THA 2019 International Conference on Water Management and Climate Change towards Asia's Water-Energy-Food Nexus and SDGs

23-25 January 2019, Swissôtel Bangkok Ratchada, Thailand

Flood Computations for Changing River Environment in Korea

Kyung Soo Jun

Sungkyunkwan University

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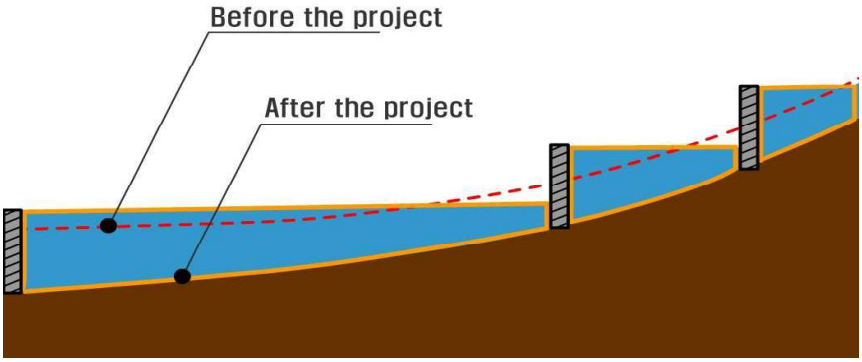
Location of the Four Major Rivers of South Korea

- **Low Flow Channel Water Storage due to the Combined Effect of Channel Dredging and Weirs**



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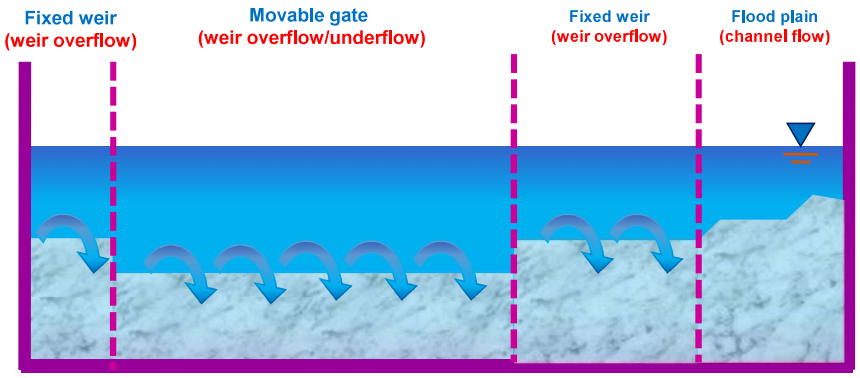
- **Typical Bird's Eye View of the Four Major Rivers after the Project Completion**

- Schematic Representation of the Flow at the Weir



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Numerical Model

- Governing Equation

Node :

$$\sum_{k=1}^{L_j} Q_{j,k} + Q_{ext}(j,t) = 0\ ,\quad j = 1,\ \cdots,\ J$$

$$y_{j,k} = y_j,\quad k = 1,\ \cdots,\ L_j,\quad j = 1,\ \cdots,\ J$$

Fluvial Links :

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = 0$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\alpha \frac{Q^2}{A}\right) + gA\frac{\partial y}{\partial x} + gA\frac{Q|Q|}{K^2} = 0$$

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Numerical Model

- Governing Equation

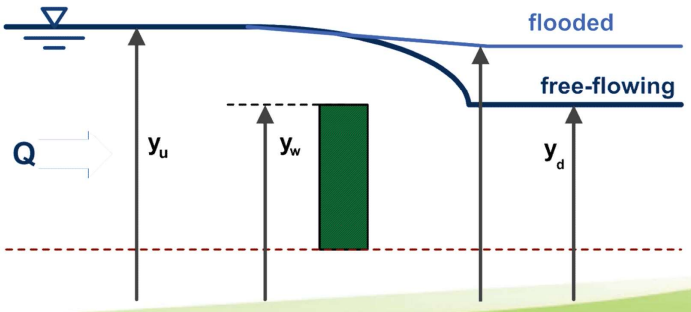
Weir-type

$$Q_u = Q_d$$

Links :

$$Q_u = \mu_s b\sqrt{2g}\sqrt{y_u - y_d}\,(y_d - y_w),\ \left(y_d - y_w \geq \frac{2}{3}(y_u - y_w)\right)$$

$$Q_u = \mu_f b\sqrt{\frac{2g}{3}}(y_u - y_w)^{3/2},\qquad \left(y_d - y_w < \frac{2}{3}(y_u - y_w)\right)$$



Numerical Model

- **Governing Equation**

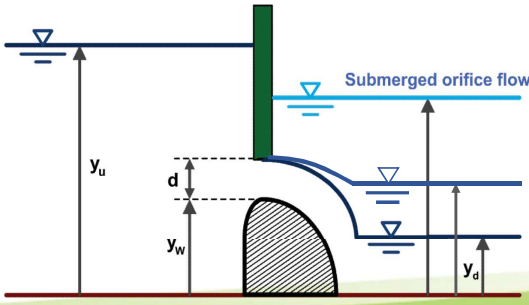
Orifice-type $Q_u = Q_d$

Links :

$$Q_u = \frac{2}{3}\sqrt{2g}\mu_{f0}b_0((y_u - y_w)^{3/2} - (y_u - y_w - d)^{3/2}), \quad (y_d \le y_w)$$

$$Q_u = \frac{2}{3}\sqrt{2g}\mu_{f0}b_0((y_u - y_d)^{3/2} - (y_u - y_w - d)^{3/2}) + \mu_{s0}b_0(y_d - y_w)\sqrt{2g(y_u - y_d)}, \quad (y_w \le y_d < y_w + d)$$

$$Q_u = \mu_{s0}A\sqrt{2g(y_u - y_d)}, \quad (y_d > y_w + d)$$



Numerical Method

- Finite difference method
- Preissmann's 4-pt. scheme
- Newton-Raphson method
- Matrix double-sweep algorithm
  - ✓ Link forward sweep
  - ✓ Node matrix loading and solution
  - ✓ Link backward sweep

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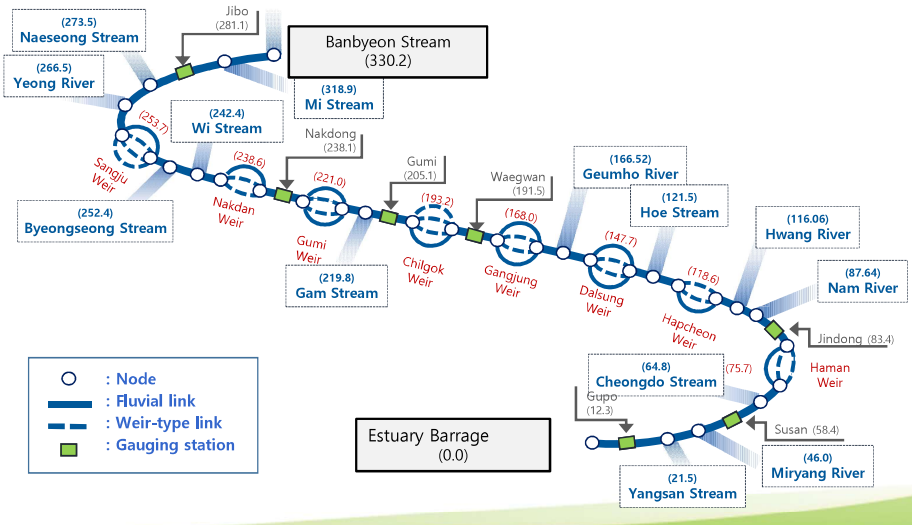
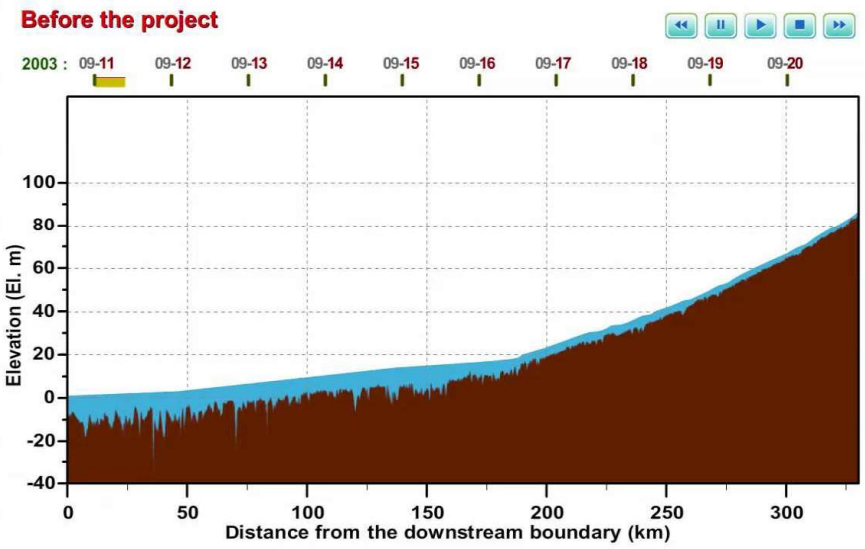
Schematic Representation of Modeled River Reach: the Nakdong River





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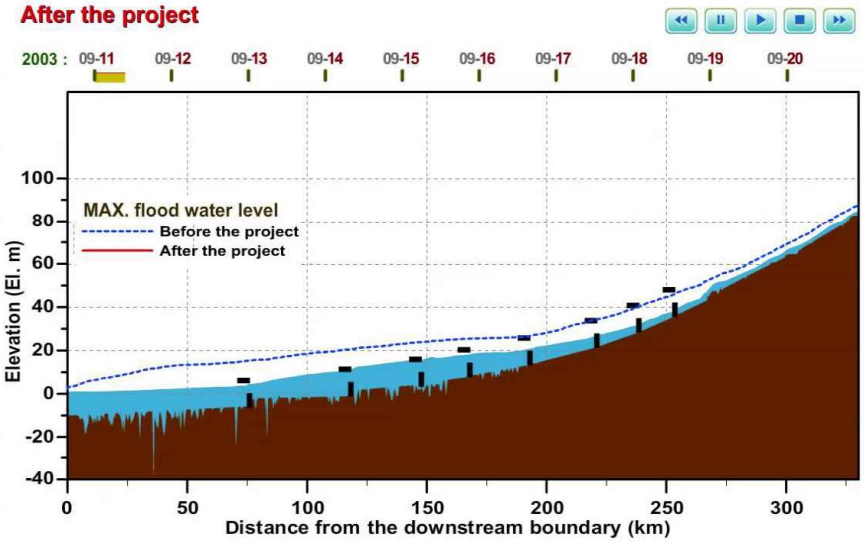
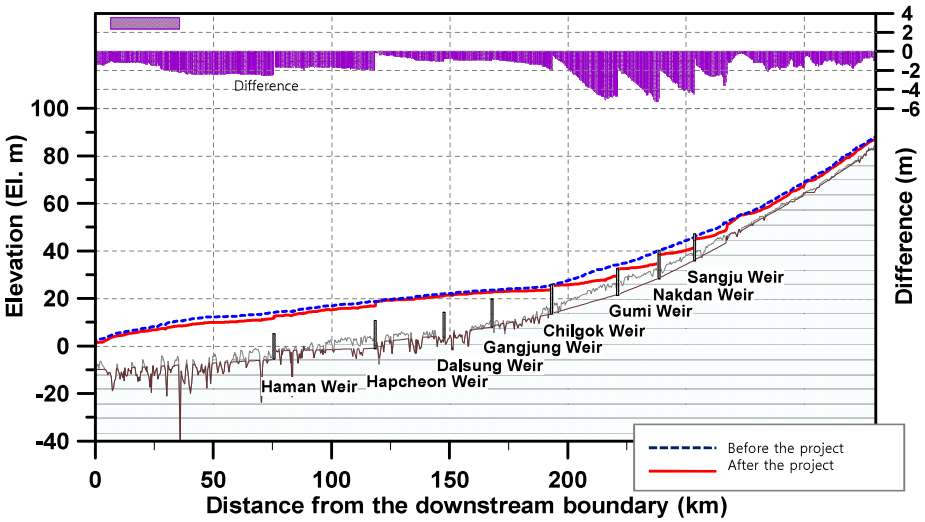
Flood Flow Simulations



- **Maximum Flood Water Level, Sept 2003 Flood**



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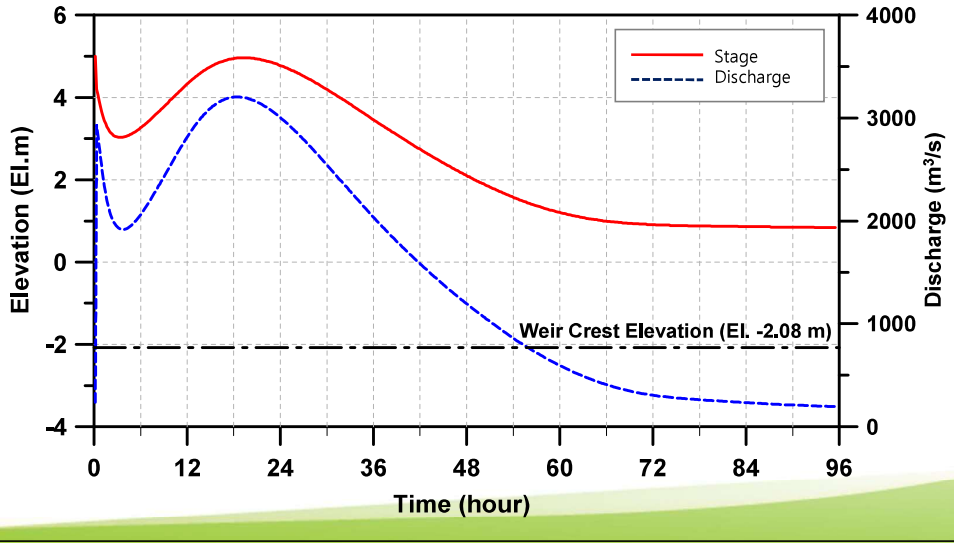
Gate Fully Open with No (External) Flood

- Upstream of Haman Weir



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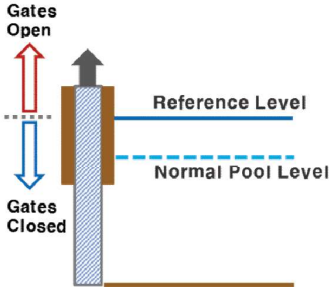
Gate Operation

- Objectives
  - Lower the flood water level ➔ Open the gate !
  - Secure water in the channel ➔ *Close it !!!*
- Strategy
  - Increase gate openings as water level rises.



Proposal

– Gate Opening = $INT\left(\alpha \times \frac{Current\ stage - Refere\quad level}{d}\right) \times d$

d : gate opening increment

– Close the gate below the reference level

Numerical Model

▪ Governing Equation

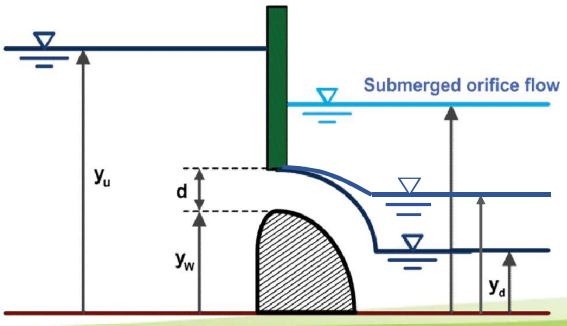
Orifice-type Links :

$$Q_u = Q_d$$

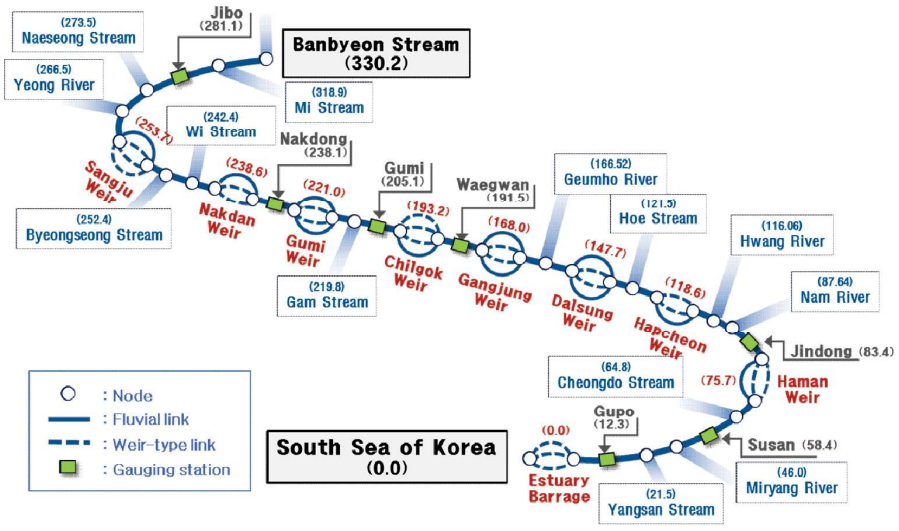
$$Q_u = \frac{2}{3}\sqrt{2g}\mu_{f0}b_0((y_u - y_w)^{3/2} - (y_u - y_w - d)^{3/2}), \quad (y_d \le y_w)$$

$$Q_u = \frac{2}{3}\sqrt{2g}\mu_{f0}b_0((y_u - y_d)^{3/2} - (y_u - y_w - d)^{3/2}) + \mu_{s0}b_0(y_d - y_w)\sqrt{2g(y_u - y_d)}, \quad (y_w \le y_d < y_w + d)$$

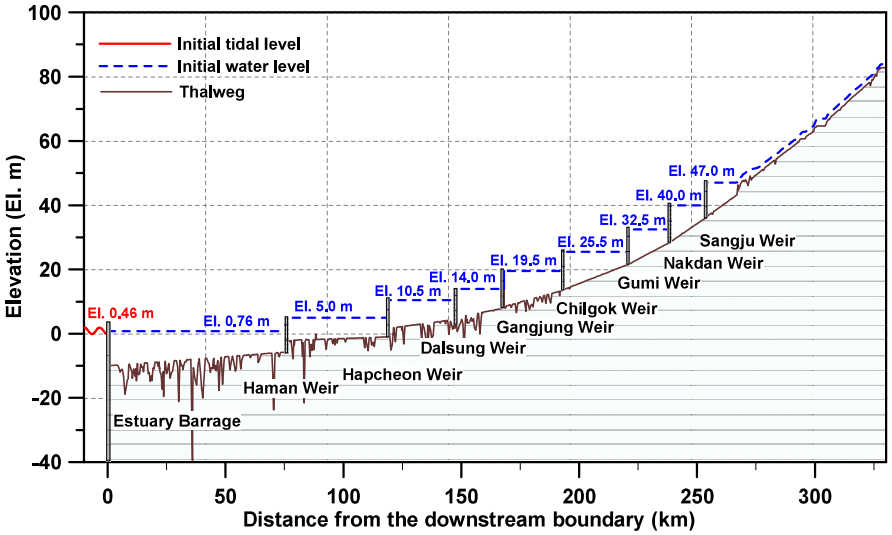
$$Q_u = \mu_{s0}A\sqrt{2g(y_u - y_d)}, \quad (y_d > y_w + d)$$



▪ Schematic Representation of Modeled River Reach



▪ Initial Condition: Normal Pool Level + Steady Flow Simulation



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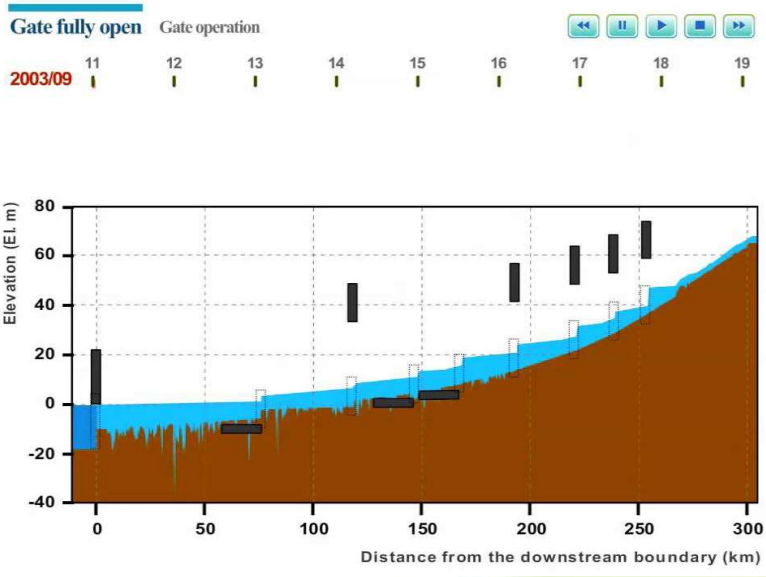
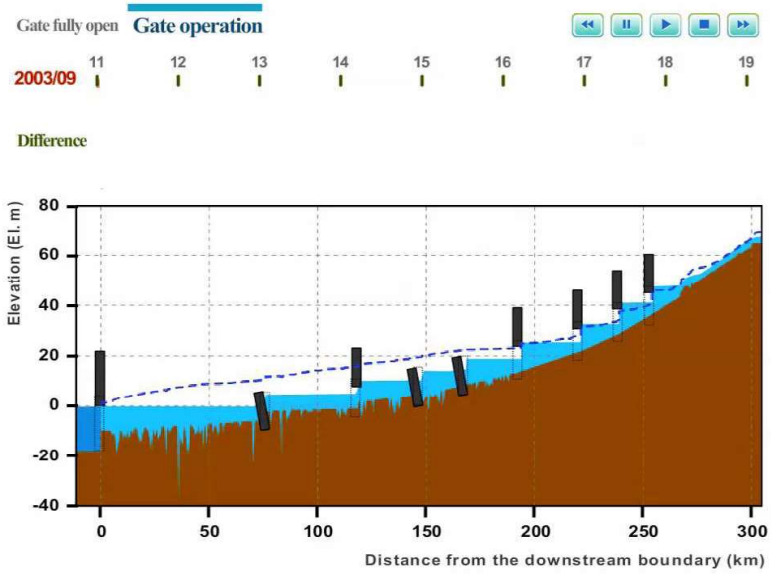
Flood Flow Simulations

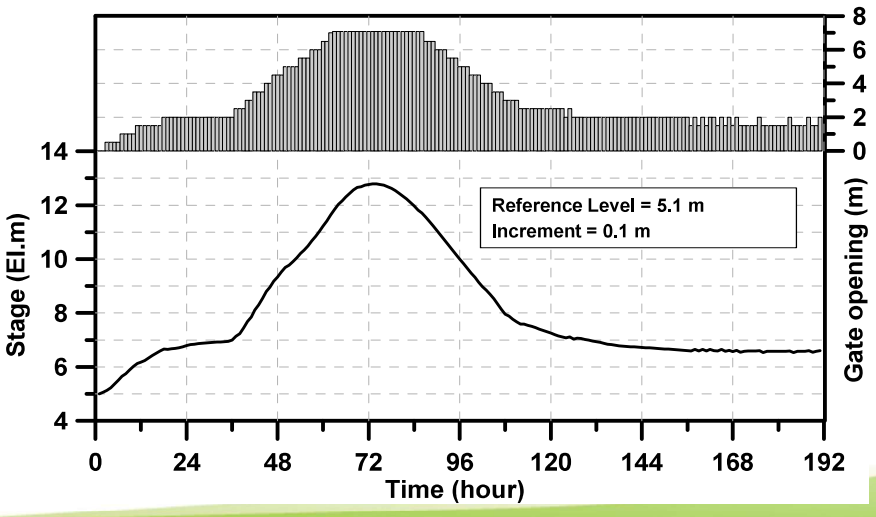


Flood Flow Simulations



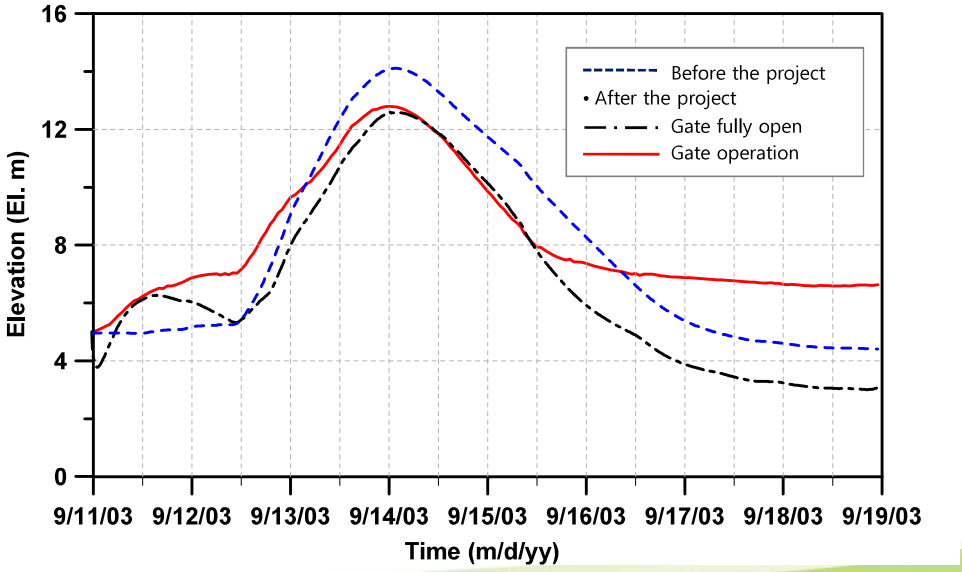
Simulated Stages and Gate Openings

- Haman Weir



Flood Flow Simulations

- Haman Weir



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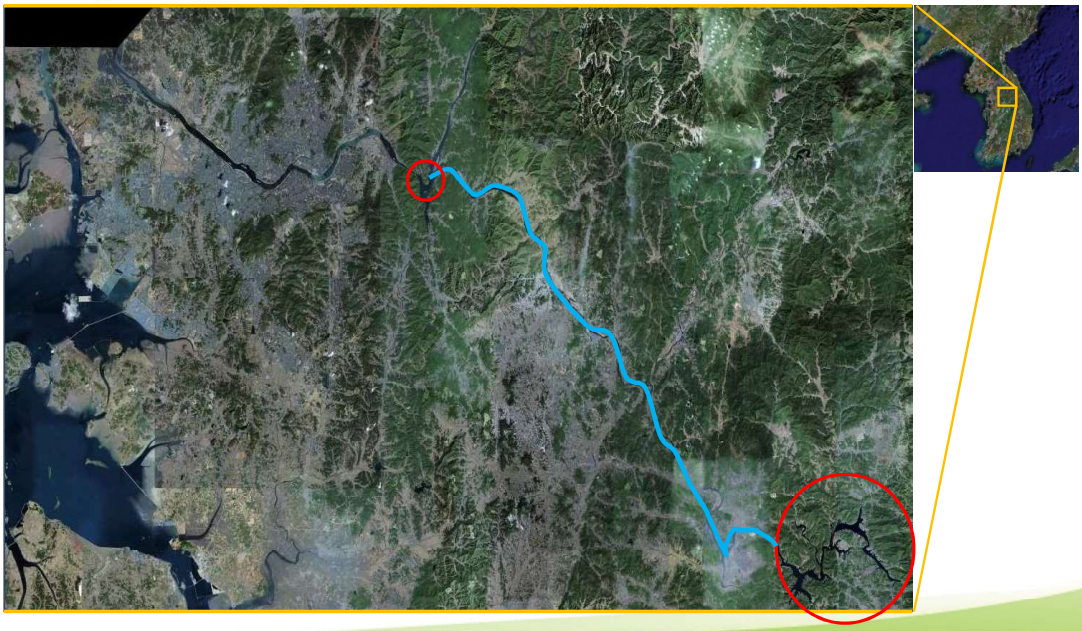
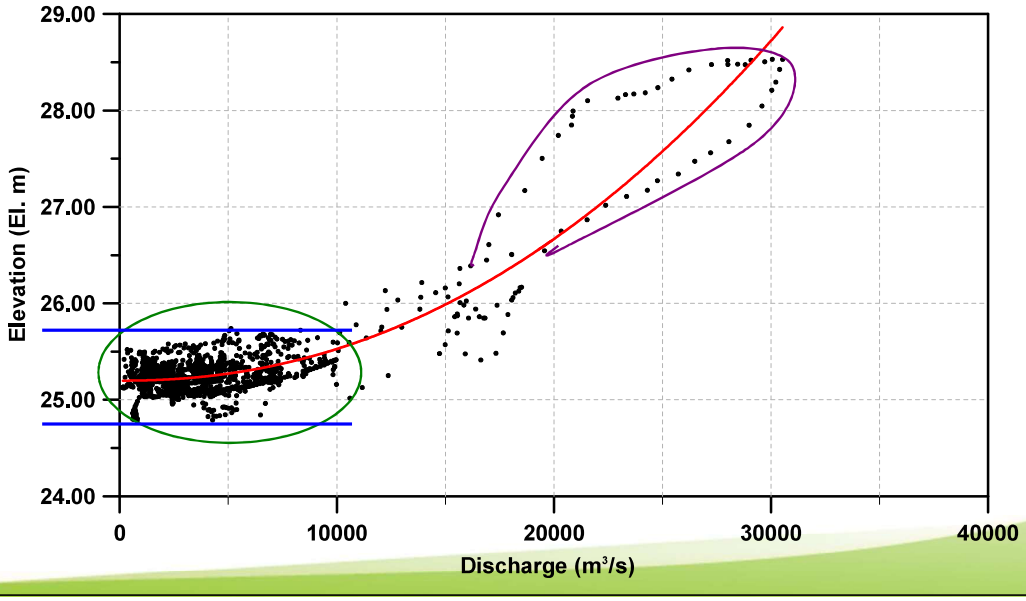
The (South) Han River



- Schematic Representation of Modeled River Reach: The Han River (Before the Project)

Stage-Discharge Relationship Developed from Numerical Simulation

5 km Upstream of the Paldang Lake, Before the Project



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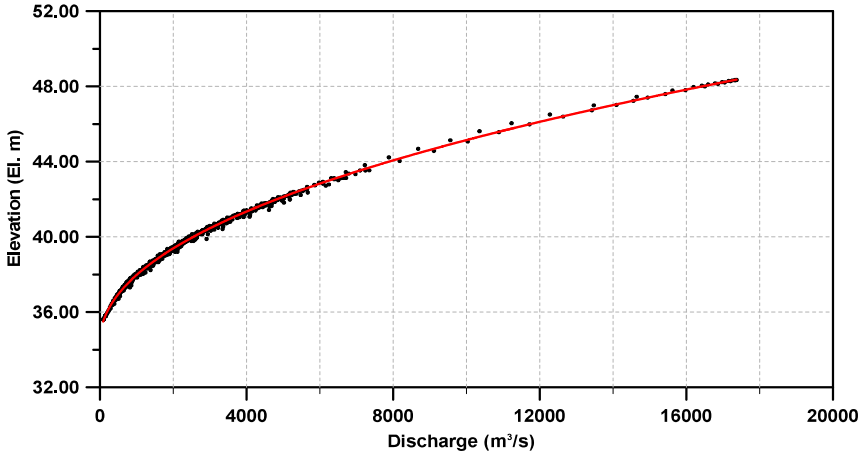
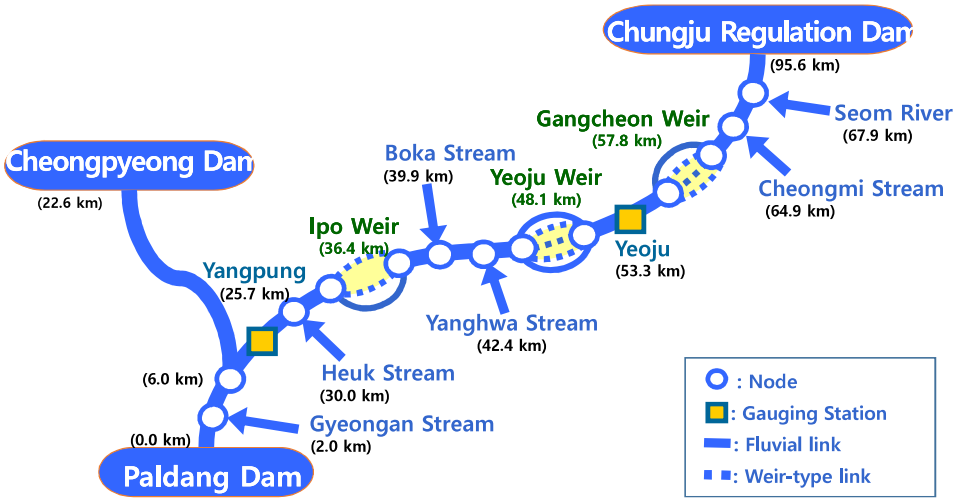
Stage-Discharge Relationship Developed from Numerical Simulation

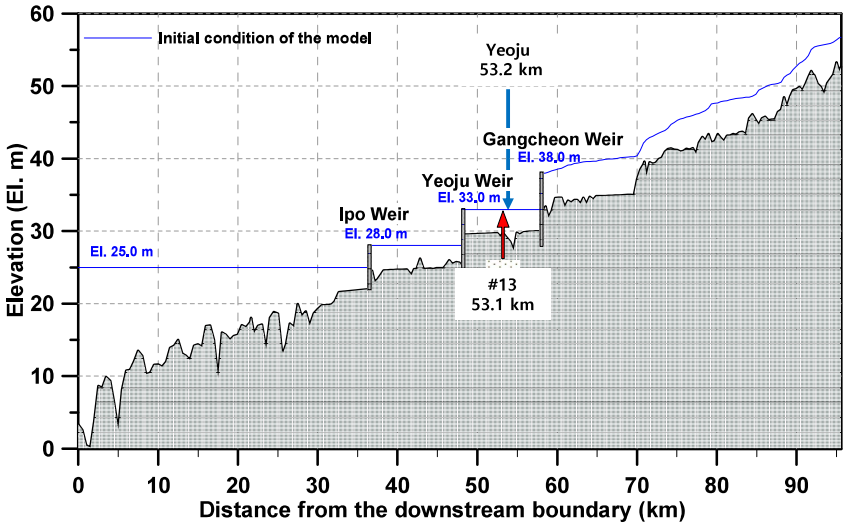
60 km Upstream of the Paldang Lake, Before the Project



▪ Schematic Representation of Modeled River Reach



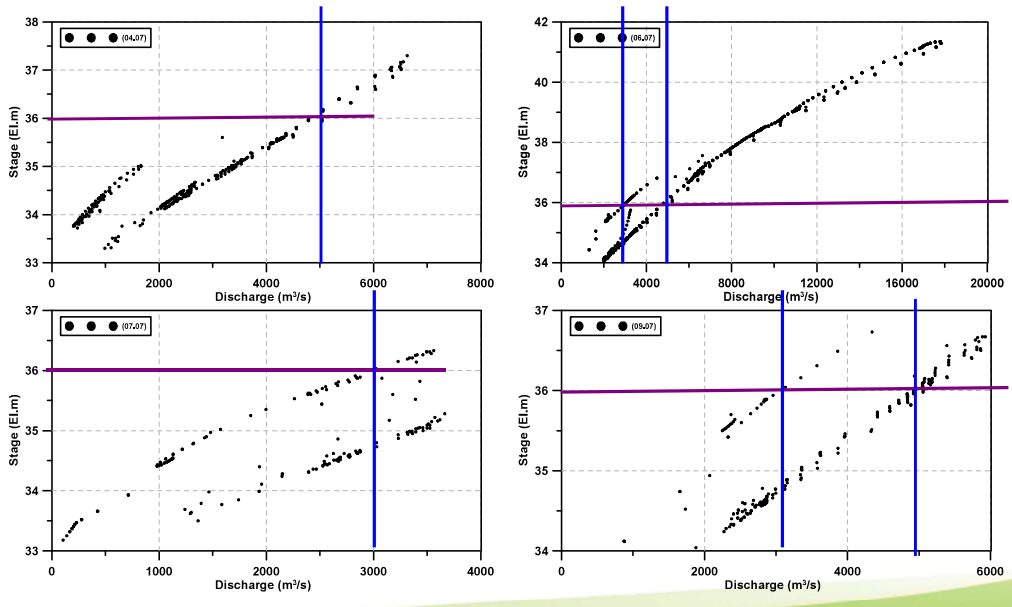
▪ Initial Condition: Normal Pool Level + Steady Flow Simulation



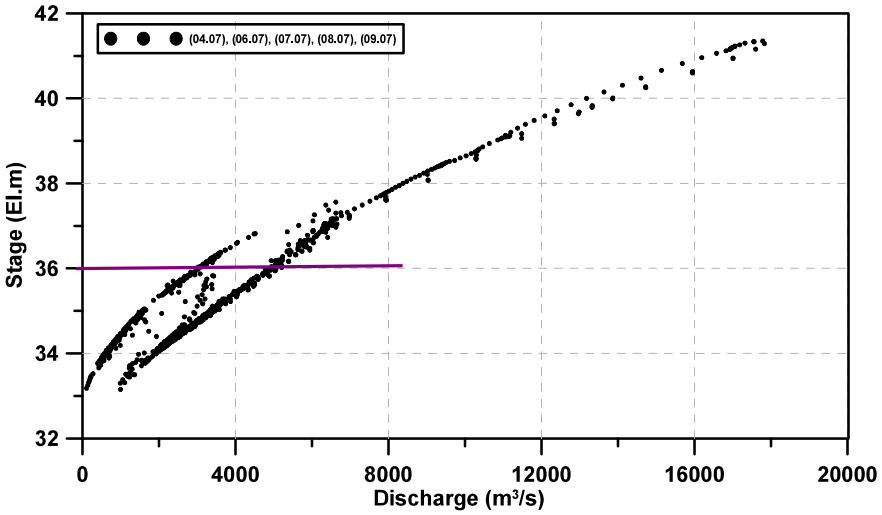
▪ Simulated Flood Events

Event	Duration	Max. Discharge from Chungju Dam (m^3/s)	Max. Discharge from Chungpyung Dam (m^3/s)	For
01	2004/07/15~07/23	3,360	3,962	Development of the relationship
02	2006/07/14~07/23	13,515	11,497	
03	2007/07/24~07/26	1,742	365	
04	2008/07/24~07/27	2,248	7,405	
05	2009/07/14~07/16	3,180	8,348	
06	2002/08/07~08/12	10,340	4,402	Verification
07	2004/08/18~08/21	1,494	1,477	
08	2005/07/01~07/03	1,710	2,883	
09	2005/08/02~08/05	1,058	1,174	
10	2006/07/26~07/30	4,866	5,042	

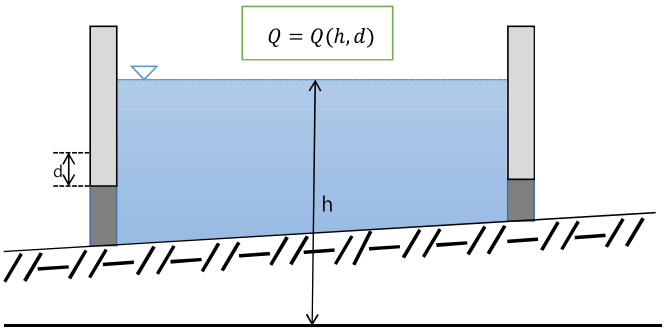
▪ Calculated Stage vs. Discharge for Each Flood Event



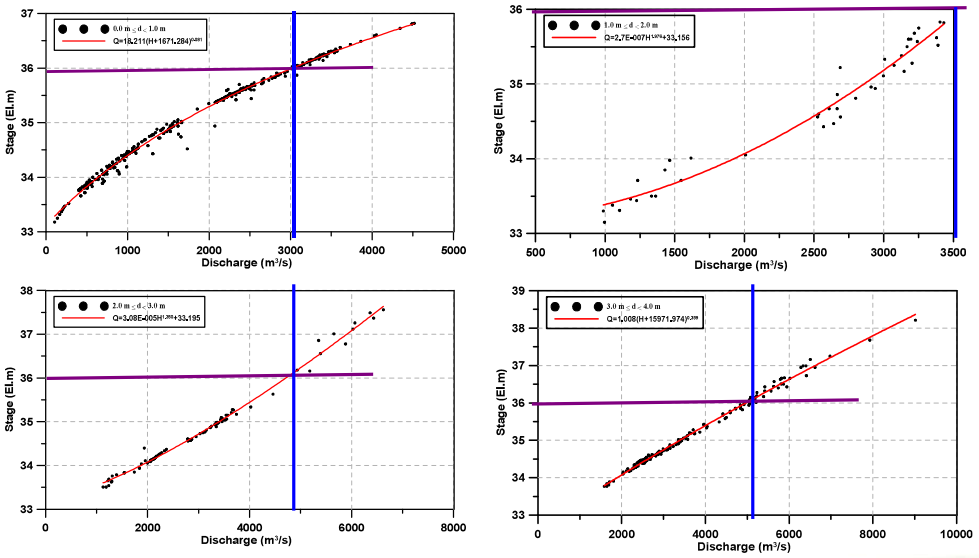
- Calculated Stage vs. Discharge for 5 Flood Events



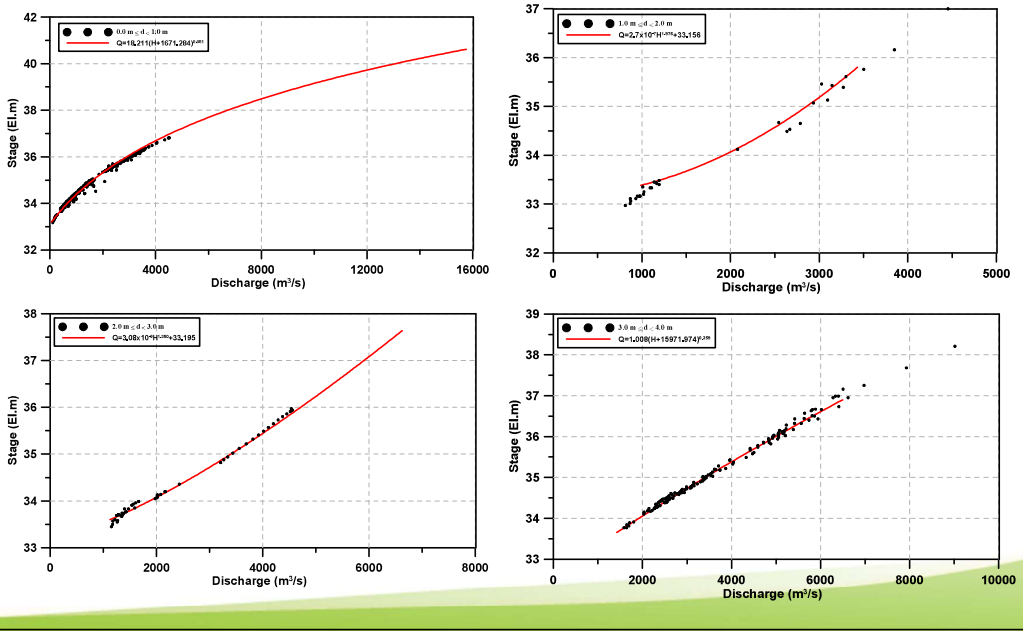
- Definition Sketch: Discharge vs. stage and gate openings



- Stage-Discharge Relationship Developed for Each Group of Different Gate Openings



- Verification of the Developed Relationship



Thank You