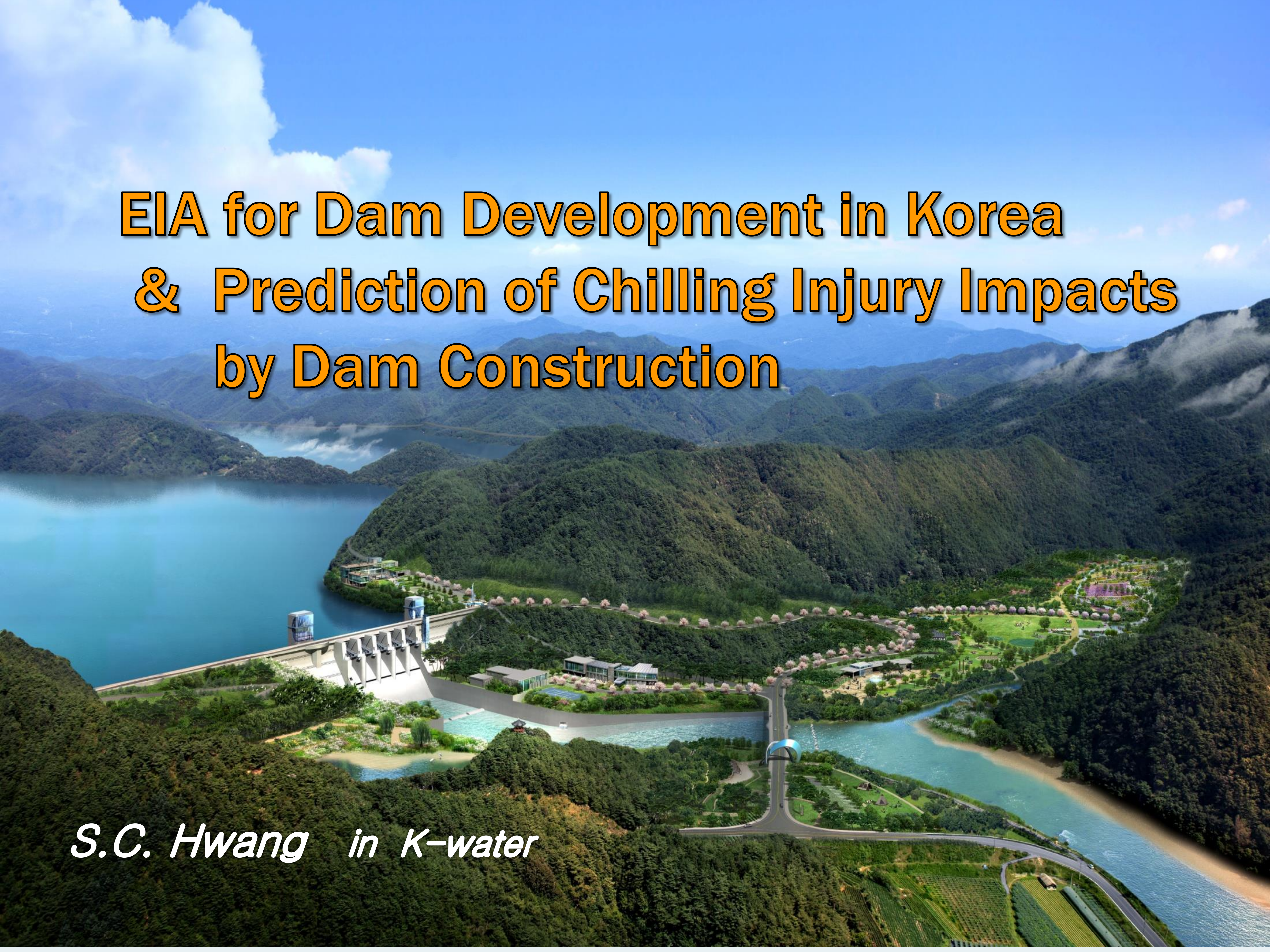
EIA for Dam Development in Korea & Prediction of Chilling Injury Impacts by Dam Construction



S.C. Hwang in K-water

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K water

Precipitation

- annual precipitation of Korea is 1.3 times higher than that of the global
- precipitation per capita of Korea is only 1/8 of the global average
- 70% of the precipitation is concentrated from June to September

Ⅰ. Introduction – Dams in Korea

Topography

- Total Area : 222,135 ㎢

  (100,000㎢ for South Korea

  ; forest 65.7%, farmland 21.9%, …)

- About 70% of land is mountainous

  (river slopes are steep)

- Most rivers flow into the west and south sea

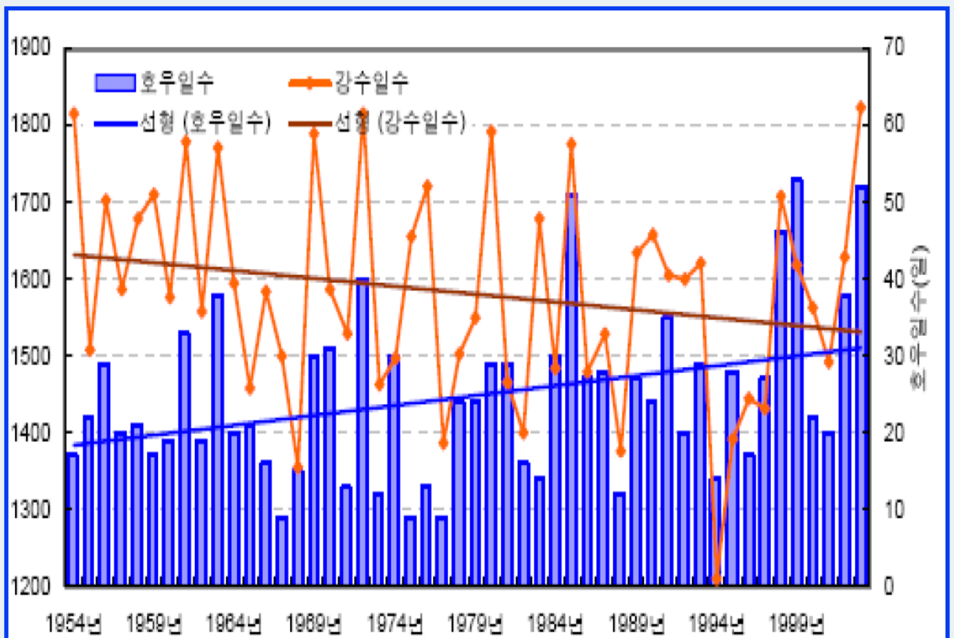
- floods run off immediately

Ⅰ. Introduction – Dams in Korea

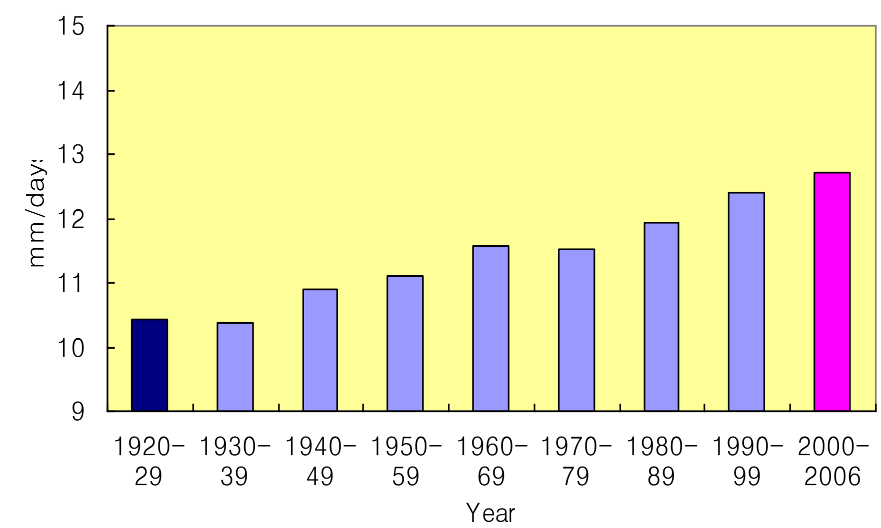
K water

Unexpected Climate

- Precipitation pattern changed by unexpected climate (recent 20years)
  → Annual precip. 7% ↑, Rainy days 14% ↓, Intensity 18% ↑
- Imply the necessity of risk management
  → drought, flood, dam break, etc.



<Increase of Intensity of Precipitation>



Ⅰ. Introduction – Dams in Korea

K water

Dams in Korea

- **Present** : Totally 17,735 dams

  20 Multi-purpose dam

  → **Water Supply(11 b m^3/yr), Flood Control(2.4 bm^3)**

- **Under construction (~ 2015)**

  3 Multi-purpose & Flood control dam

  → **Water Supply(224 m m^3/yr), Flood Control(349 m m^3)**

- **Future (~2021)**

  14 Small size dams (Long-term dam plan)

  → **Water Supply(110 m m^3/yr) , Flood Control(240 m m^3)**

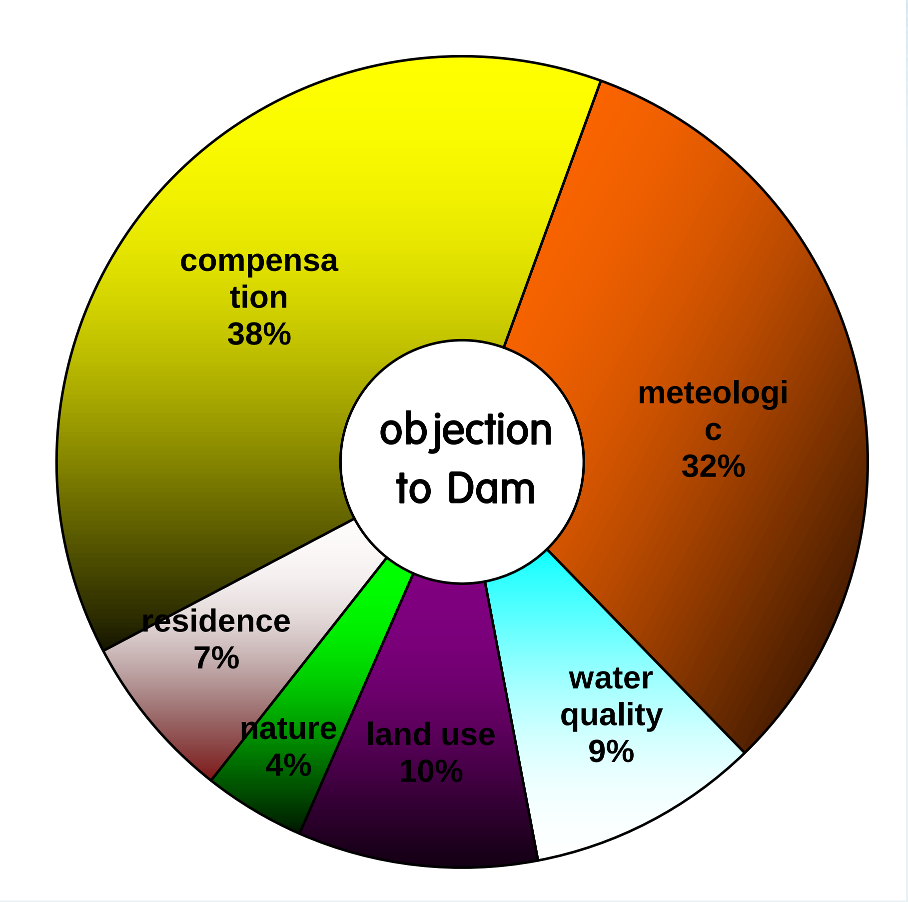
※ Water and Sustainable Development, 2015, K-water

Ⅰ. Introduction – EIA for Dam development

K water

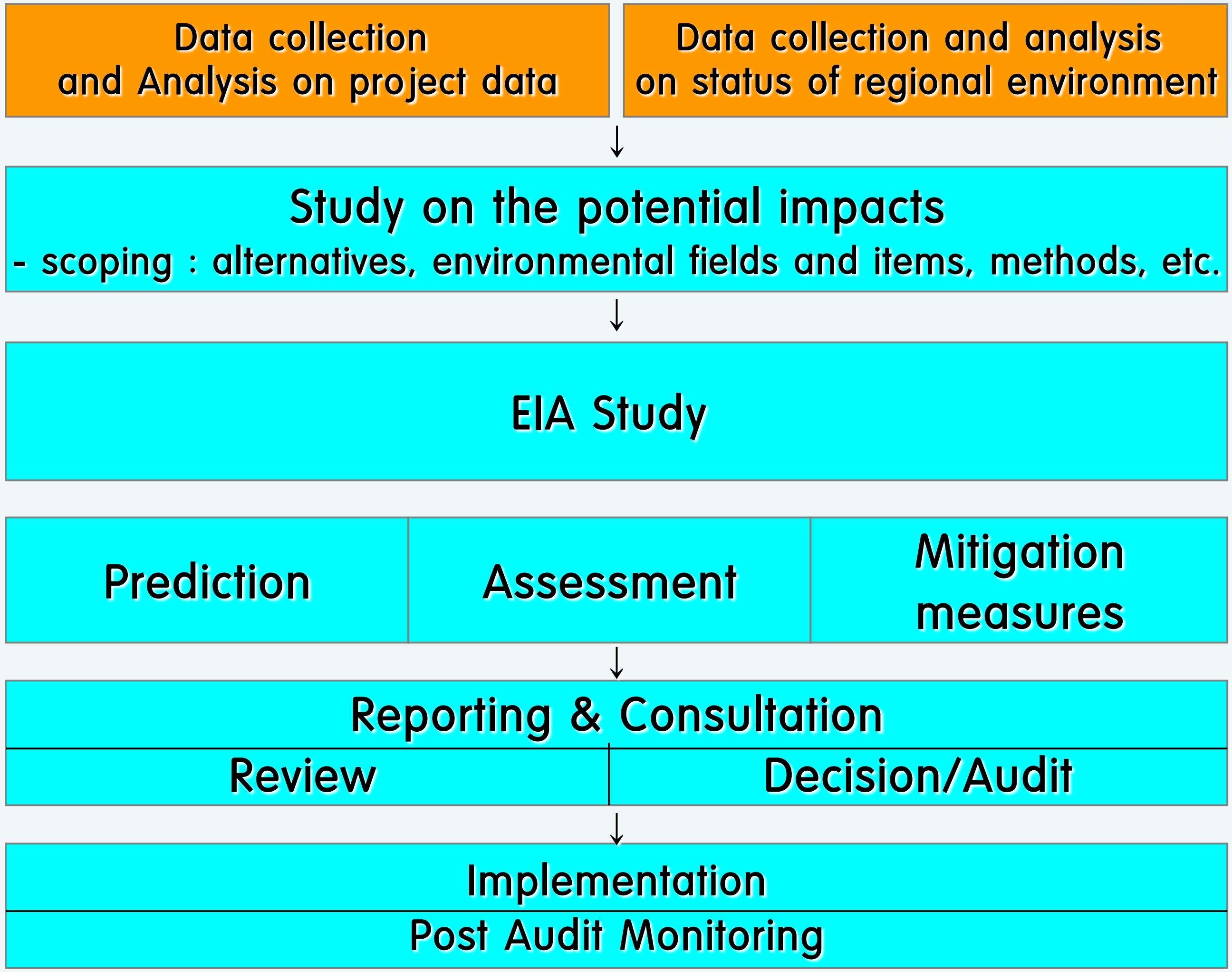
Difficult new dam project

- Dam construction is large-scale development
- becoming more difficult due to the
  - shortage of appropriate location
  - damage to environments
  - objections from residents
- we need harmonious and balanced development of solving water problem



K water

Conceptual framework for EIA-Study



Ⅰ. Introduction – EIA for Dam development

K water

Environmental Impacts due to Dam

Increase of water surface	Discharge of lower water temperature	Changes in river flow
Increase of water vapor	Thermal Stratification	river → reservoir
↓	↓	↓
Changes in local weather condition (wind, fog, air temp.)	Chilling Injury in the downstream region	Changes in Water quality & Aquatic ecosystem (Eutrophication, Turbidity)

Fog

Chilling Injury

Eutrophication

Ⅰ. Introduction

Chilling Injury ?

Sterility Injury

Poor pollination

Normal ear

- **Chilling Injury = Cold weather damage**
  - Crops are damaged by cold contact (water, weather), the growth & reproduction are inhibited.
  - Time-delay Injury : contact with the cold water in early growth, growth is slow and the heading ear is delayed.
  - Sterility Injury : contact in reduction division, the crops are infertile

Ⅰ. Introduction

K water

Purpose of the study

- lower water temp. is distributed in the deep water than that of natural stream (Thermal stratification)
  → the withdrawal of the deep water may have chilling injury in the downstream
- Many complaints due to chilling injury have been claimed from Juam, Milyang Dam
- Changes in water temp. of water discharged from the selective water intake was simulated using EFDC model
  - consideration of intake location, tributary joining, flow distance, seasonal time, etc.

– a degree of chilling injury effects on agricultural crops is calculated as intake location, seasonal time, flow distance, etc.

– validation of the effect of selective water intake towers & foundation data to provide a measure to reduce the chilling injury

Ⅱ. Methodology

Ⅱ-1. Study Subjects (Dam & Stream)

K water

Study subjects

Site : YJ Dam & NS Stream

● overview of YJ Dam (under construction)

Item	Unit	Value
◦ Basin Area	km^2	500
◦ nor water level	EL.m	163.0
◦ starage capacity	Mil m^3	181.1
◦ surface area	km^2	10.46
◦ water supply	Mil m^3/y	203.3
- river maintenance	Mil m^3/y	186.6

● overview of NS Stream

Item	Unit	Value
◦ Basin area	km^2	1,814
◦ flow path	km	108.2
- national stream	km	27.0

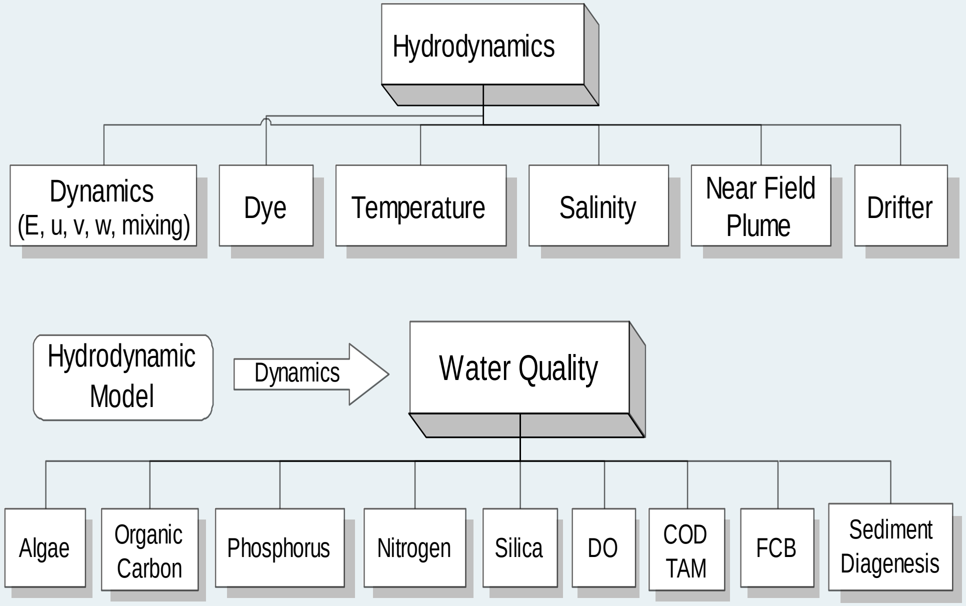
※ water discharged from YJ Dam is flowed 56km and joined to the Nakdong river

Ⅱ-2. Study Method

K water

Simulation method of change in water temp.

- Using EFDC model
  - changes in withdrawal water temp. were simulated according to intake location(water depth), period, flow distance
  - linear equation between water-air temp. was created based on the measured data and utilize this equation as the input data and estimation of parameters

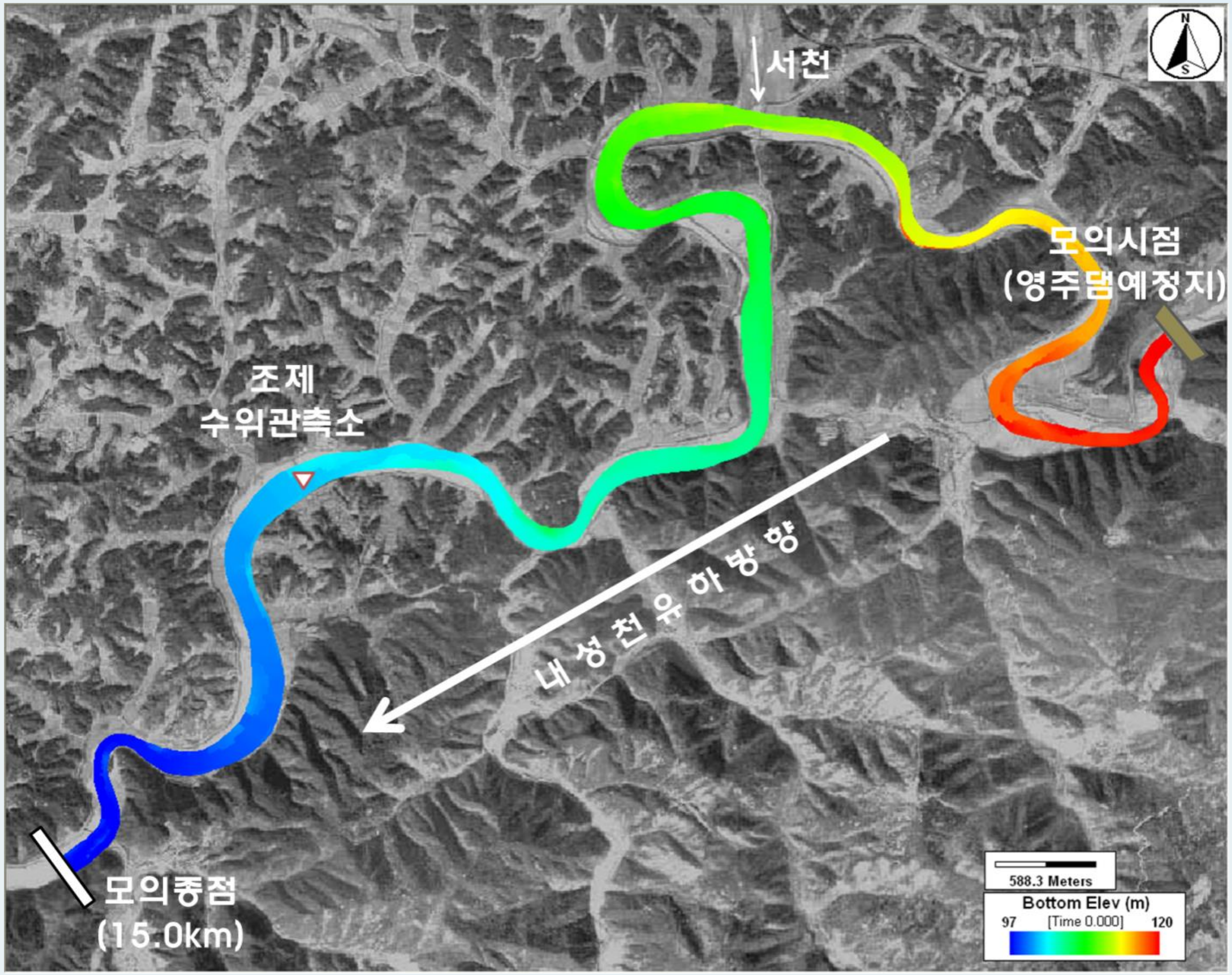


- EFDC (Environmental Fluid Dynamics Code)
  - 3-dimensional hydrodynamic model
  - simulation of hydrological movement & water quality
    : fluid movement, salinity, temperature, eutrophication, dilution by pollutants, etc.)
  - physical movement mechanism (transfer & diffusion) of the hydrodynamics module were used.

Ⅱ-2. Study Method

K water

Construction of Simulation grid



- Using data
  - Basic Plan of Naesung stream (2012, MLTM)
  - measured topographic data
- Simulation range
  - proposed site of YJ Dam ~ downstream up to 15km
- Simulation grid
  - avg. grid size 20.6m x 14.4m
  - 5,920 horizontal grids
  - 2 layers of vertical grids

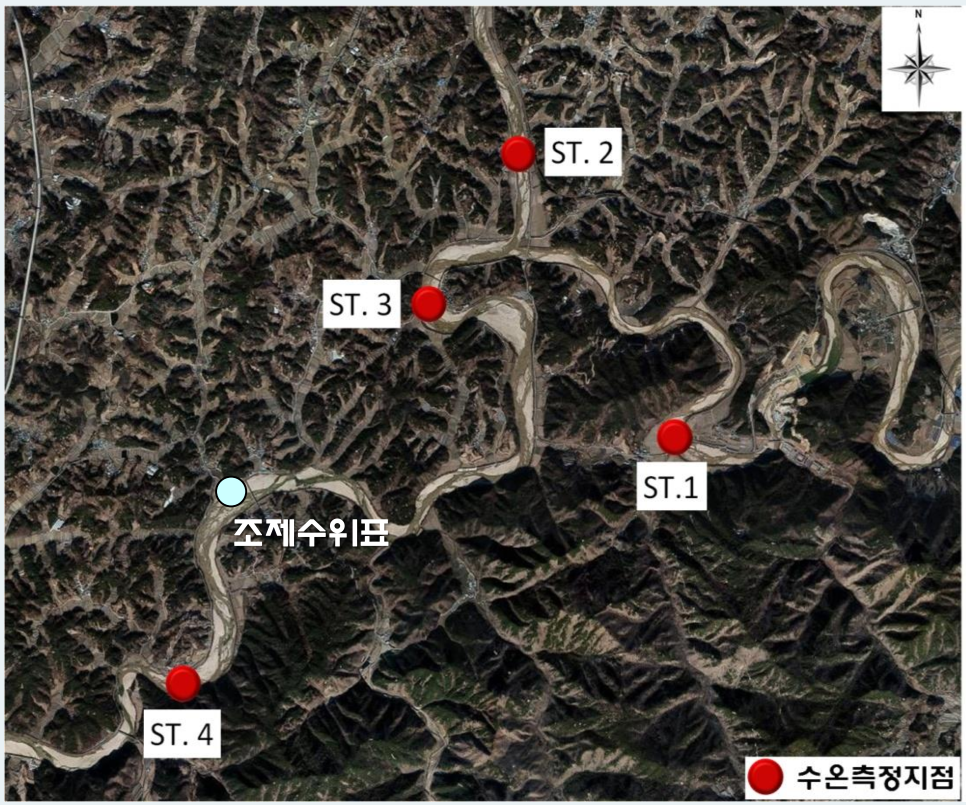
Ⅲ. Result & Discussion

Ⅲ-1. Parameter Estimation

K water

Measurement of water temp.

- Measurement of water temp. in Naesung stream
  - by hour was measured from May to Sept. (irrigation period in Youngju)
  - 3 location in NS stream(st. 1, 3, 4), 1 location in Seo stream (st.2)



St.1

St.2

St.3

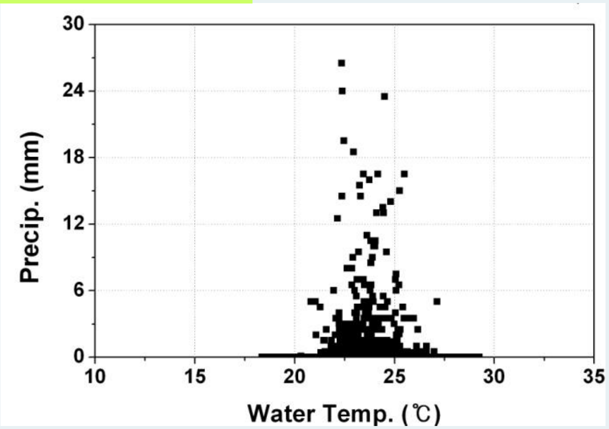
St.4

Ⅲ-1. Parameter Estimation

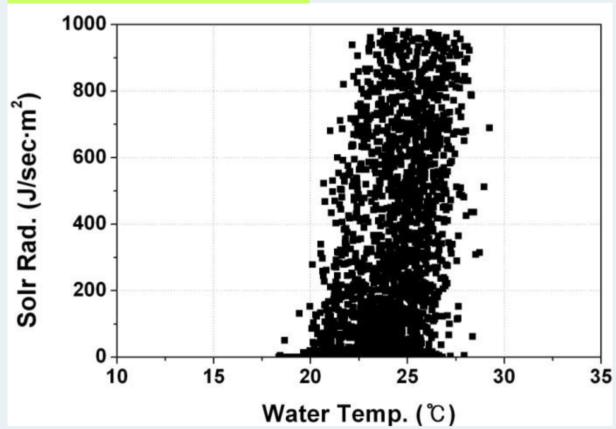
K water

Regression analysis (st.1)

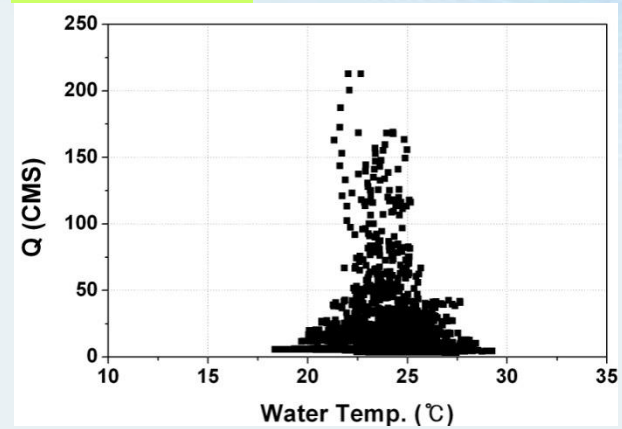
vs precipitation



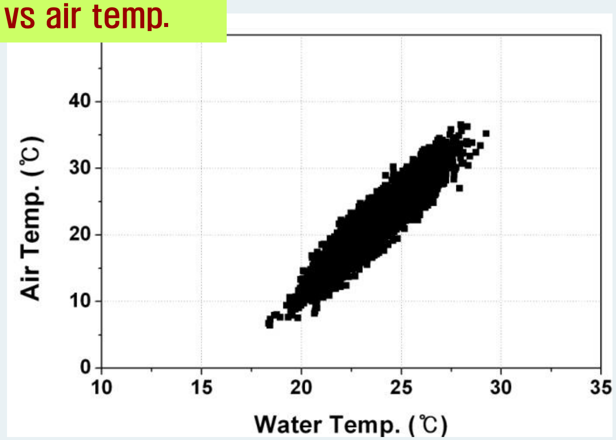
vs solar radiation



vs flow rate



vs air temp.



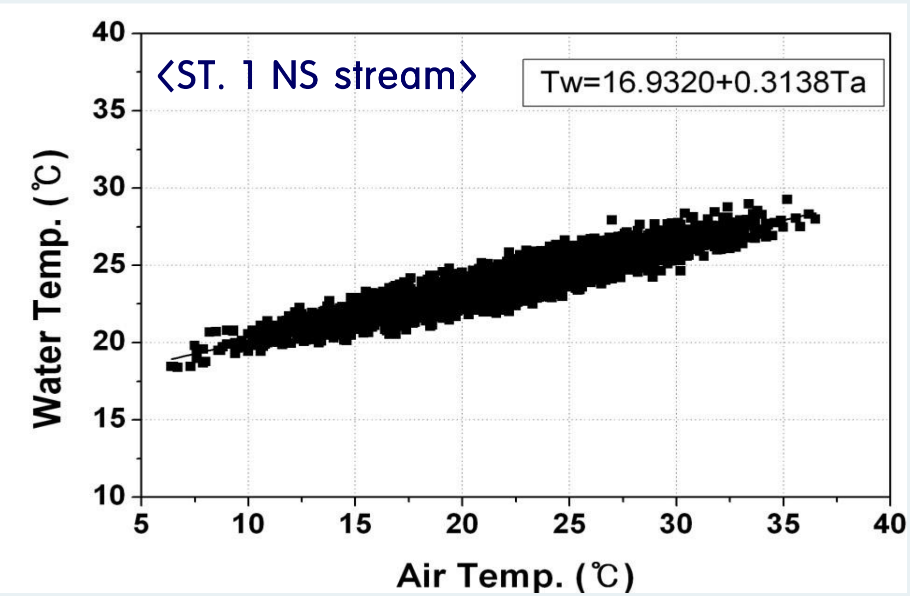
- Correlation was determined with hourly water temp., meteorological data, flow rate

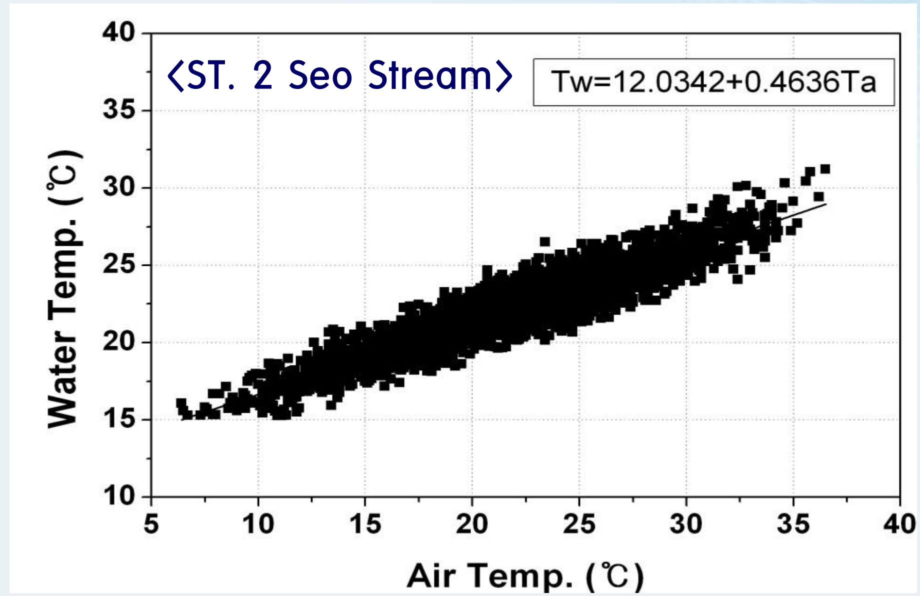
  - high correlation : water temp. & air temp.
  - low correlation : water temp. & other factor (flow rate, solar radiation, precipitation, etc.)

Ⅲ-1. Parameter Estimation

linear equation

- Linear equation of water temp. & air temp.





Item		Equation	RMSE	R^2	AME
Linear equation	St.1	Tw = 16.9320 + 0.3138 × Ta	0.624	0.866	0.501
	St.2	Tw = 12.0342 + 0.4636 × Ta	0.958	0.857	0.764

Ⅲ-1. Parameter Estimation

K water

Parameter Estimation

- The EFDC model Temp. pareameters were set up
  - input measured data at St.1, St.2 (model boundary condition)
    → comparing the model result and measured data at St.3, St.4
  - Trial & Error method was used to minimize errors and parameters were set up

- Parameter applied to simulate water temp. in NS stream

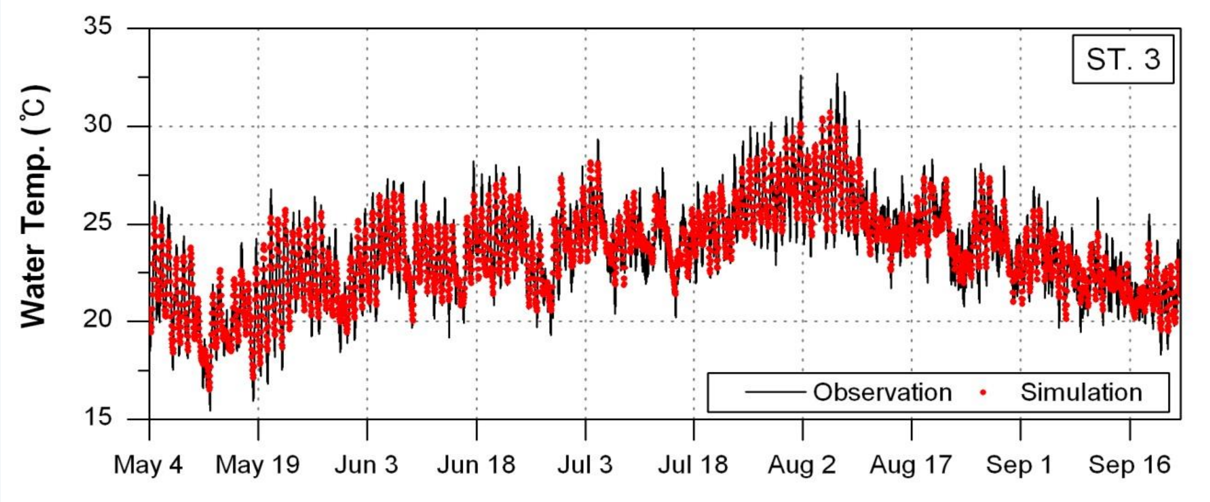
Item	EFDC range	Applied value
DABEDT(Bed depth)	1 ~ 10 meters	1
TBEDIT(Bed temp.)	10 ~ 20 ℃	10
HTBED1(Convection)	0.001 ~ 0.005	0.005
HTBED2(Heat exchange)	1×10^{-7} ~ 15×10^{-7} m^2/s	1×10^{-7}

주) EFDC Technical Memorandum Bed Thermal Model, March 19. 2007, John Hamrick

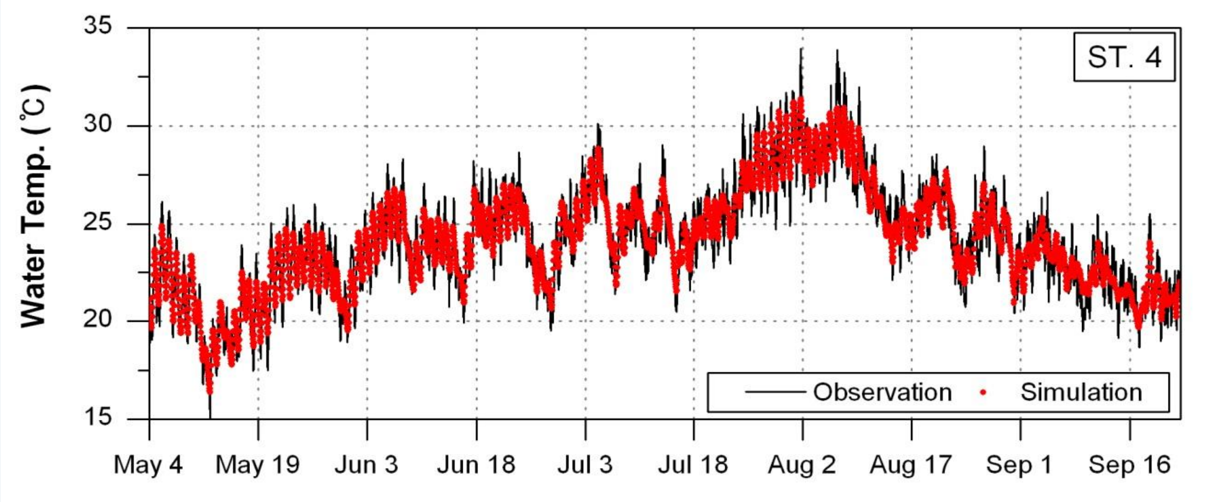
Ⅲ-1. Parameter Estimation

Evaluation of reproducibility

- A graph that compares simulated and measured values → similar pattern



- st.3
  - Avg. measured : 23.47℃
  - Avg. simulated : 23.46℃
  - RMSE : 0.961



- st.4
  - Avg. measured : 24.08℃
  - Avg. simulated : 24.07℃
  - RMSE : 0.971

Ⅲ-2. Construction of scenario

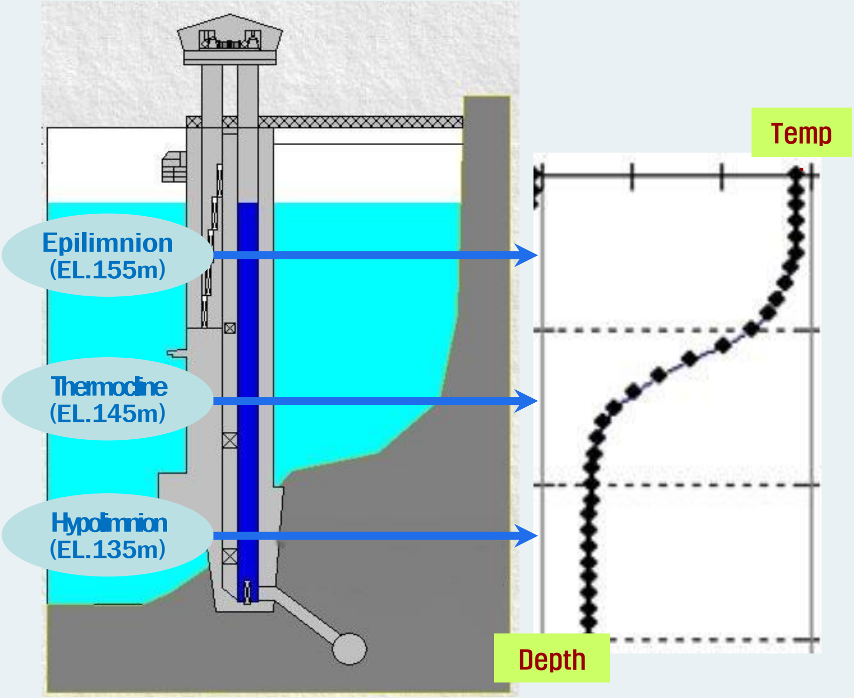
K water

Construction of Simulation Scenario

- **Consideration of selective water intake tower**
  - YJ Dam is planned to take water depth of discharge water selectively
  - 4 scenarios : natural stream condition prior to the dam
    & the selected water was assumed to be withdrawn at Epilimnion, Thermocline, Hypolimnion

- Construction of scenario

Item	Contents		Note
Scenario1	Prior to dam const.		At 2008
Scenario2	After dam const.	Epilimnion (EL.155m)	
Scenario3		Thermocline (EL.145m)	
Scenario4		Hypolimnion (EL.135m)	



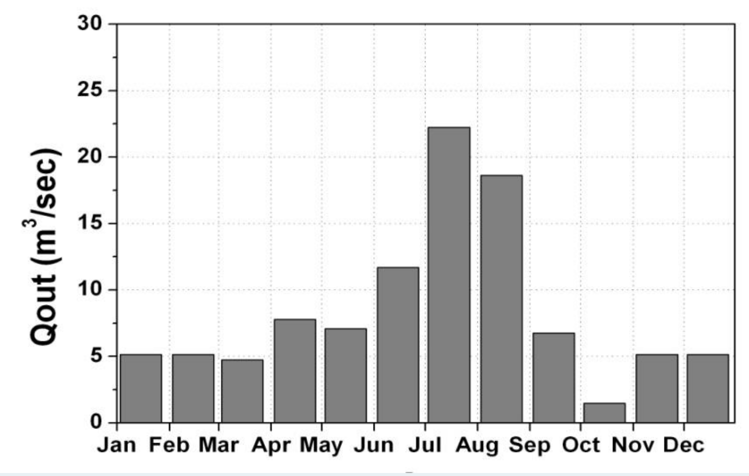
Ⅲ-2. Construction of input data

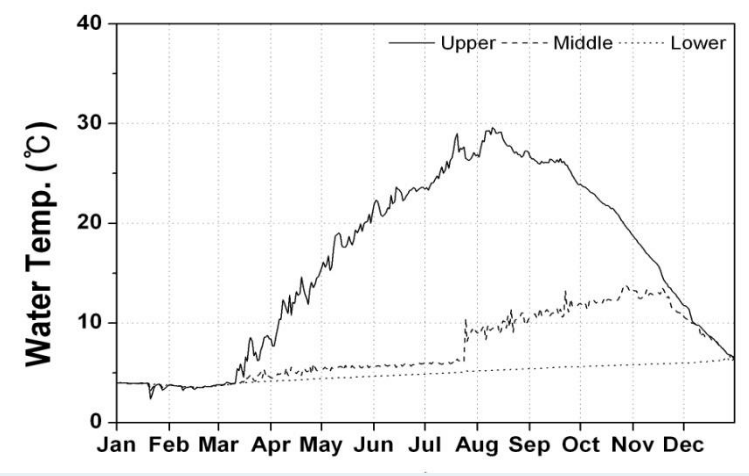
K water

Input data per scenarios

- **Inflow rate**
  - NS Stream : drainage-area ratio (before), planned discharge flow rate (after)
  - Seo Stream : drainage-area ratio method
    ※ water level observatory in Chojae
- **Water temp.**
  - calculated using the linear equation between water and air temp. (Stream)
  - water temp. distribution date by water depth in YJ Dam (simulated in CE-QUAL-W2)
    ※ EIA in YJ Dam
- **Meteorological data**
  - atmospheric pressure, temp, humidity, precipitation, wind direction & speed, etc.
    ※ Youngju, Andong weather station

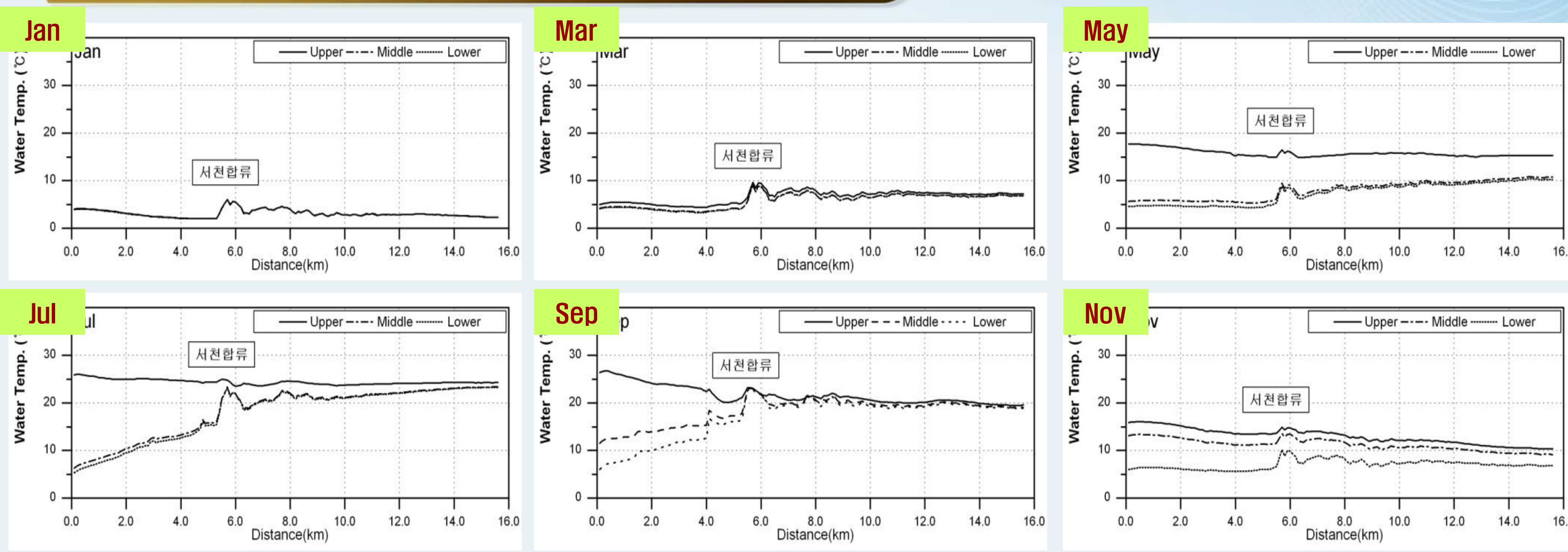
Withdrawal flow rate & water temp. in YJ Dam





Ⅲ-3. Simulation of changes in water temp.

Change in water temp. in the downsteam



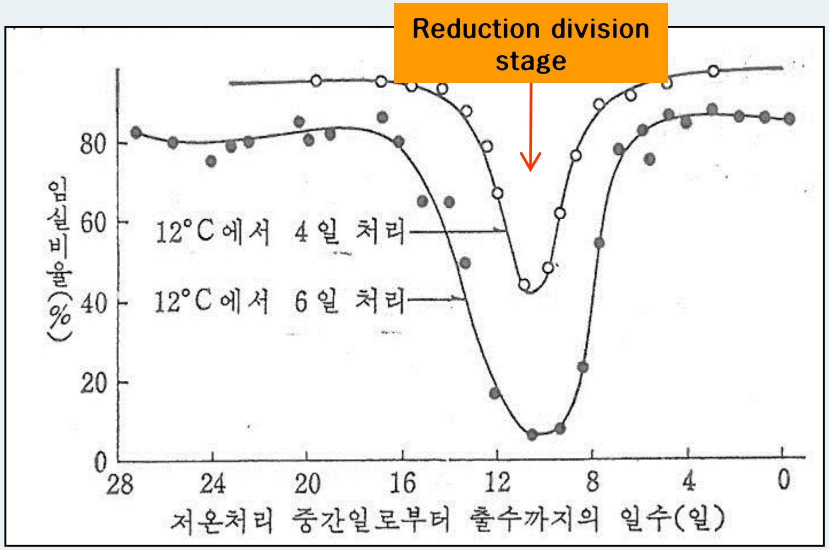
- **Changes in water temp. by dam intake location, period, flow distance**
  - water temp. difference increased from March when thermal stratification was formed
  - water temp. rise and stabilize due to the air temp. effect and joining of tributary
  - epilimnion withdrawal was relatively similar water temp. distribution compared to natural stream before dam, thermocline and hypolimnion withdrawal was much lower water temp. distribution due to low temp. dam discharge

Ⅲ-4. Simulation of chilling injury

Chilling injury disorder temp. criteria

※ source : Rural Development Administration

Growth stage	Growth temp.(℃)	Disorder temp.(℃)	Period	Injury symptoms
Germination stage	30~34	<10	Month. 3~4	poor germination
Nurse stage	15~25	<13	Month. 4	growth inhibition, sallowed seeding
Rooting stage	25~28	<13	Month. 5	poor rooting, withered leaf
Tillering stage	25~32	<15	Month. 5~6	decrease in tiller number, growth inhibition
Reduction division	23~33	<17	Month. 7	pollen productivity inhibition, sterility
Heading stage	23~33	<17	Month. 7~8	inflorescence delayed, poor pollonation
Ripening stage	20~26	<14	Month. 9~10	ripening delayed



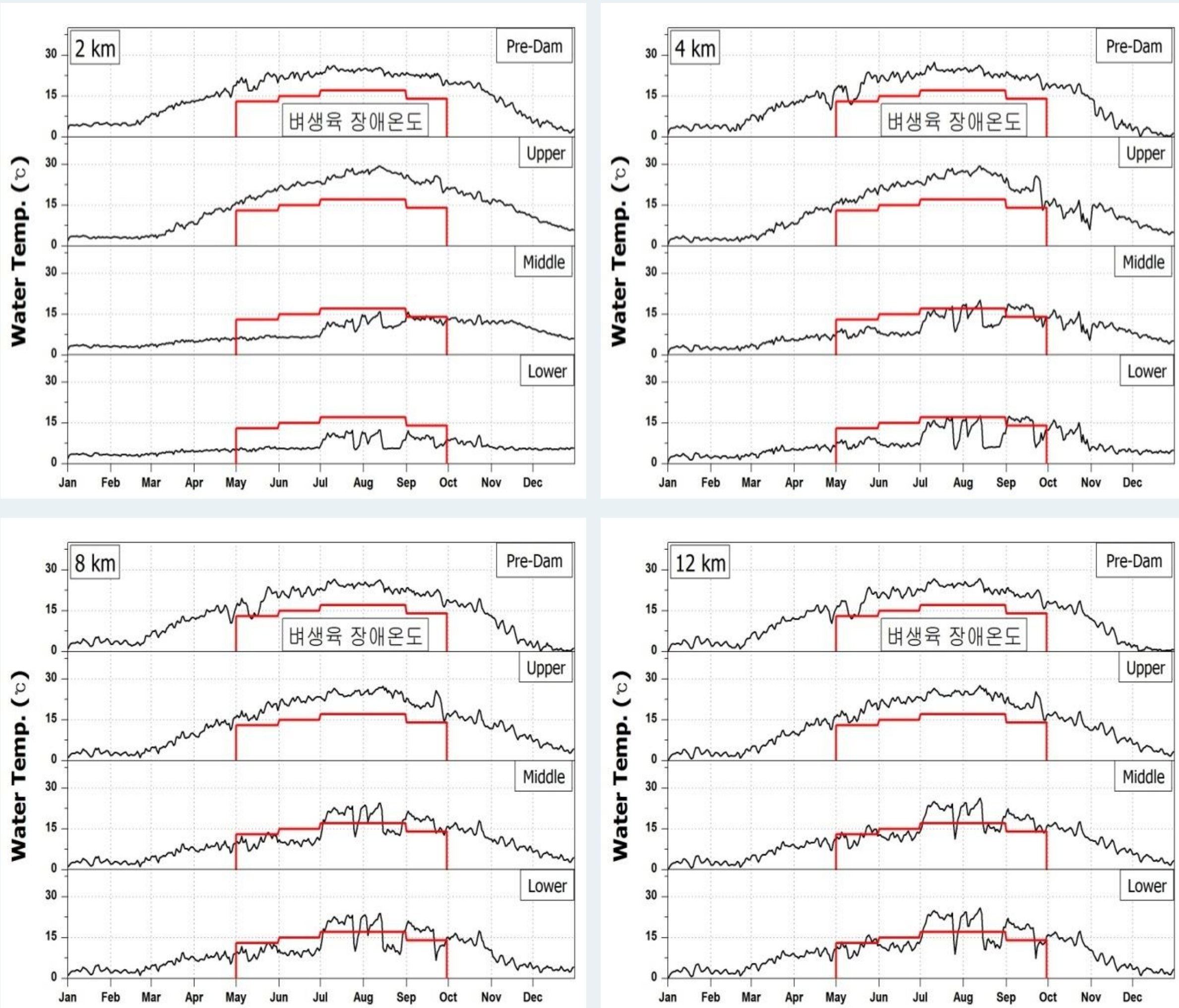
- Over the whole cultivation period, occurrence of chilling injury is concerned.
  - in reduction division stage, it has most affected.
- the days(number) of growth disorder occurrence was calculated by putting the chilling injury disorder temp. criteria

Ⅲ-4. Simulation of chilling injury

K water

days of growth disorder due to chilling injury

※ rice irrigation period in YJ : 5~9



- epilimnion withdra. Indicate little possibility of chilling injury
- thermocline & hypolimnion withdra.
  chilling injury is concerned

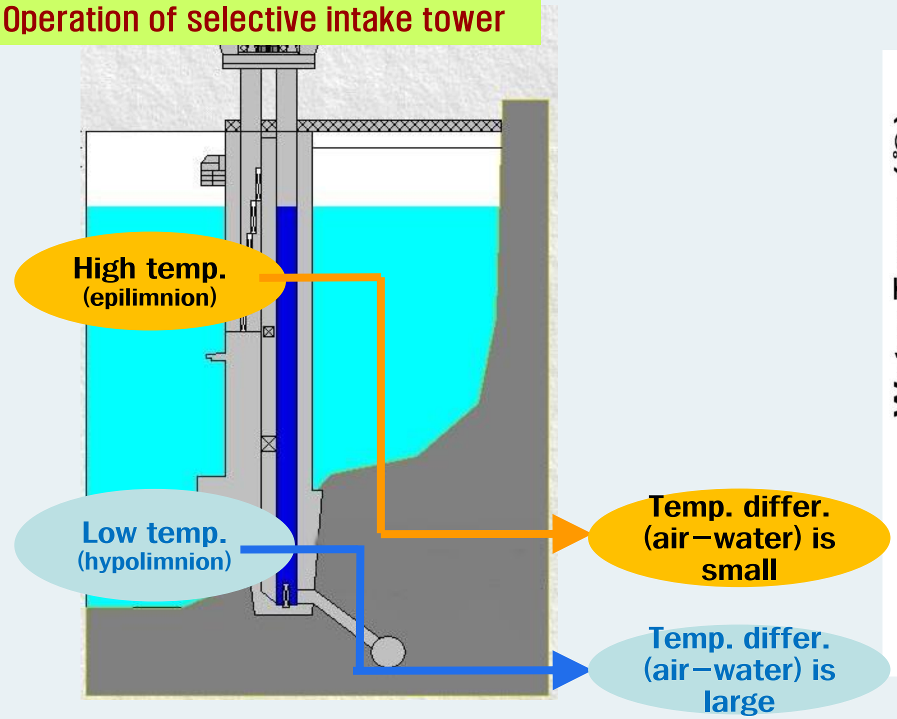
- 4km downstream of dam
  - before dam : 3days
  - epilimnion withdra. : 2days
  - thermocline withdra. : 121days
  - hypolimnion withdra. : 132days
- 8km downstream of dam
  - before dam : 4days
  - epilimnion withdra. : 0
  - thermocline withdra. : 79days
  - hypolimnion withdra. : 91days

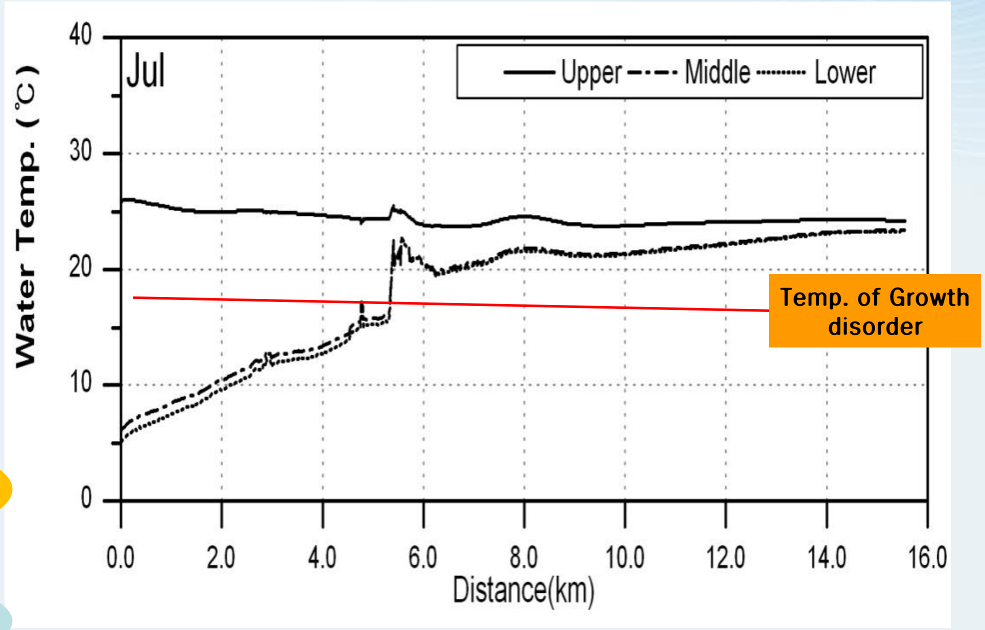
Ⅲ-4. Simulation of chilling injury

K water

mitigation of chilling injury

Operation of selective intake tower





- reduction of chilling injury effects using selective intake tower
  - water temp. of epilimnion withdrawal can be kept over the chilling injury disorder temp.
  - thermocline & hypolimnion withdrawal had a large water temp. difference within 5km downstream before tributary joining (Seo stream)
  - selective intake tower can control chilling injury effects in the downstream effectively

Ⅳ. Conclusion

Ⅳ. Conclusion

K water

- The withdrawal of the deep water may have chilling injury in the dam downstream (many complaints have been claimed from local farmers)
- In the EIA stage(dam planning stage), need to simulate the change in water temp. and the degree of chilling injury effect
  → consider a measure to reduce chilling injury
- changes in water temp. discharged from selective water intake tower were simulated using EFDC model
  (according to intake location(water depth), period, flow distance)
- linear equation between water–air temp. was created based on the measured data and utilize as the input data and estimation of parameters

Ⅳ. Conclusion

- withdrawal water temp. rise and stabilize due to the air contact effect and joining of tributary
- epilimnion withdrawal was relatively similar water temp. distribution compared to natural stream before dam.
- thermocline and hypolimnion withdrawal was much lower water temp. distribution due to low temp. dam discharge
- selective intake tower can control chilling injury effectively
- Based on this study result, it is necessary to establish appropriate operational criteria of selective water intake tower considering effects of fog, water quality(turbidity, eutrophication), ecosystem and recreational activities comprehensively

Thank you

Water for the happier world. K-water

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