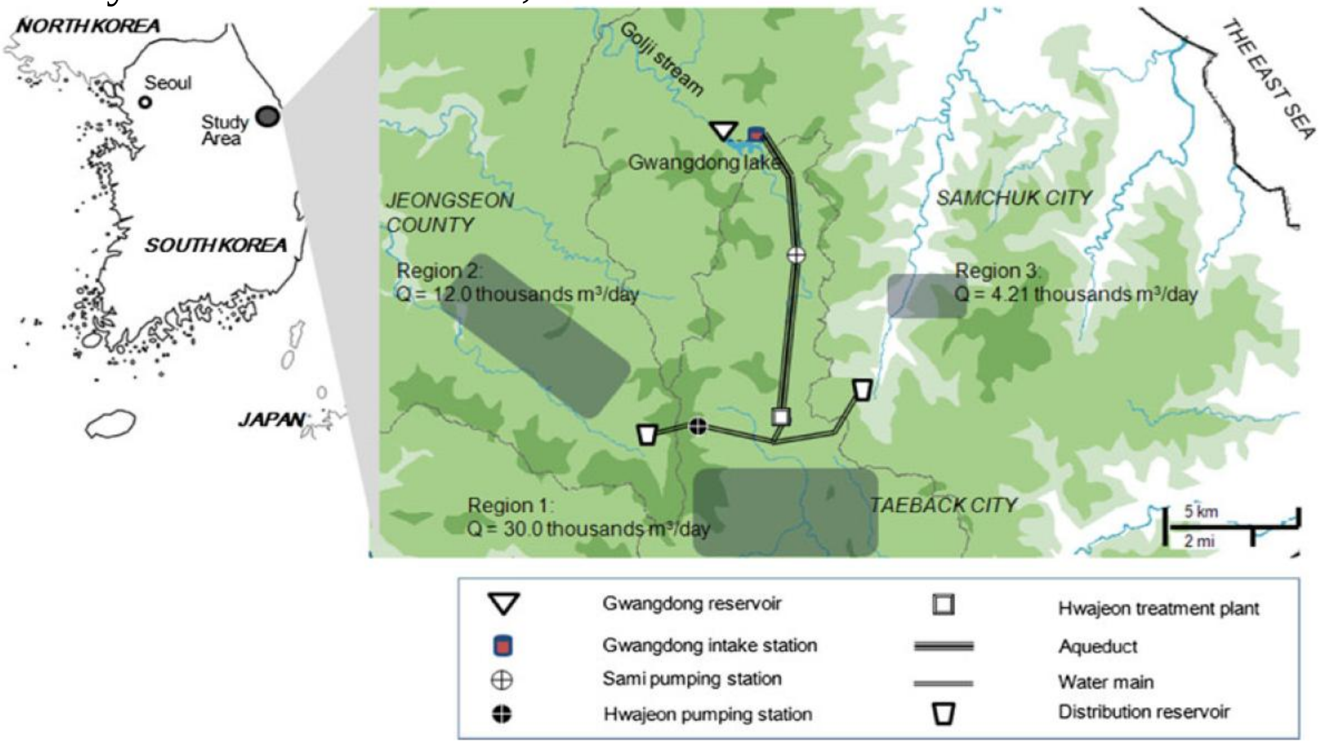
- Designing sewer systems again such that their discharge capacity handles heavier rainfall
- Often mentioning that the return period of 50 or 100 years should be considered
- Requiring huge investment in flood control facilities including sewers, pumps, drainage tanks, and rain gutters

➢ LOCAL GOVERNMENT'S PLAN

- Increasing the current capacity (10 years for sewers; 30 years for pumps and retention tanks) to cover 50-year rainfall
- Implying replacement of 1,000 km sewers and construction 3,400 pumps and some drainage channels
- Total cost: estimated to be more than 10 bil. USD
- Meaning that wastewater service charge would be raised to more than 3-10 times the current level

CASE 2: DROUGHT & RESTRICTION OF WATER SUPPLIES – FROM JAN. TO MARCH, 2009 (1/3)

- Unexpectedly low inflow started from September, 2008
  - Monthly rainfall in 2008: 47.7 mm; historical average: 220.9 mm (about 20%)
- Water storage: exhausted in the late Dec. as commitments to maintain water supply contracts were honored
- 50% restriction of water intake and water supplies
  - from the 5th day of January to the end of March, 2009



CASE 2: DROUGHT & RESTRICTION OF WATER SUPPLIES – FROM JAN. TO MARCH, 2009 (2/3)

- Damages and/or sufferings
  - Inconvenience in urban life and economic losses in the tourism industry
  - Total damage: estimated to be 24.3 mil. USD for 3 months
  - Hardest hit area = the Taebaek city (population: 50,000 persons)

Sources: Yonhap news

CASE 2: DROUGHT & RESTRICTION OF WATER SUPPLIES – FROM JAN. TO MARCH, 2009 (3/3)

➢ THE CONVENTIONAL PRACTICE

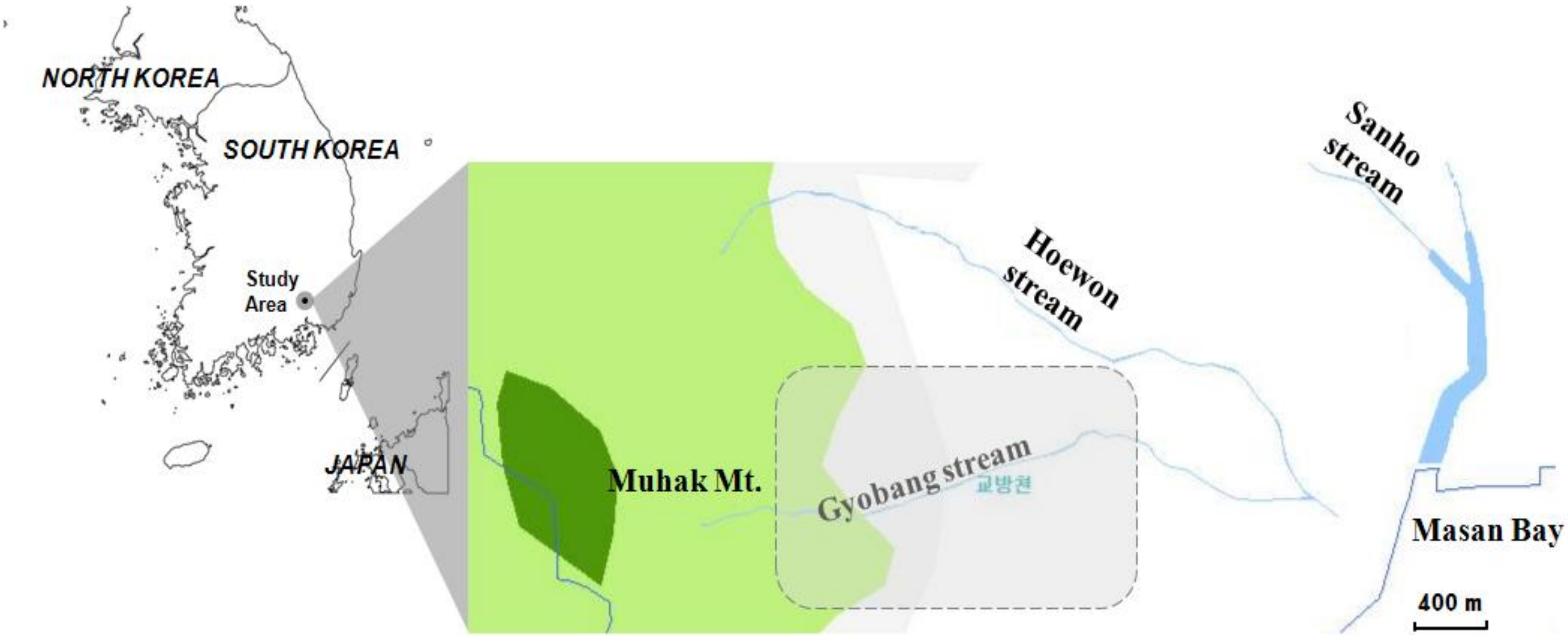
- Expanding storage capacity of the dam reservoir so as to ensure water supplies when return period of inflow drops to, say, 50 or 100 years
- Extremely expensive; unnecessary in the normal condition

➢ CENTRAL GOVERNMENT'S PLAN FOR ADDING STORAGE CAPACITY (2009)

- Announced immediately after the accident
- Construction cost: about 22 mil. USD for adding 16% of the existing capacity
- Much criticized for its economics
- Besides, residents are severely opposing it, worrying about deterioration of underground water sources and the ecosystem

CASE 3: DEPLETION OF THE GYOBANG STREAM – FEB., 2011 (1/3)

- Changwon city
  - Total area of 743.5 km^2
  - Population of some 1 million people
  - Ongoing endeavor to be the "environmental capital" of Korea



CASE 3: DEPLETION OF THE GYOBANG STREAM – FEB., 2011 (2/3)

➢ **Gyobang stream in Changwon city**

- Suffering from serious flow depletion and hence water quality deterioration since the 2000s
- Water-ecosystem destroyed
- Landscape spoiled

※ 4 services of environmental resources (Ortolano, 1997)

- Material inputs: impossible
- Life-support functions: very poor
- Amenity services: very poor
- Waste receptor services: only as the “wastewater collection facility” into the sea, and not the receptor

➔ No service available

➢ **Causes for urban stream depletion**

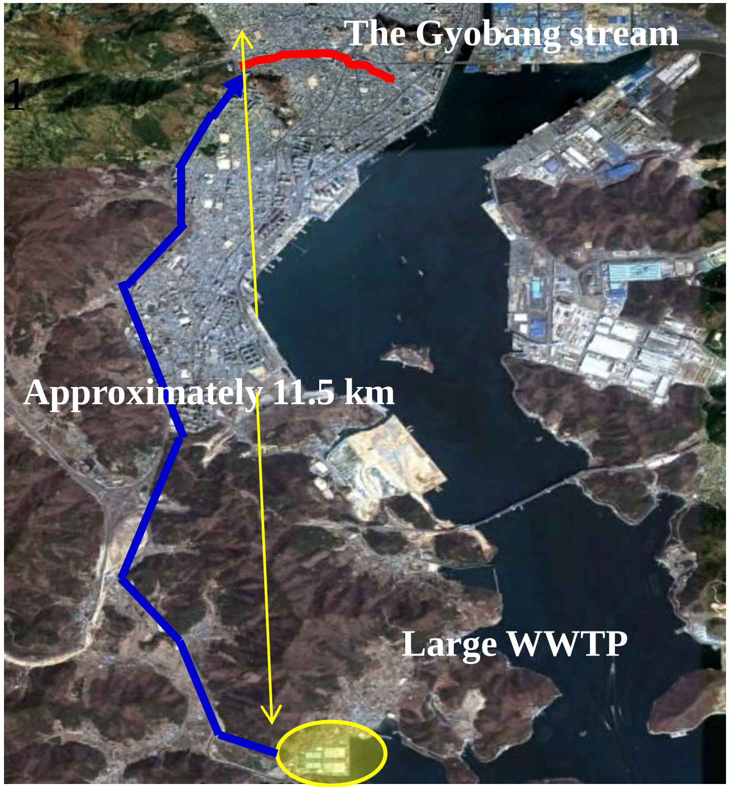
- Increase of impervious surfaces due to the long-term urbanization

➔ Hydrological changes including rapid runoff and raised evaporation

CASE 3: DEPLETION OF THE GYOBANG STREAM – FEB., 2011 (3/3)

➢ THE CONVENTIONAL PRACTICE

- Resorting to conveyance capacity of channels or water mains so as to make use of sufficient water sources usually at the very far distance
- Extremely expensive in construction and also O&M; consuming water sources ineffectively, not improving urban water circulation in the region at all



➢ LOCAL GOVERNMENT'S PLAN FOR SUPPLYING IN-FLOW

- Seeking sufficient water sources to divert into the Gyobang stream
- Tentatively, planning to use discharged water of a large WWTP 11.5 km distant via water mains which have conveyance capacity of 6,000 ton/day
- Too expensive in both construction and O&M
- B/C ratio: estimated to be "0.51"
- 29 mil. USD for the initial cost only
- Besides, the NGOs are severely opposing it because of low economics

LESSONS OF THE RECENT CASES

Spring, 2009

Winter, 2010

Summer, 2011

- **Taking usual approach (=providing more structural capacity):**

- Even if not work for the kind of variations expected by climate change

- Not affordable: To be too much costly to be implemented in a foreseeable future

➔ This suggests us to look at another approach

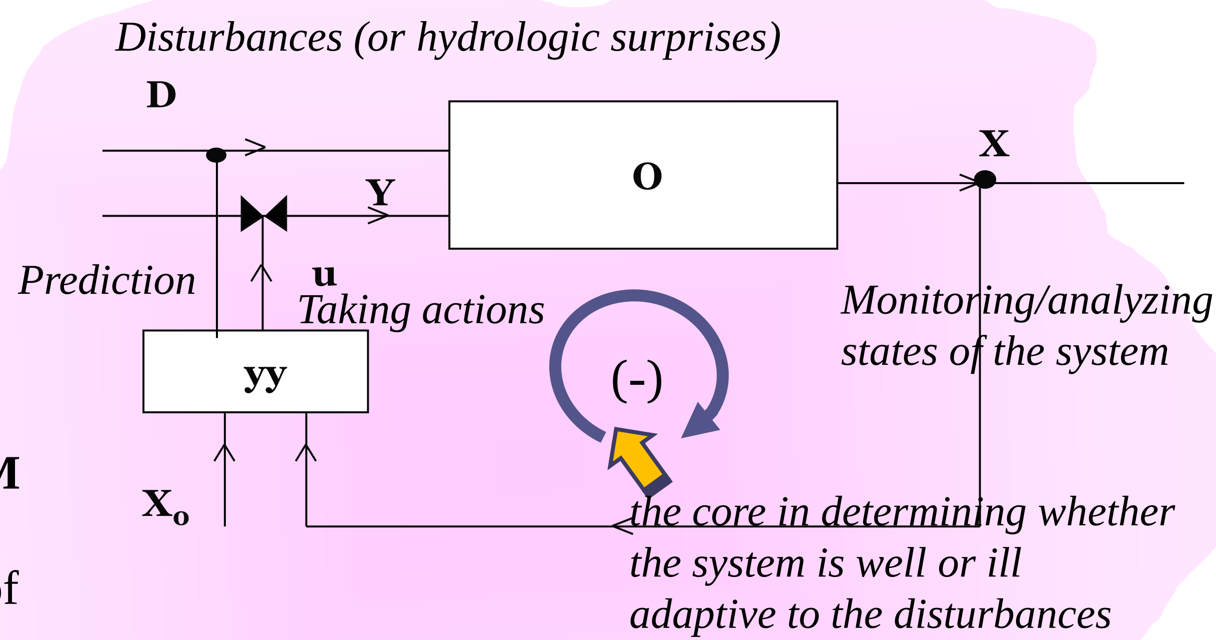
ADAPTAITON MECHANISM OF A SYSTEM FOR ACHIEVING ITS OWN SUSTAINABILITY

➢ ADAPTIVE CAPACITY

- Determining survival or success of the adaptive system, but very vague and unmeasurable

➢ ADAPTATION MECHANISM

- Cybernetists: seeing it in terms of feedback structure of the whole management system
- Depending on how properly the negative feedback functions against disturbances D



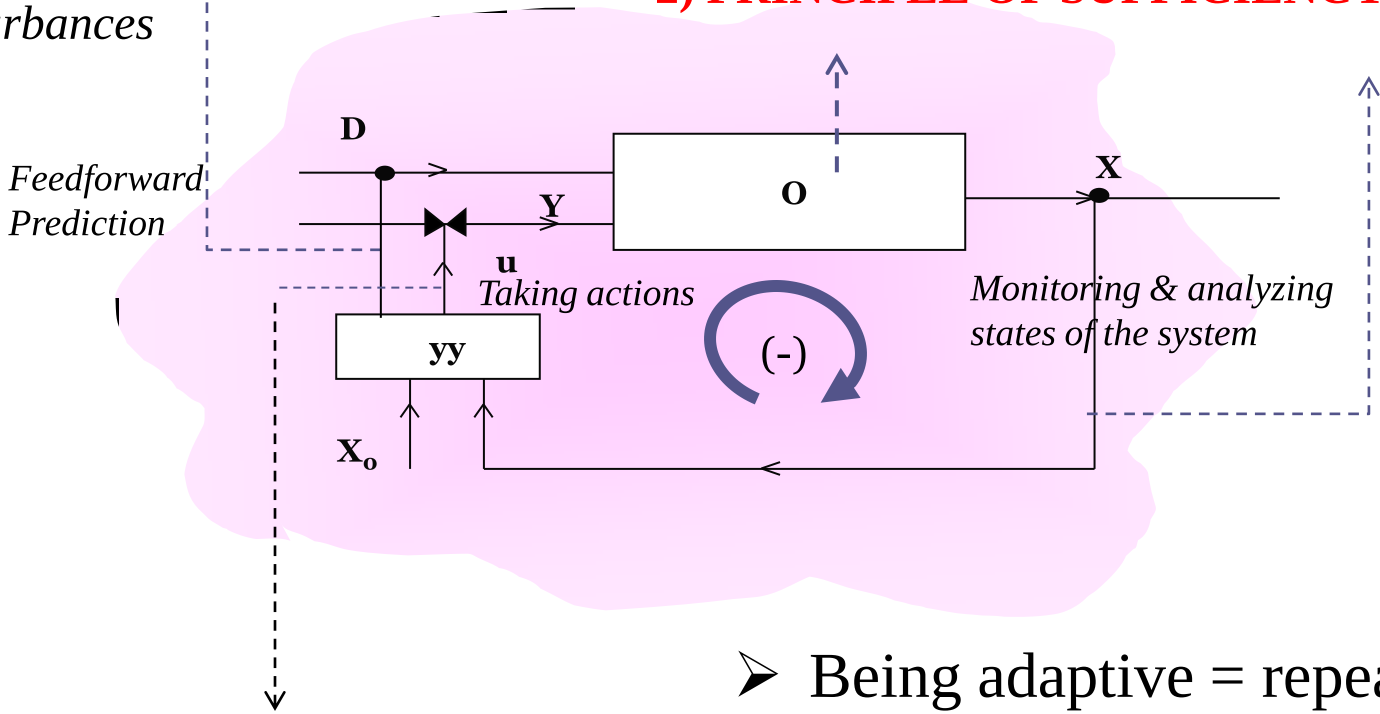
O: target system, e.g., state variables of a storage reservoir
yy: regulator, e.g., a reservoir operator
D: disturbances, e.g., unexpected low inflow
X: output state of controlled system, e.g., trends of water level
Y: input state of controlled system
X': perceived state of controlled system, e.g. perceived trends of water level
X_o: goal of controller, e.g., acceptable water level at the given time
u: control action, e.g., variety of measures to maintain X to be near X_o

THREE PRINCIPLES OF CONTROL DYNAMICS IN ADAPTATION MECHANISM

1) PRINCIPLE OF ACCURACY

- *Adequacy of data and prediction on the external disturbances*

2) PRINCIPLE OF SUFFICIENCY

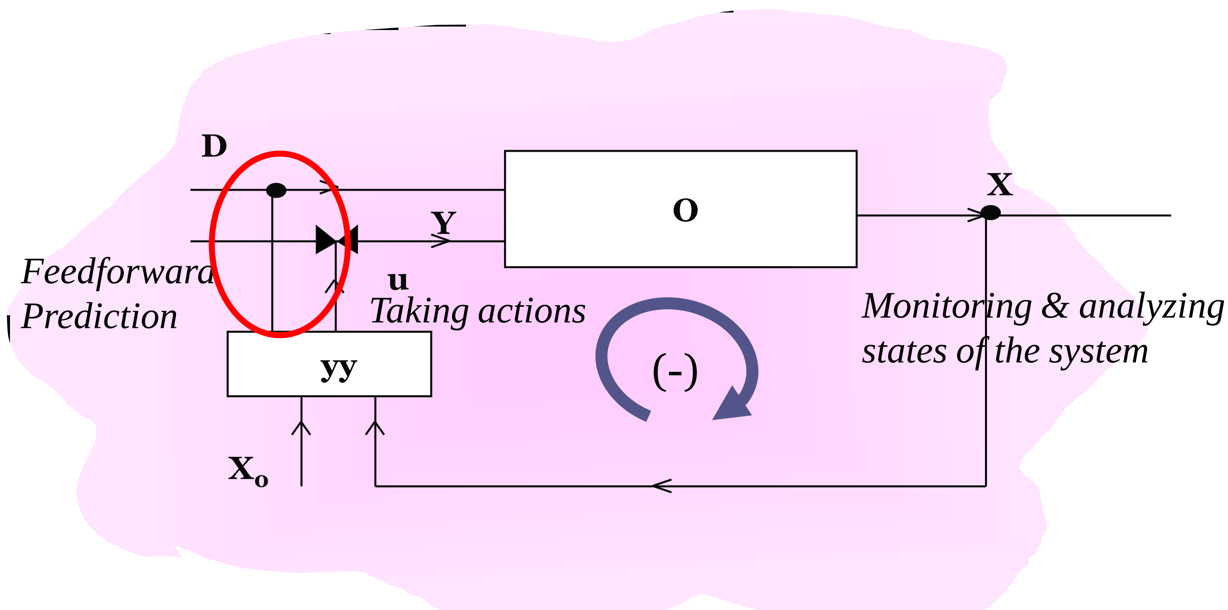


3) PRINCIPLE OF VARIETY

- *Implementation of management options*
- *'Law of variety'*

➢ Being adaptive = repeatedly doing something according to the Principles.

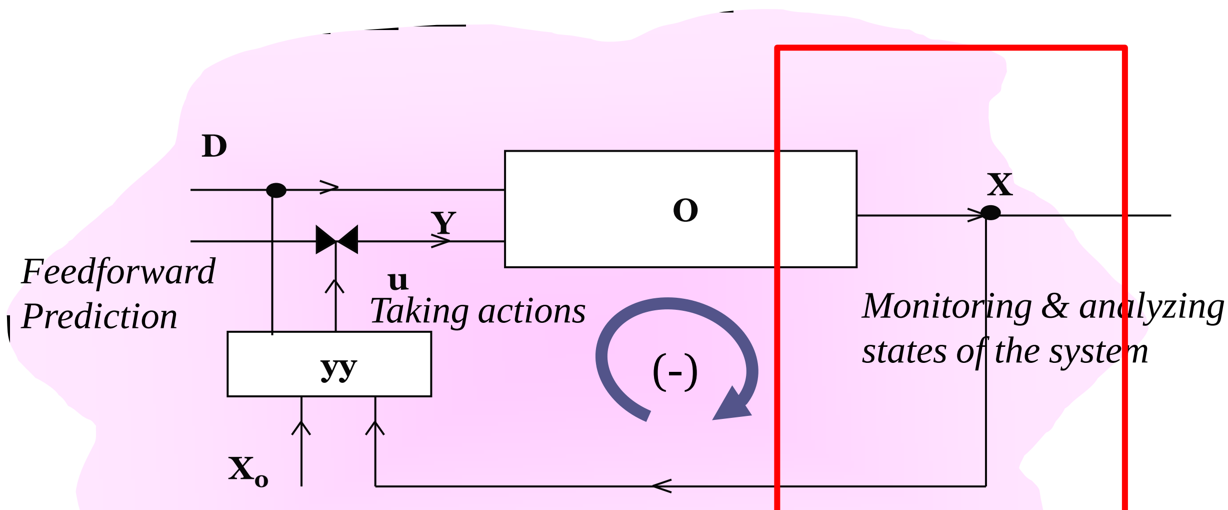
PRINCIPLE OF ACCURACY



- Solving the problems related to insufficient data and predictions on the occurrences of disturbances

	More Structural Options	Other Management Options
ACCURACY	-	• **Build the risk map by using historical records and forecasts (relocation of residents and facilities)** • **Analyze events and trends of climatologies and socio-economic variables with much improved prediction models** • **Collect much information by using PR/data-mining technologies**

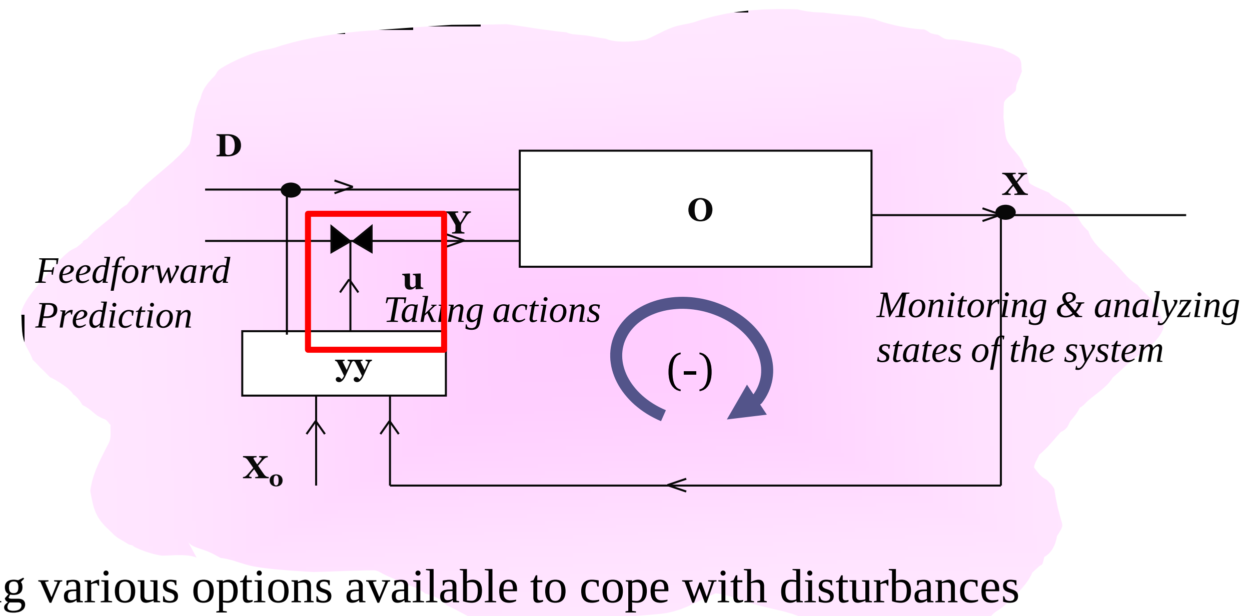
PRINCIPLE OF SUFFICIENCY



- Solving the problem as to whether the current system is sufficient, or not and what modifications are needed to achieve defined goals
- Presenting "system evaluation methods" that tell needed modifications from knowledge about disturbances, current system performances, and defined goals

	More Structural Options	Other Management Options
SUFFICIENCY	• **Install observation instruments as many as possible** • **Operate the MIS linked to GIS**	• **Identify key problems of an object in advance** • **Develop system planning & design methods** • **Monitor the short-term trend of hydrologies by using the RS technologies**

PRINCIPLE OF VARIETY



- Implementing various options available to cope with disturbances
- Determining the "means" enough to achieve the needed system modification
  e.g. excess capacity, density, connectivity, etc

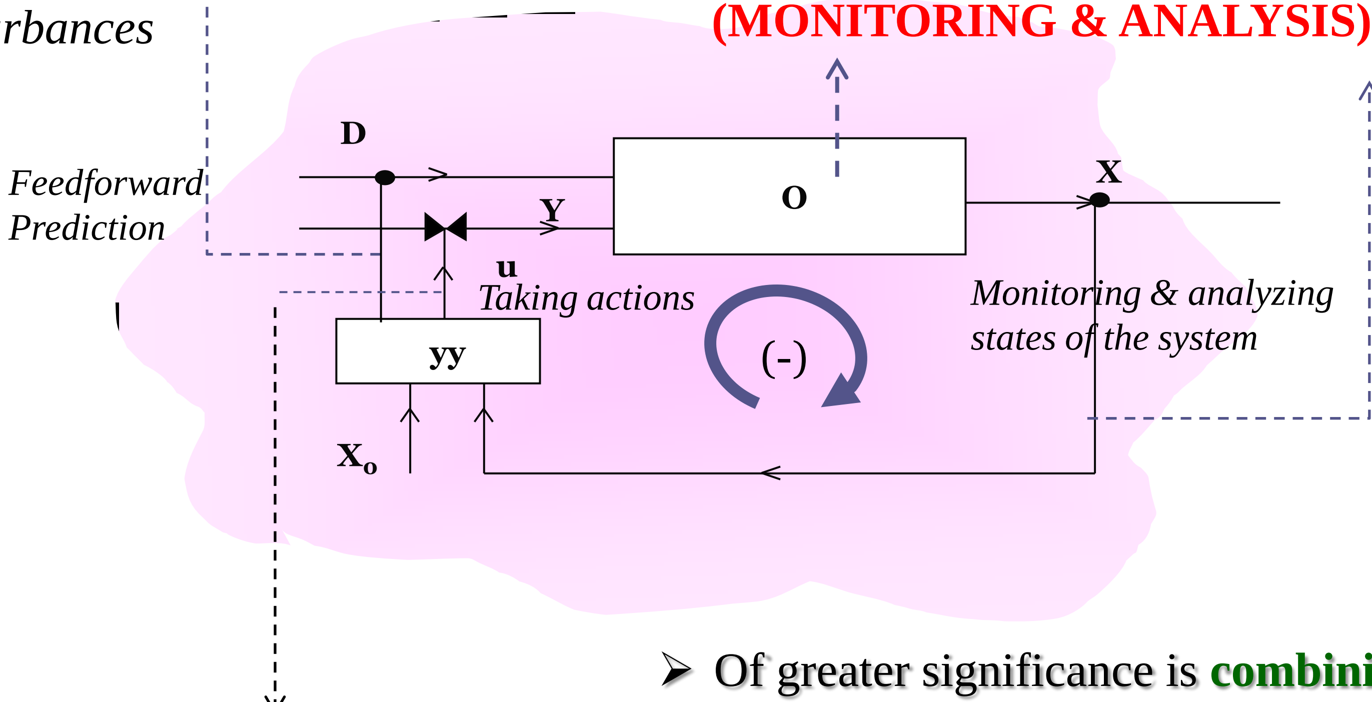
	More Structural Options	Other Management Options
VARIETY	• Increase structural capacity • Construct emergency spillways • Design the drainage system sharing flood intensity over the watershed basin • Increase connectivity of storm water infrastructure	• Build the emergency aid & action plans • Manage water level of river in a more reliable way during the wet season

THREE PRINCIPLES OF CONTROL DYNAMICS IN ADAPTATION MECHANISM

1) PRINCIPLE OF ACCURACY (DATA & PREDICTION)

- *Adequacy of data and prediction on the external disturbances*

2) PRINCIPLE OF SUFFICIENTY (MONITORING & ANALYSIS)



- Of greater significance is **combining all efforts** for achieving success of the system
- Moderately but in a scientific manner

➔ SYSTEMS APPROACH

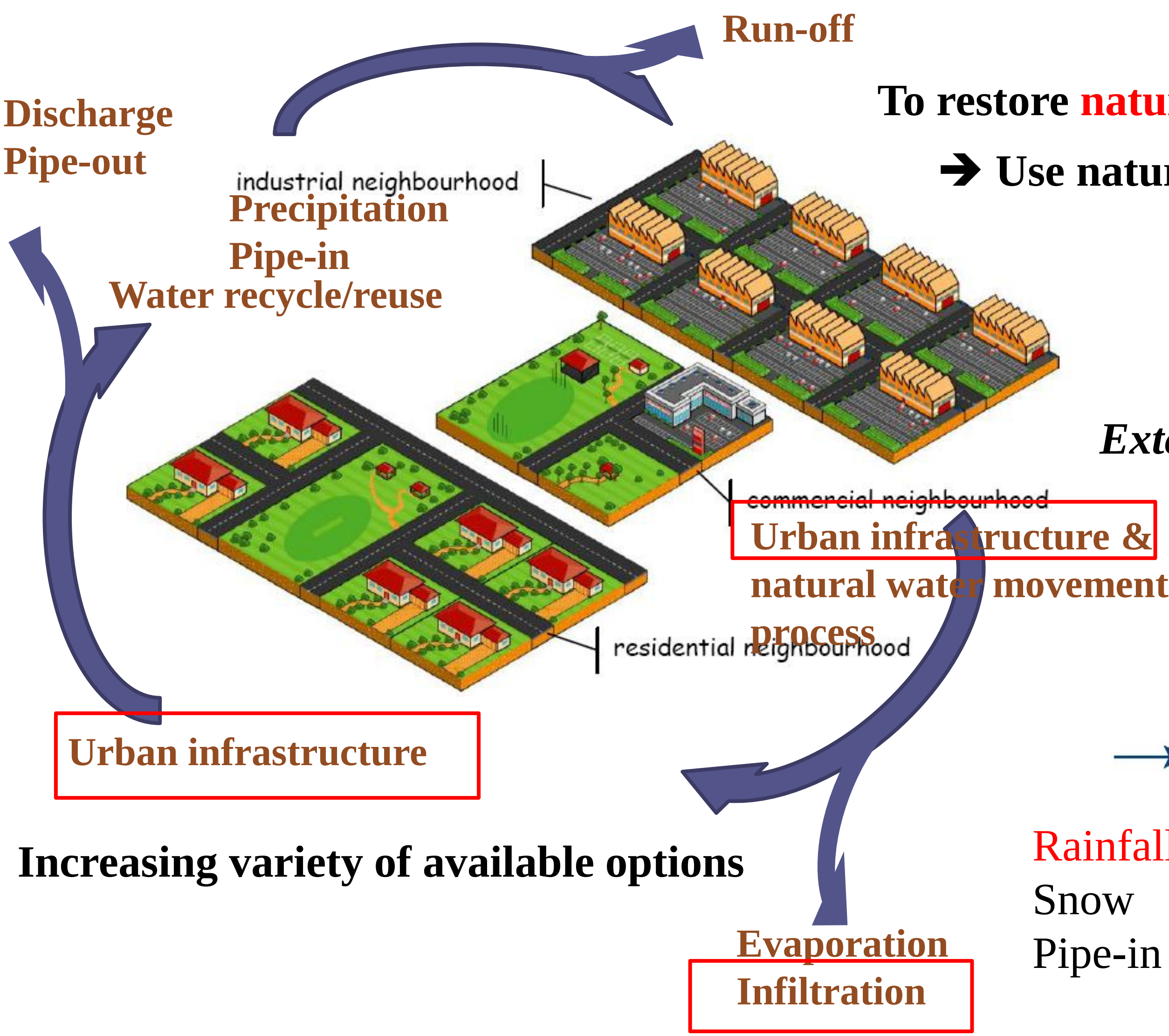
3) PRINCIPLE OF VARIETY (from Socio-Economic Points of View)

- *Implementation of management options*
- *'Law of variety'*

AN EXAMPLE OF ADAPTATION OPTIONS FOR URBAN FLOOD

To restore natural water cycle in urban spaces,

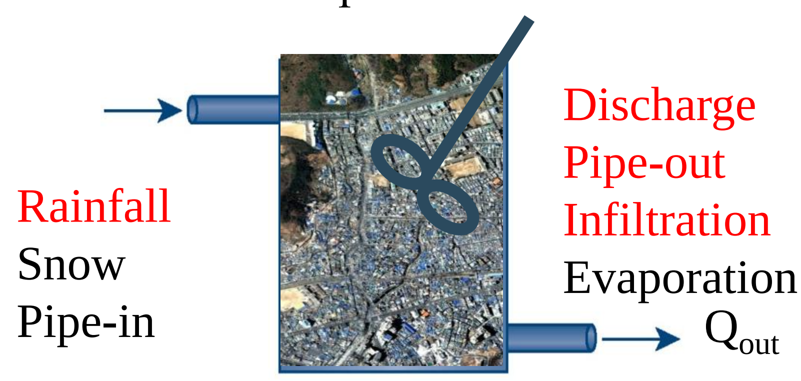
➔ Use natural storage in underground



Extending time of concentration

Increasing variety of available options

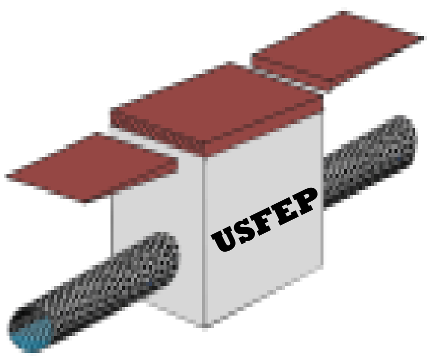
“Urban space” reactor



USFEP (Unclogging Surface Filtering Elastic Paving Technology and Facility)

- Infiltration and storage facilities that graft surface filtration with elastic pavement

- Application of USFEP



UEP (Unclogging Elastic Paving Technology and Facility)

- Maintenance of USFEP

CONCLUSION

Many people are saying

“climate change will affect Korea harder than the global average”

“There will be many challenges for proper water management in Korea.”

“We, engineers, need to devise more cost-effective adaptation options, according to the three principles, to cope with the challenges since usual practices, relying on increasing structural *capacity*, may not be affordable by us and future generations”

Impacts of Climate Change on the Water Infrastructure Management

- Climate change impacts on urban infrastructure

Sector	Time scale (year)	Exposure
Water infrastructures (e.g., dams, reservoirs)	30–200	+++
Land-use planning (e.g., in flood plain or coastal areas)	>100	+++
Coastline and flood defences (e.g., dikes, sea walls)	>50	+++
Building and housing (e.g., insulation, windows)	30–150	++
Transportation infrastructure (e.g., port, bridges)	30–200	+
Urbanism (e.g., urban density, parks)	>100	+
Energy production (e.g., nuclear plant cooling system)	20–70	+

Source: Hallegatte (2009)

- Water infrastructure
  - Most seriously exposed to climate change impacts. (Ex. to more extreme weather events)
  - Planned for the very long-term future; from 30 to 200 years

→ Today's decision: affecting generations in the distant future so much, although hydrological situations become unknowable more and more

→ Improper decisions: providing the future generations with damages or huge costs
- "Lock-in" effects

→ Need to prepare for climate change long before the shapes of uncertain impacts are revealed, and examine adaptation options, not makeshifts