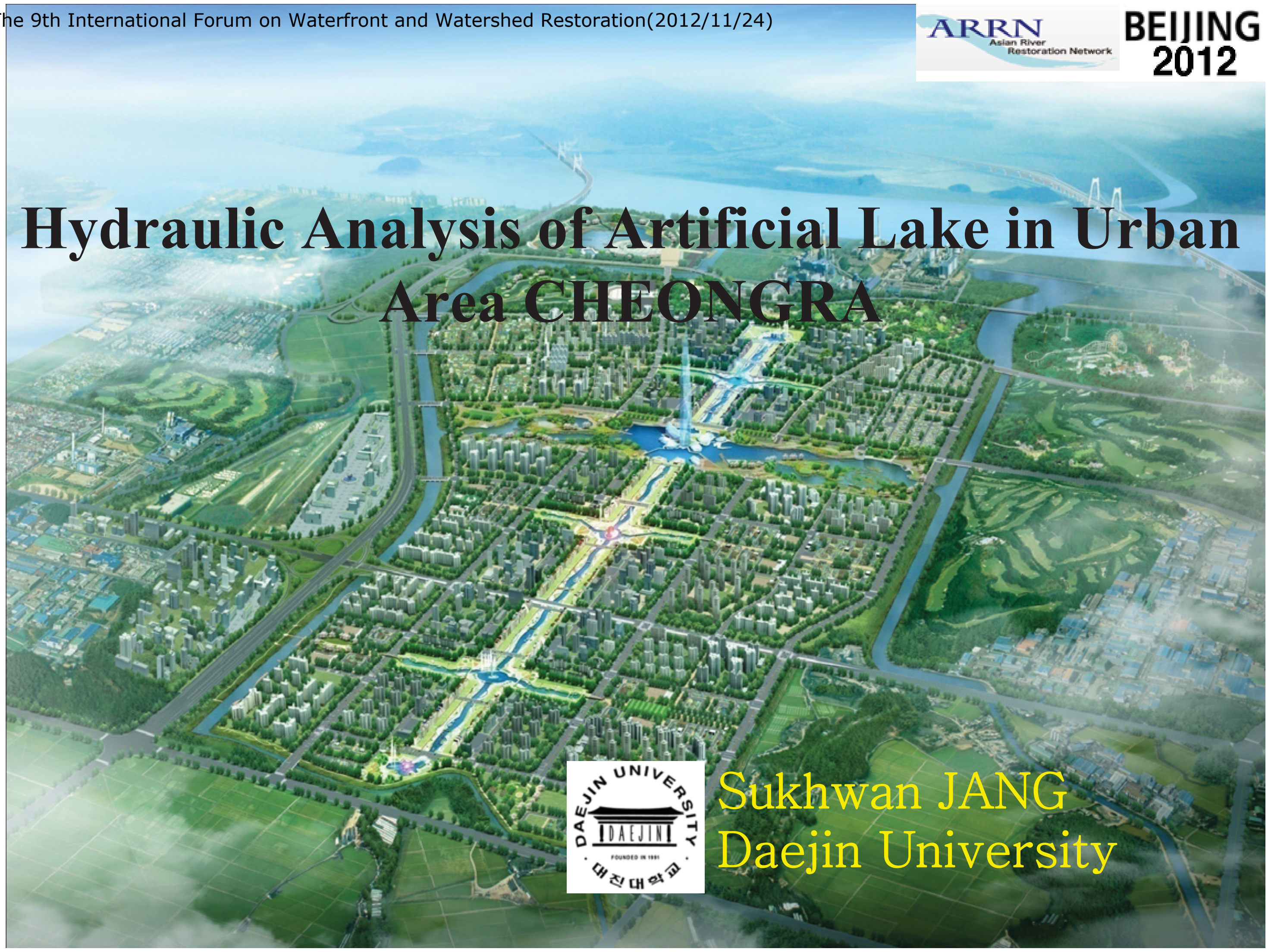

Hydraulic Analysis of Artificial Lake in Urban Area CHEONGRA

Sukhwan JANG
Daejin University

Introduction

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Introduction

- Water circulation system facility in newly developing urban area is popular in Korea.

- It is important to analyze flow patterns and water quality distribution because most of the water circulation systems has very low velocities and depth in the inland navigation.

- The reference site of this study is composed of artificial lake and waterways in urban area developing residence complex

- The purpose of this study is to review the velocity distribution, flow trace and water quality in the lake and navigation waterways.

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Plan of Water Circulation and Canal Way

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Project Outline

- Location :FEZ, Incheon, Korea
- Closed Water Canal System

Characteristics

- Waterfront, Landscaping
- Fine Amenity in Residence Comp
- Navigation for Boat and Water T.

Expenditure

- Total Budget : 70 Mil. USD

Period

- 2009.06.01 : Starting Constructi
- 2013.08.31 : Completion

4

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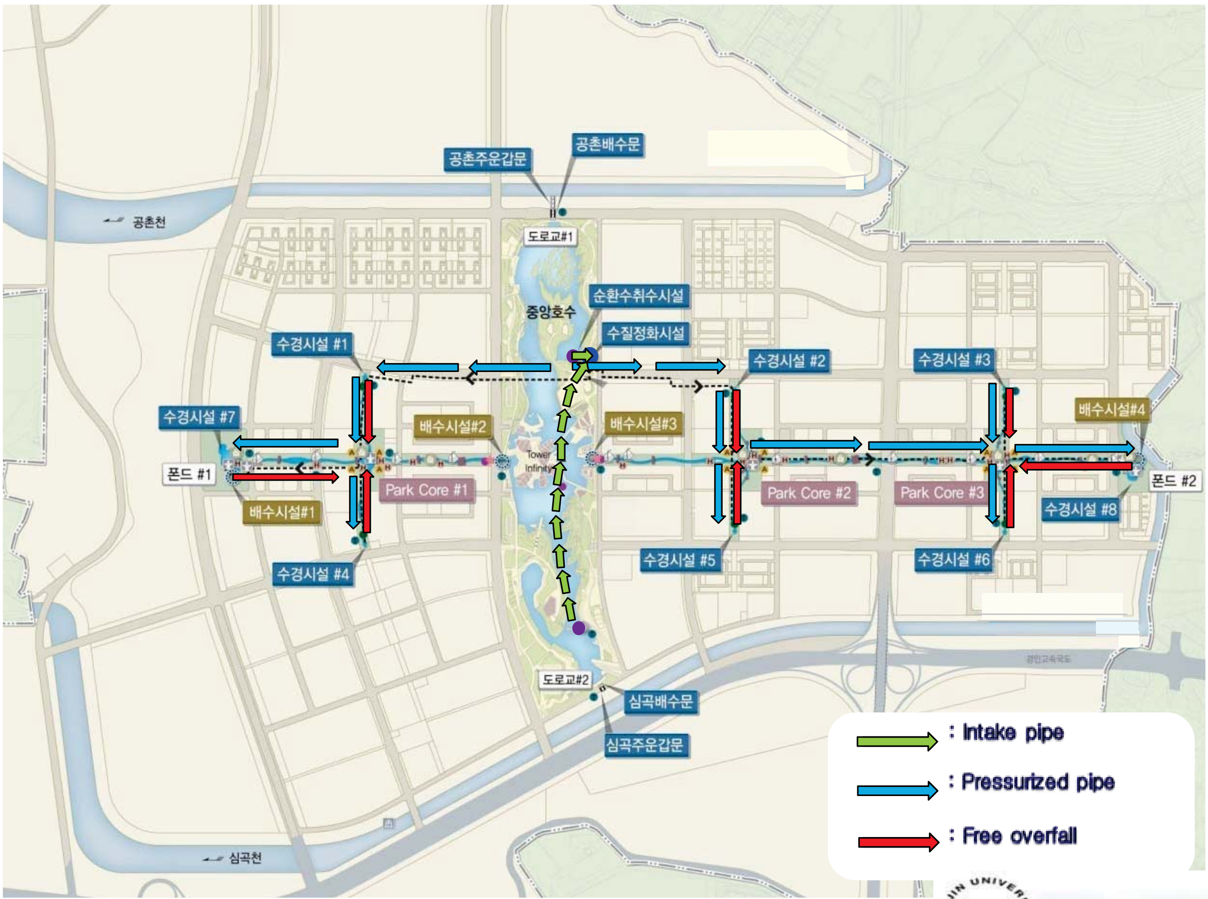
Water Circulation System



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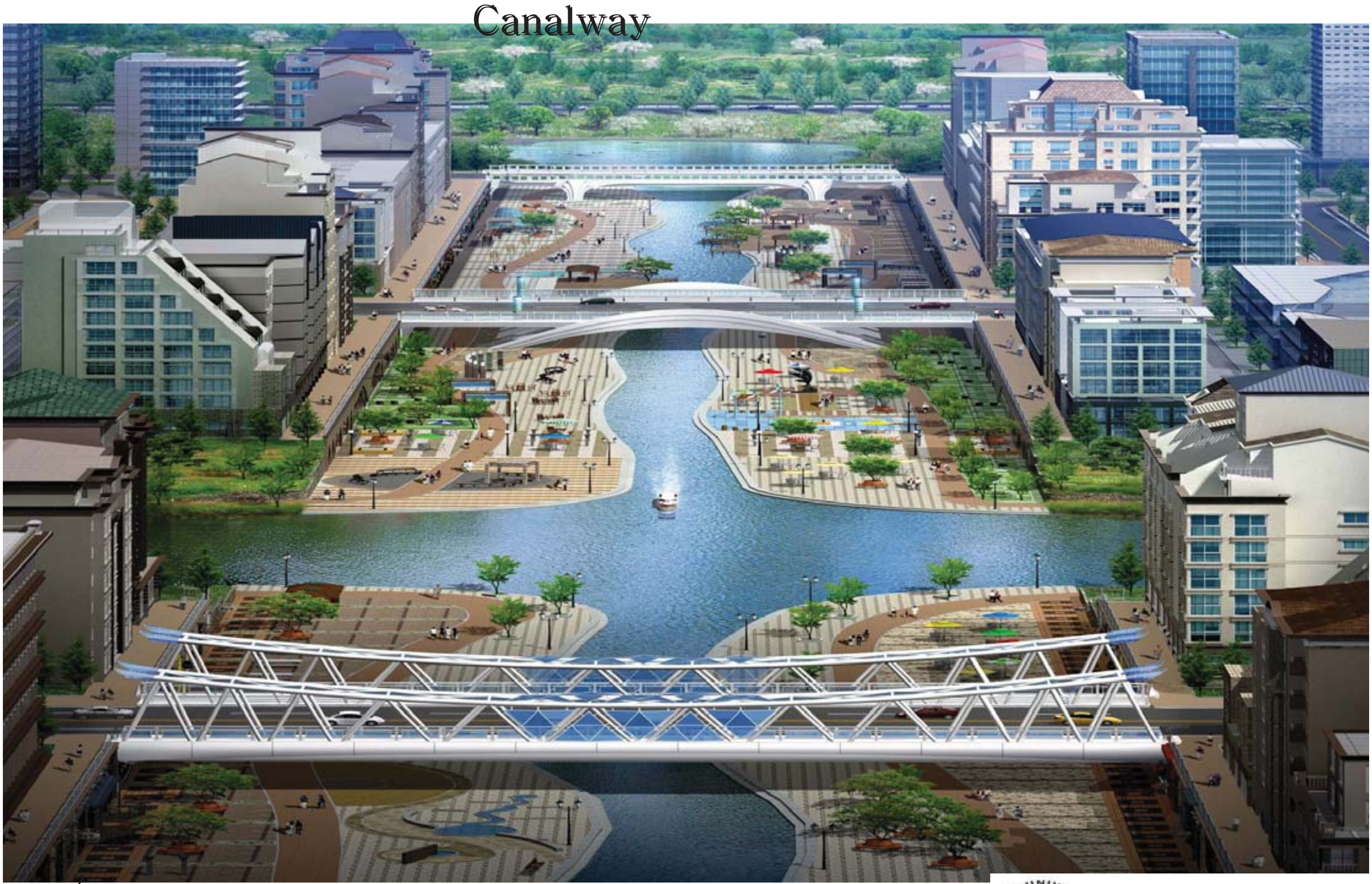
Brief Introduction of Complex

The applied system is that

- Size of central lake is 226,000 sq.m, total volume of water is 370,000 cu.m and 2km length
- Navigation waterways are 5km long.
- the circulation discharge is 16,000 tons per day
- 3,000 tons would be recharged for the loss including evaporation

Bird's Eye View of Canalway



7

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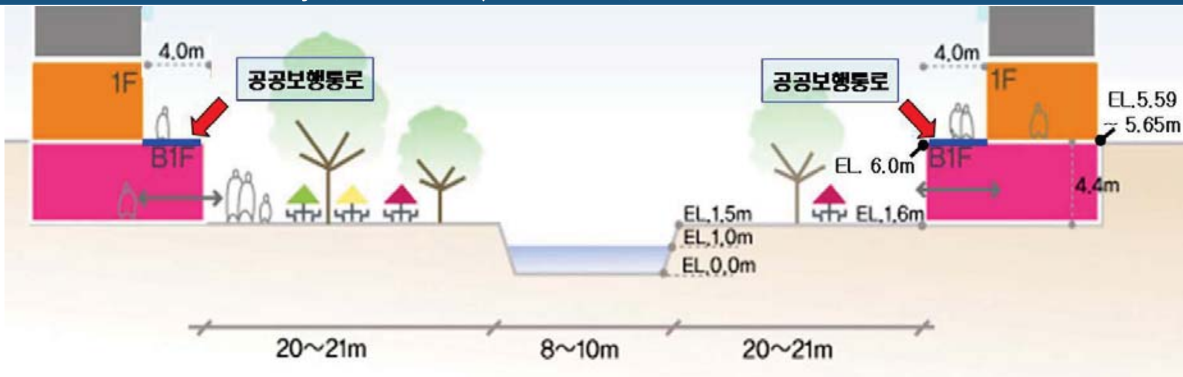
Major Facilities

主要施設物	Canalway	E-W Canal 3.0km(width 9~10m), S-N Canal 1.5km(width 5m)
	Shipping Facilities	12 Docks, 2 Operation Gates, 2 Discharging Gates, 2 Overpass Bridges
	Water Circulation System	Intake/Distribution Pump, Distribution Pipes 5.7km 2 Pond, 유입용수 수경시설
	Water Purification Facilities	Central Lake, Q = 16,100㎥/day
	Eco & Environmental Facilities	Fountain, Self Purification Plants, Water Corridor
附代施設物	Path Bridge	15 in E-W Canal, 6 in S-N Canal
	Improvement of Water Quality	Initial Rainfall Treatment(12), Aeration(20)
	Measurements	Rainfall, Water Stage, Water Qualty, CCTV
	Water Proofing	Bed of Canalway 97,162㎡

8

Cross Section of Lake and Canalway

Canal Way (Water Depth :1.0m)



Central Lake (Water Depth 1.5m)

Hydraulic Simulation

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Numerical Analysis

Flow Analysis in Lake and Canal Way

- Review of Optimal Flow Condition along the Intake Position in Central Lake
- Review of Flow Pattern and Optimal Water Distribution in the Canal Way
- 2-D Hydraulic Simulation Model : RMA-2, RMA-4,
  - ✓ Suggestion of Revised Plan in terms of Detention effect in Lake and Waterway
- 3-D Flow Analysis by FLOW-3D Model
  - ✓ Eddy Viscosity Calibration for Optimal Water Distribution

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Application of Simulation Model

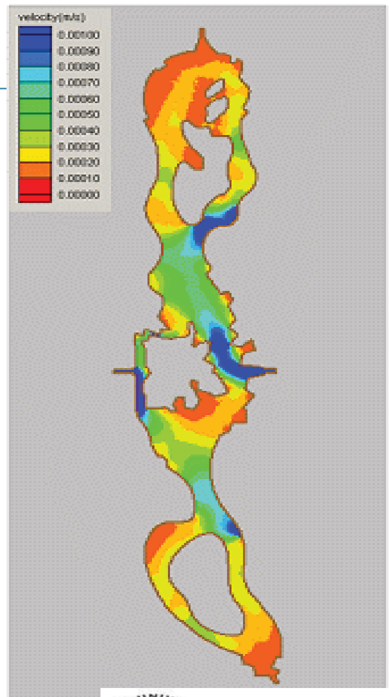
❖ RMA-2 Model

- Developed by Norton, King, Orlob and Brighham Young University
- 2-D FEM Program for Steady and Unsteady Flow
- Governing Equation :

$$\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = 0$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + g\left(\frac{\partial h}{\partial x} + \frac{\partial a_0}{\partial x}\right) + \frac{g\,u}{C^2 h}\sqrt{u^2+v^2} = \frac{\epsilon_{xx}}{\rho}\frac{\partial^2 u}{\partial x^2} + \frac{\epsilon_{xy}}{\rho}\frac{\partial^2 u}{\partial y^2}$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + g\left(\frac{\partial h}{\partial y} + \frac{\partial a_0}{\partial y}\right) + \frac{g\,v}{C^2 h}\sqrt{u^2+v^2} = \frac{\epsilon_{yx}}{\rho}\frac{\partial^2 v}{\partial x^2} + \frac{\epsilon_{yy}}{\rho}\frac{\partial^2 v}{\partial y^2}$$



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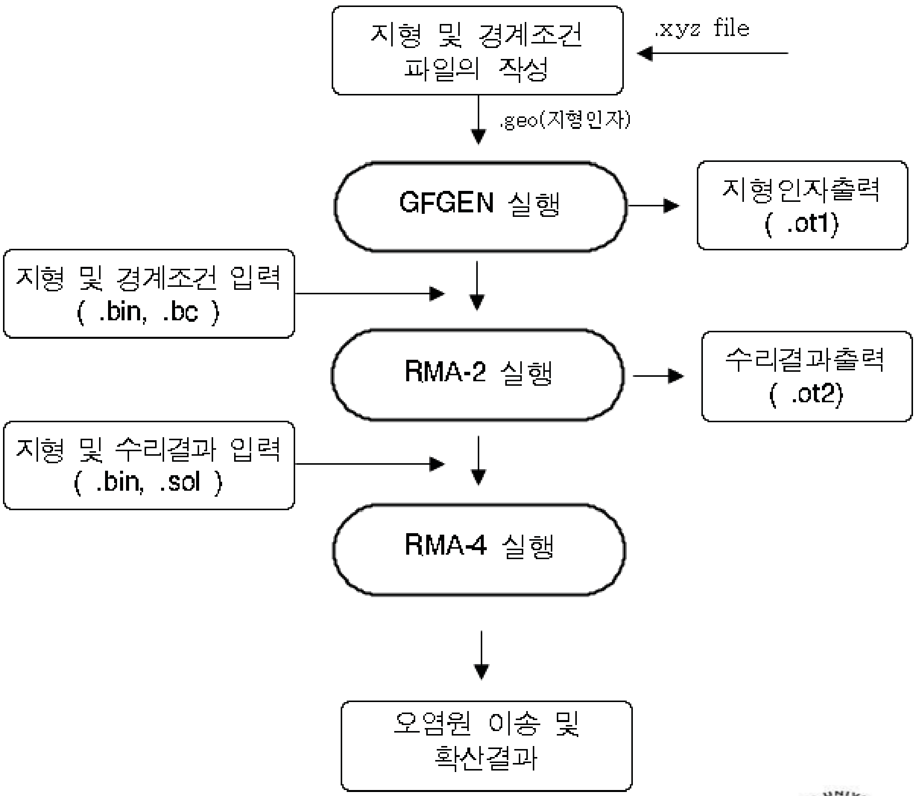
Simulation Flowchart for Flow Pattern and Pollutant Transport and Diffusion in RMA Model



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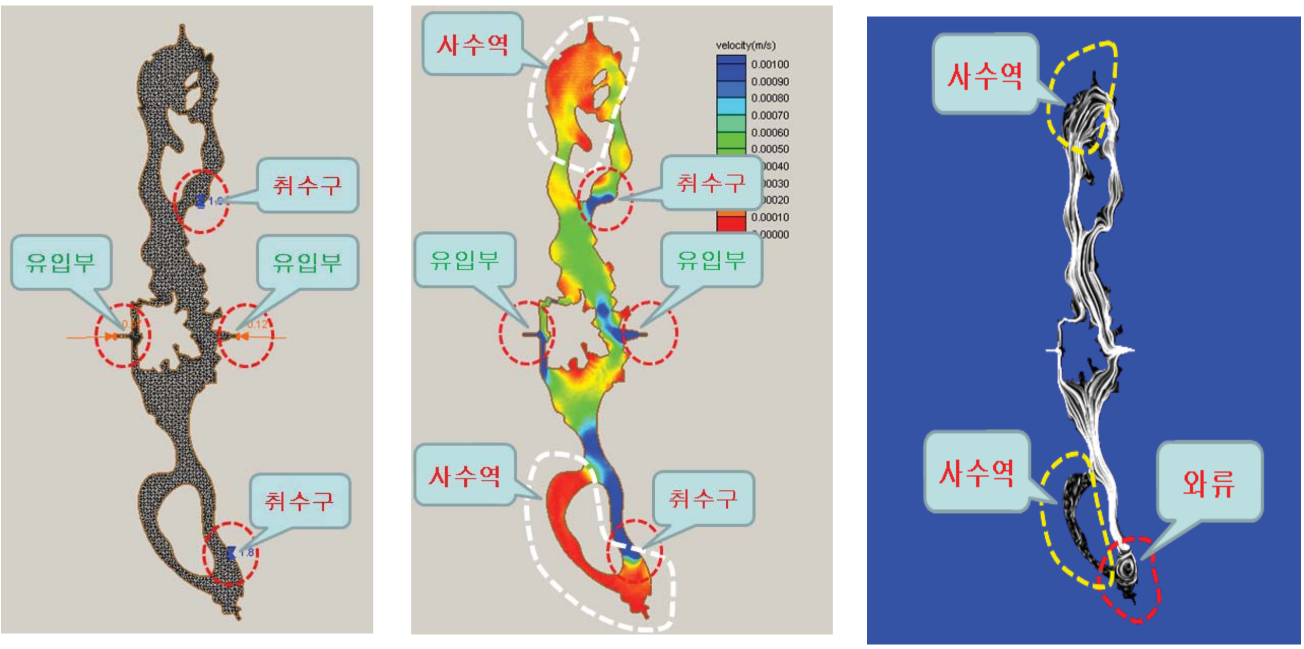
Velocity Distribution and Flow Trace for Original Plan



Discharging directly to near intake facility

☞ Short cut phenomenon and bad mixing circulation

☞ Vortex and dead zone appear in the North and South area

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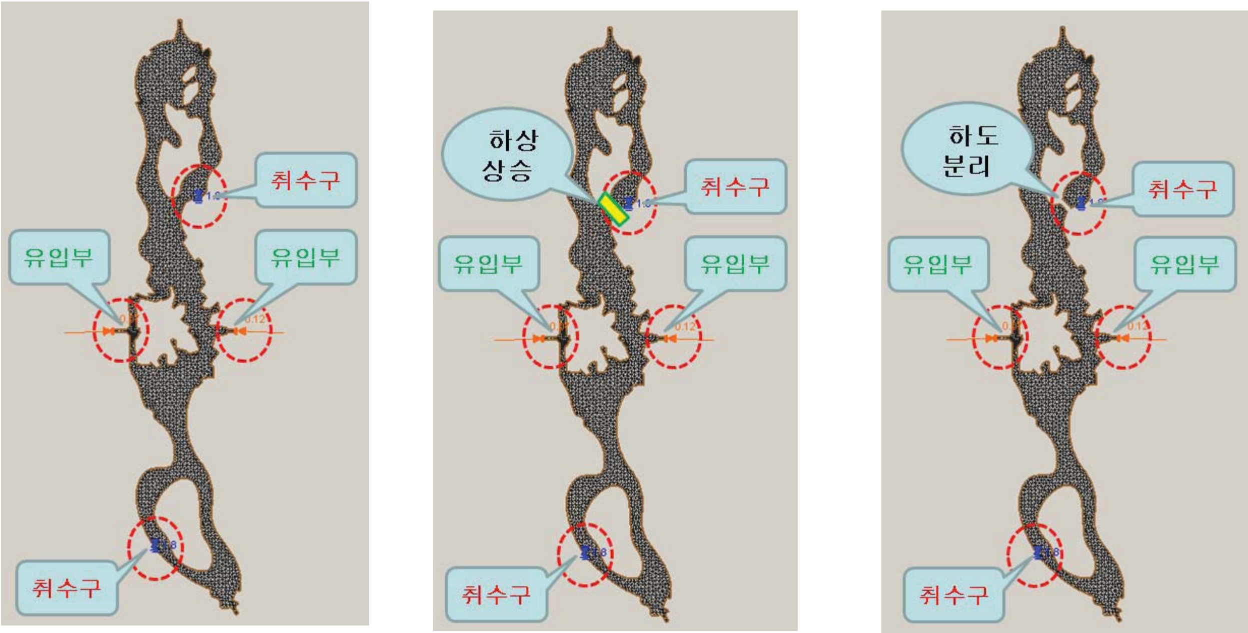
Shape of Alternative 1, 2 and 3 Improving Flow Condition



Alternative 1 : Moving South Intake Point

Alternative 2 : Rising Bed Elevation near North Intake Point

Alternative 3 : Separation near North Intake Point

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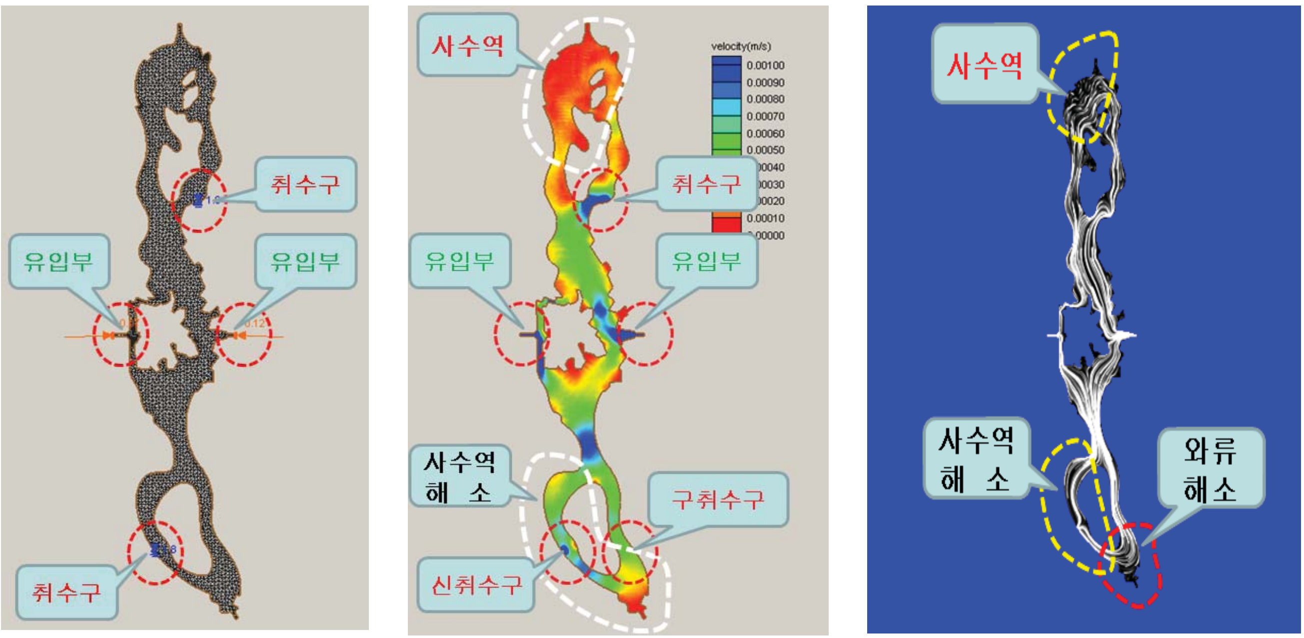
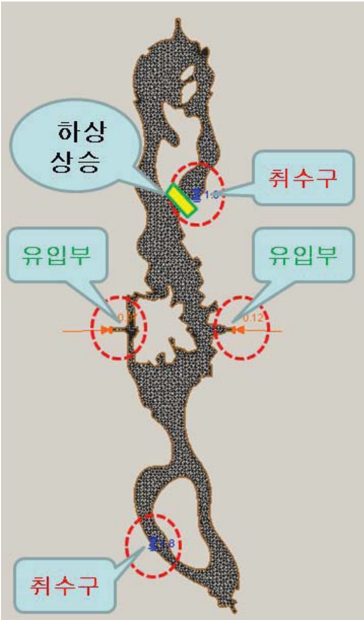
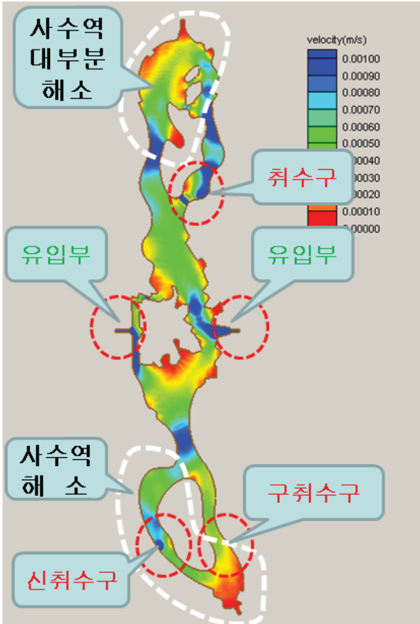
Velocity Distribution and Flow Trace for Alternative 1

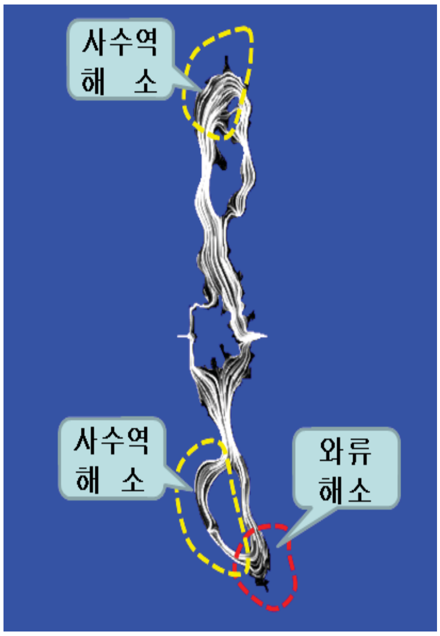


Moving Intake to the South ☞ Improving Vortex and Mixing Condition in South → But Not in North

Velocity Distribution and Flow Trace for Alternative 2







Rising the Bed Elevation near the North Intake Structure

☞ Improving Vortex and Mixing Condition in the North

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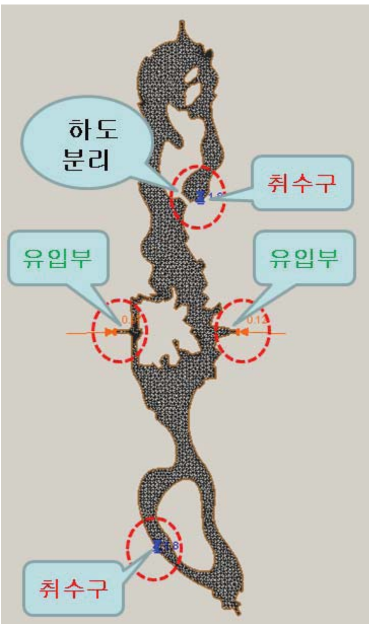
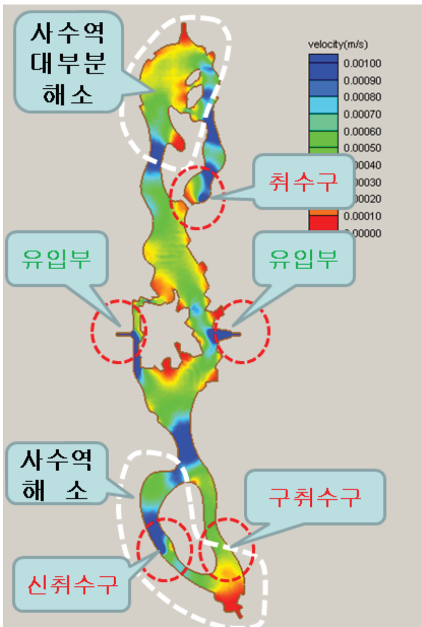
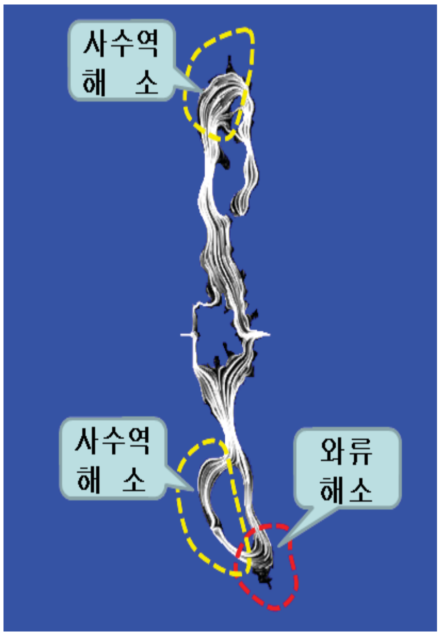
Velocity Distribution and Flow Trace for Alternative 3



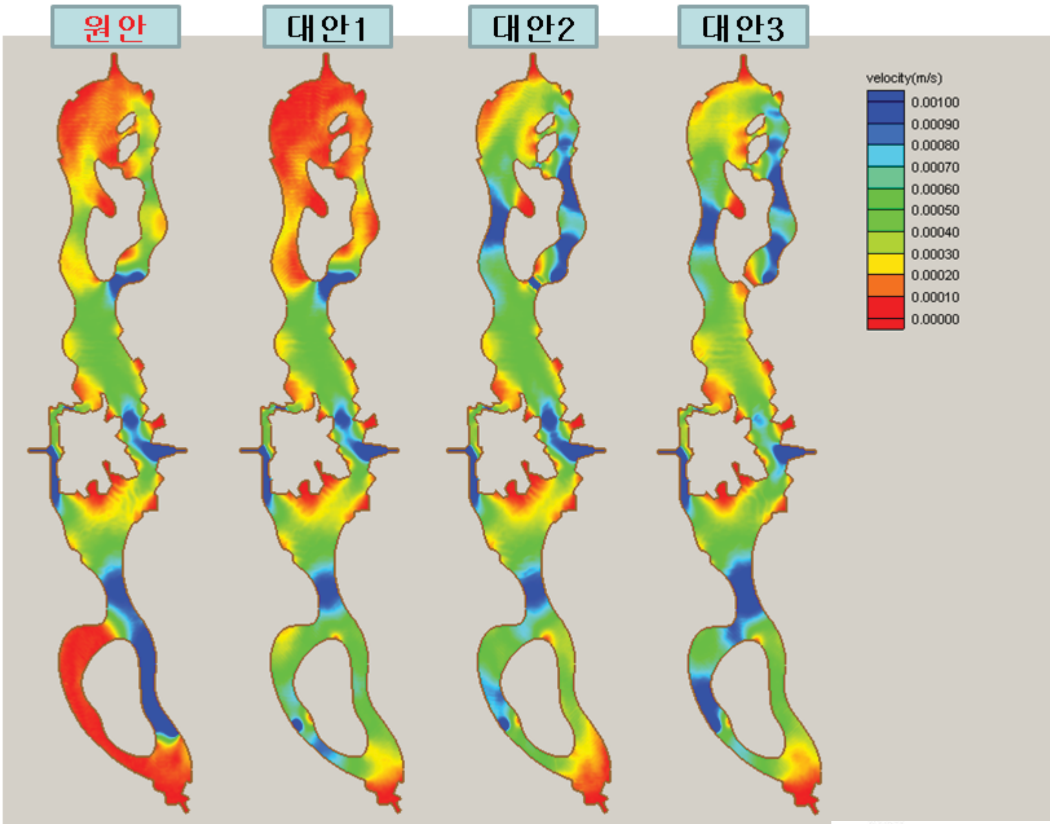




Separation of the Bed near the North Intake Structure

☞ Improving Vortex and Mixing Condition in the North

Velocity Comparison of Original Plan and Alternatives



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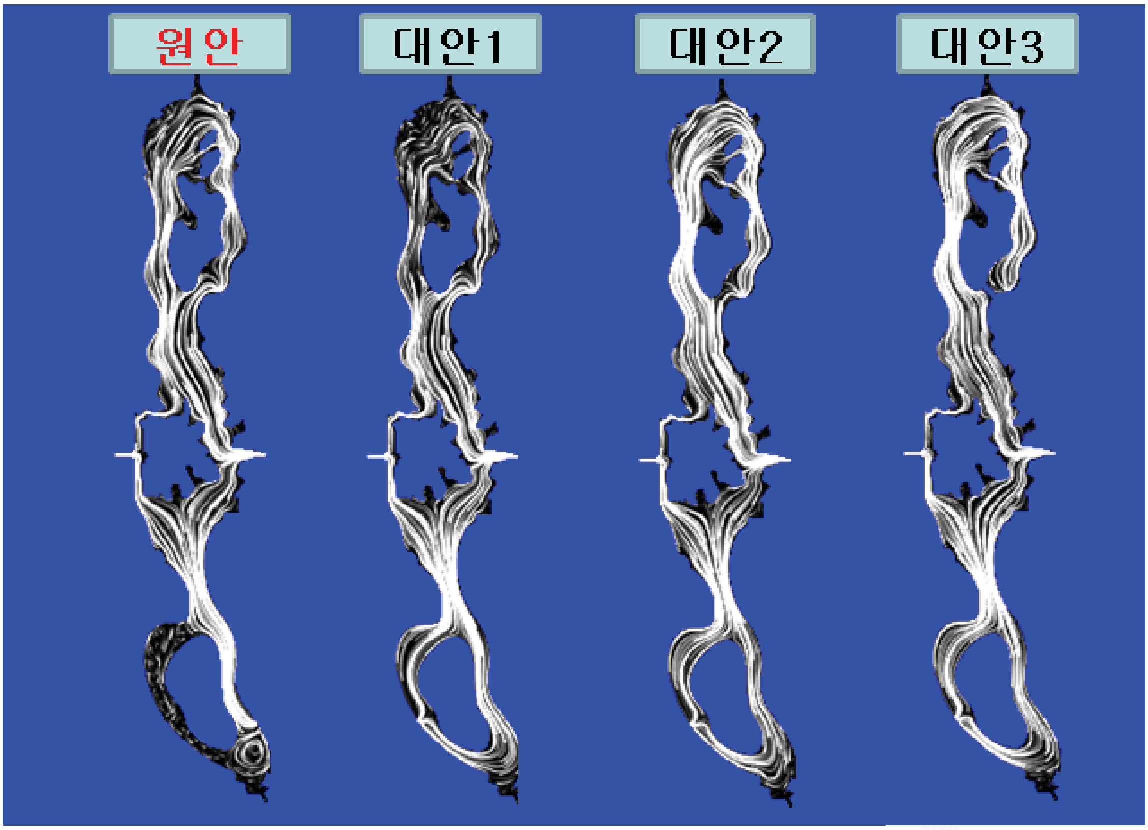
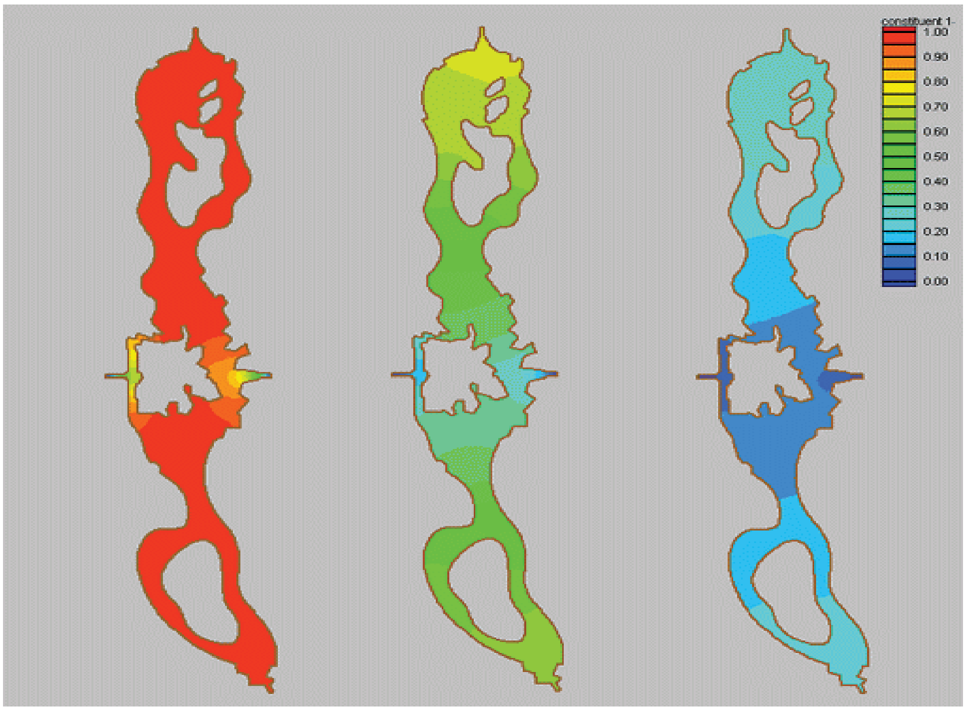
Flow Trace Comparison of Original Plan and Alternatives



Dilution Rate for the Original Plan of Lake(25 days)



10- hour 10-days 25-days

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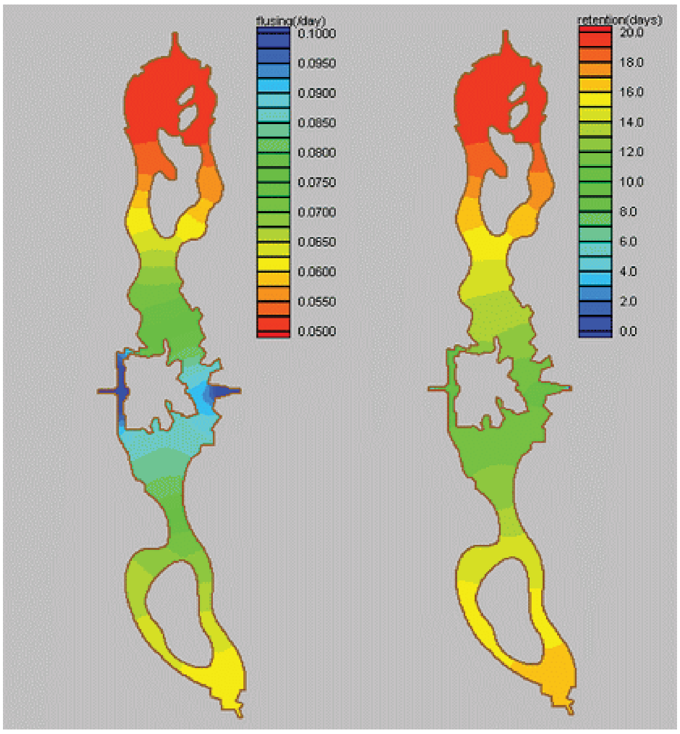
Pollutant Dilution Simulation Result for the Original Plan(25 days)



☞ Shows Detention more than 20-days in the North Area

(a) Diiution Rate (b) Detention Time

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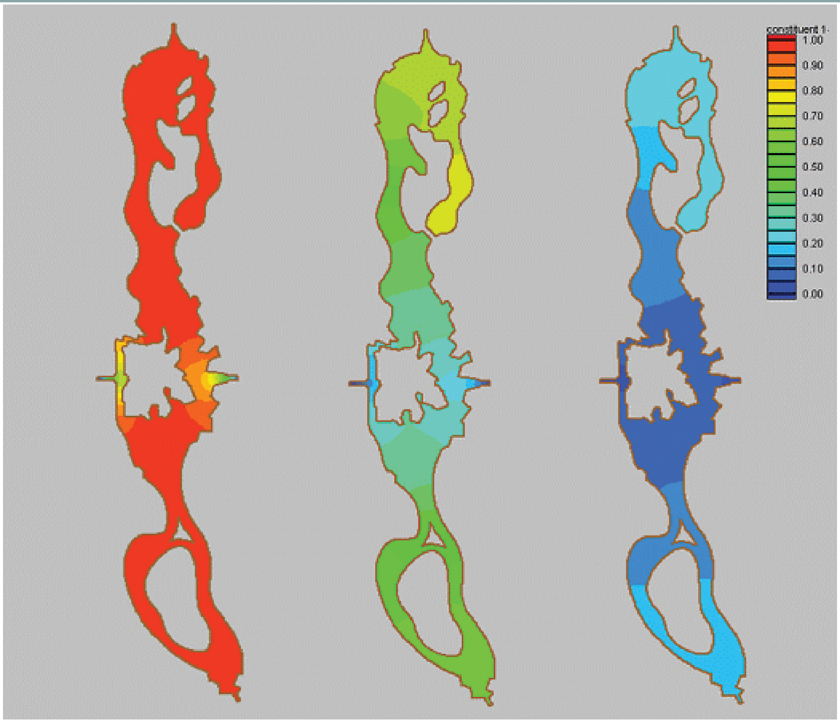
Pollutant Dilution Simulation Result for the Alternative 3 (25 days)



10 hr 10 days 25 days

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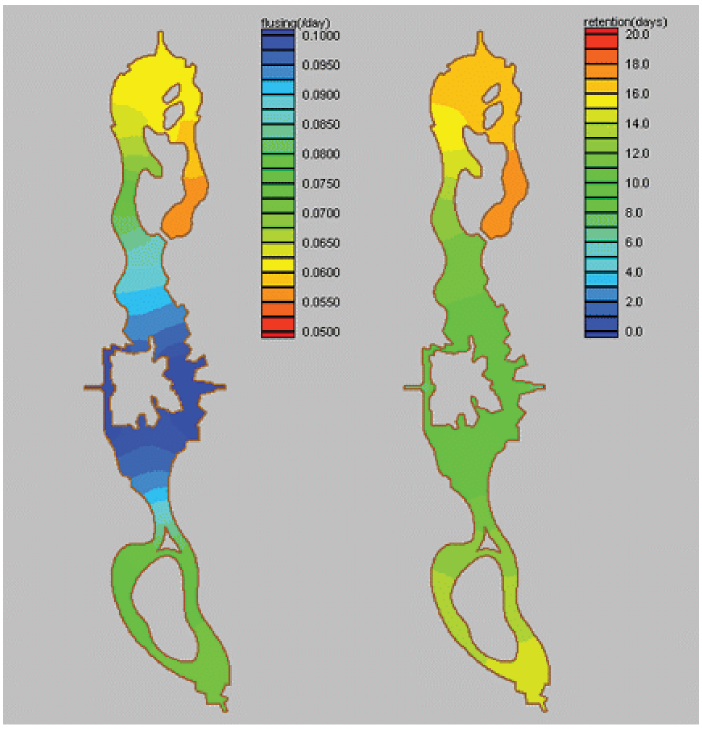
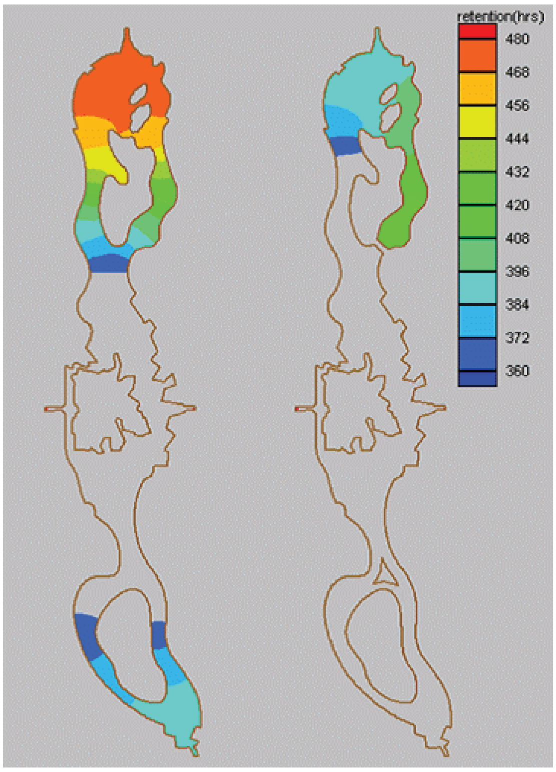
Pollutant Dilution Simulation Result for the Alternative 3(25 days)



(a) Dilution Rate (b) Detention Time

☞ Reduced Detention Time within18 days

Detention Comparison between Original and Alternative 3 for 360 hr (15 days)



(a) Original Plan (b) Alt. 3

☞ For the Original Plan, More than 480 hrs Detention Time (20 days) appears in the South and North area.

For the Alternative 3, Retention did not appear at all after 430 hrs(18 days)

※Algae can possibly appears in Case of Original Plan

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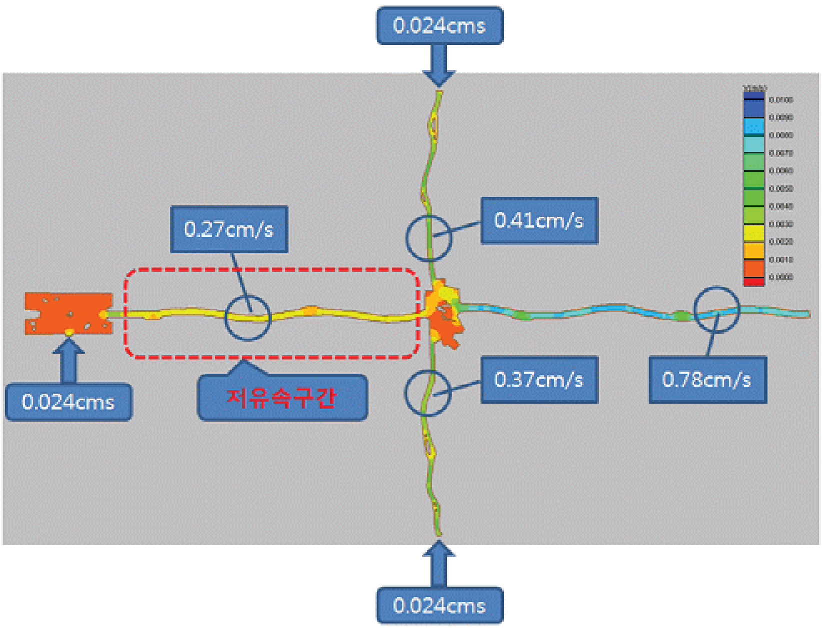
Canal Way Flow Pattern Analysis

Velocity Distribution for Left Side Canal Way in Case of Uniform Water Supply

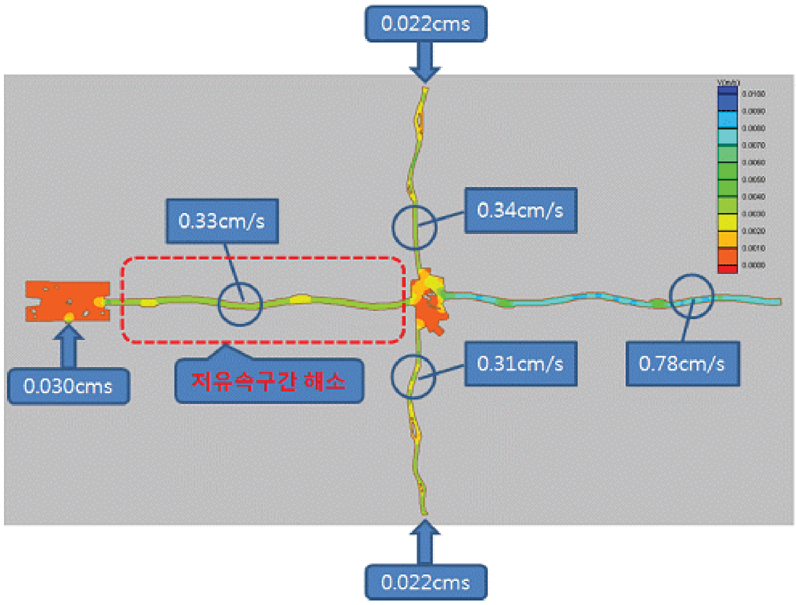


☞ For the original Plan when water Supplies Uniformly,

the Velocity of E-W water way shows 30% lower than That of N-S Waterway

Canal Way Flow Pattern Analysis

Velocity Distribution for Left Side Canal Way in Case of non-Equal Water Supply

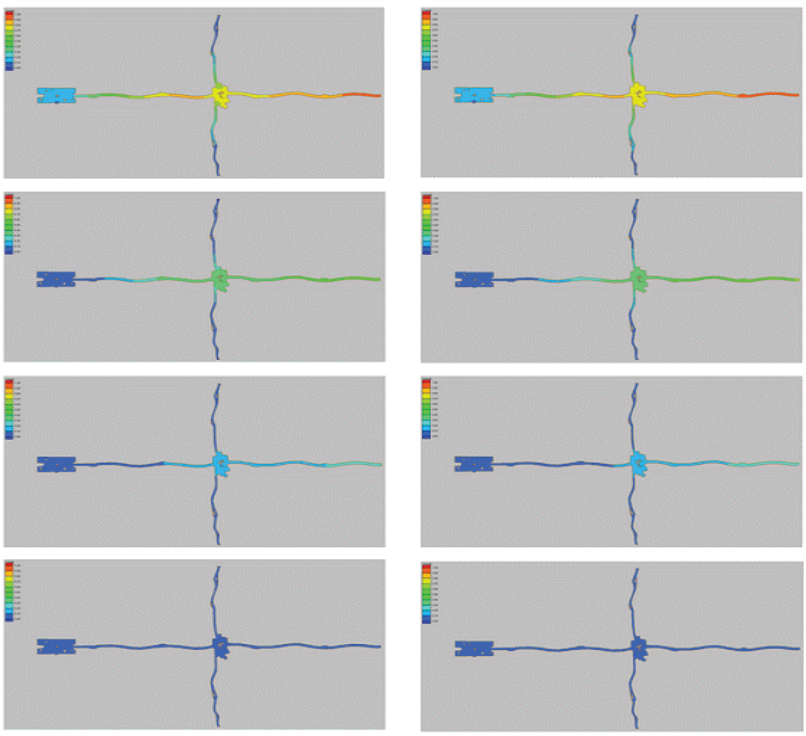


☞ For the Revised Distribution Plan when water Supplies unequally,

the Velocity of E-W water way shows 50% lower than That of N-S Waterway

☞ **Improvement of Velocity Distribution**

Dilution Rate Comparison between Original Plan and Revised Plan



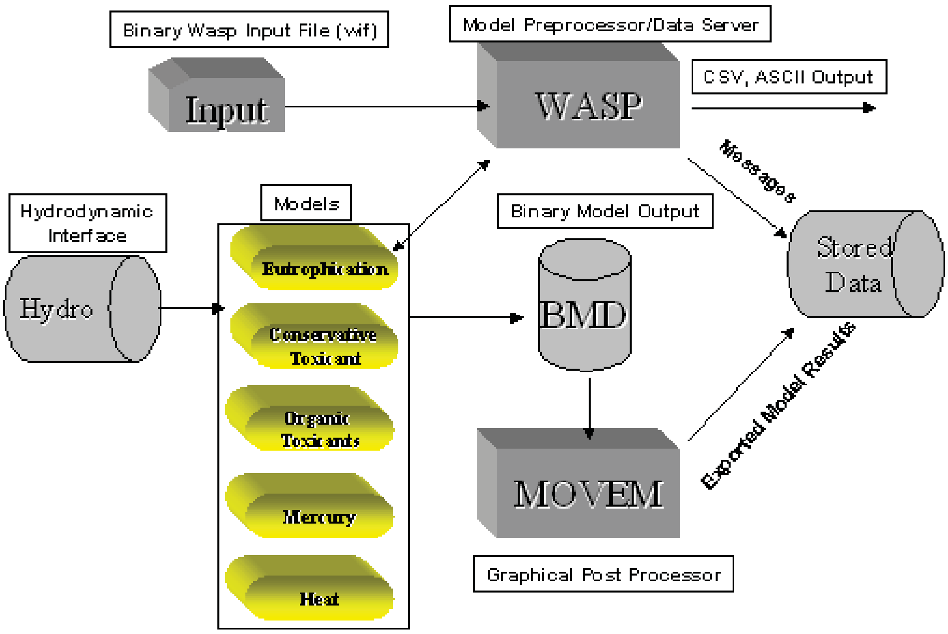
☞ For the Revised Plan,

It shows Dilution Rate Improved

O.P.(Left) and R.P.(Right) (30hr, 60hr, 90hr, 120hr)

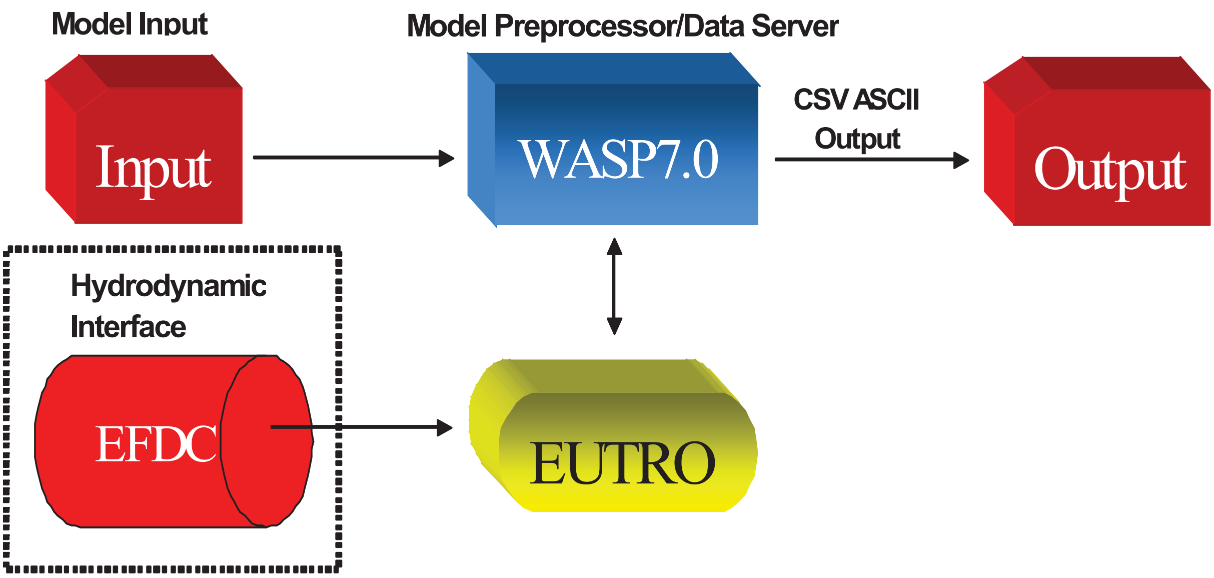
Water Quality Simulation by WASP 7 Model

Schematic of WASP Model

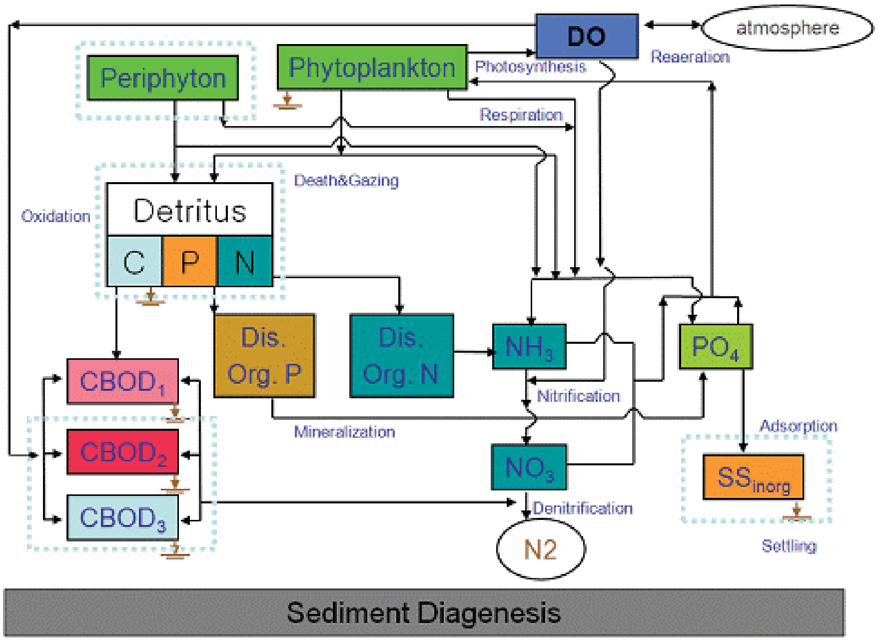


Schematic of WASP

WASP Modeling Framework



WASP 모델의 개요

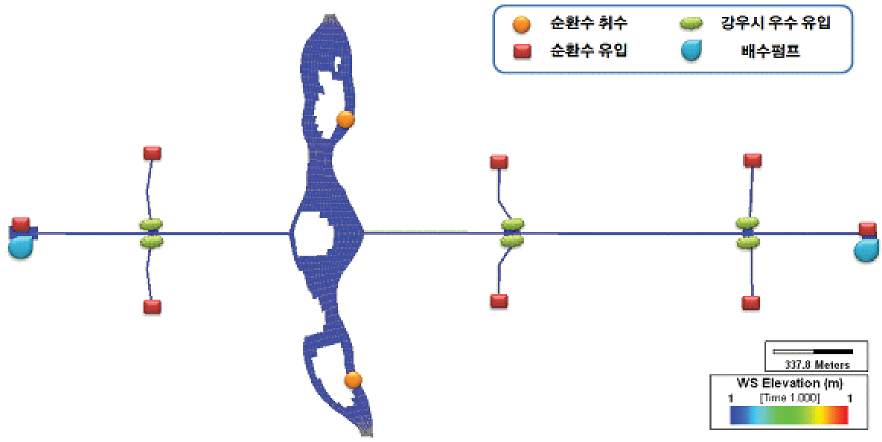


- **In the EUTRO module of WASP Model, 8 water quality item(NH3-N, NO3-N, PO4-P, DO, CBOD, Chl-a, Org-N, Org-P) can be simulated**

Application of EFDC Hydrodynamic

Input Data

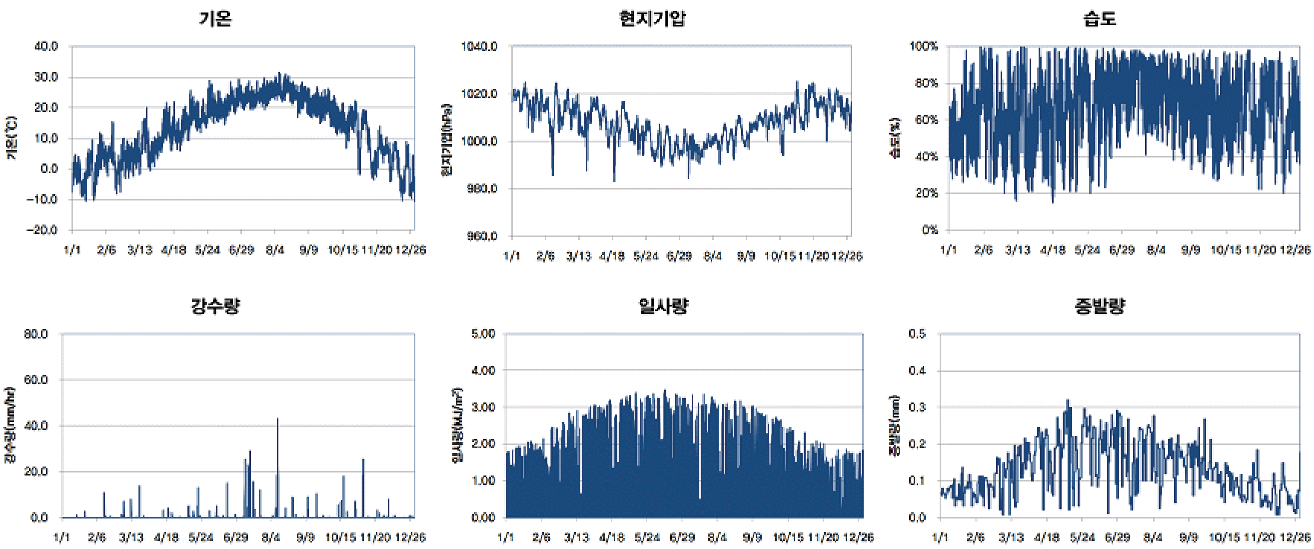
- 274 Grid cells were structured for Central Lake and Waterway
- Precipitation, Circulation Inflow and Intake were considered



Application of EFDC Hydrodynamic

Input data – Meteorological data

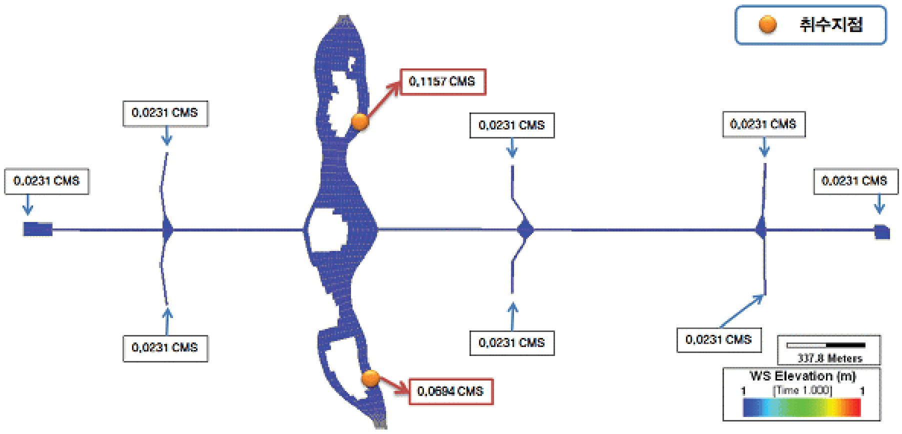
- Hourly rainfall observation data of 2010 were adopted as well as
- Temperature, air pressure, humidity, evaporation



Application of EFDC Hydrodynamic

Input data condition – Inflow and Intake outflow

- Circulation and Intake quantity16,000㎥/day) should be considered



The 9th International Forum on Waterfront and Watershed Restoration(2012/11/24)

Application of WASP Model

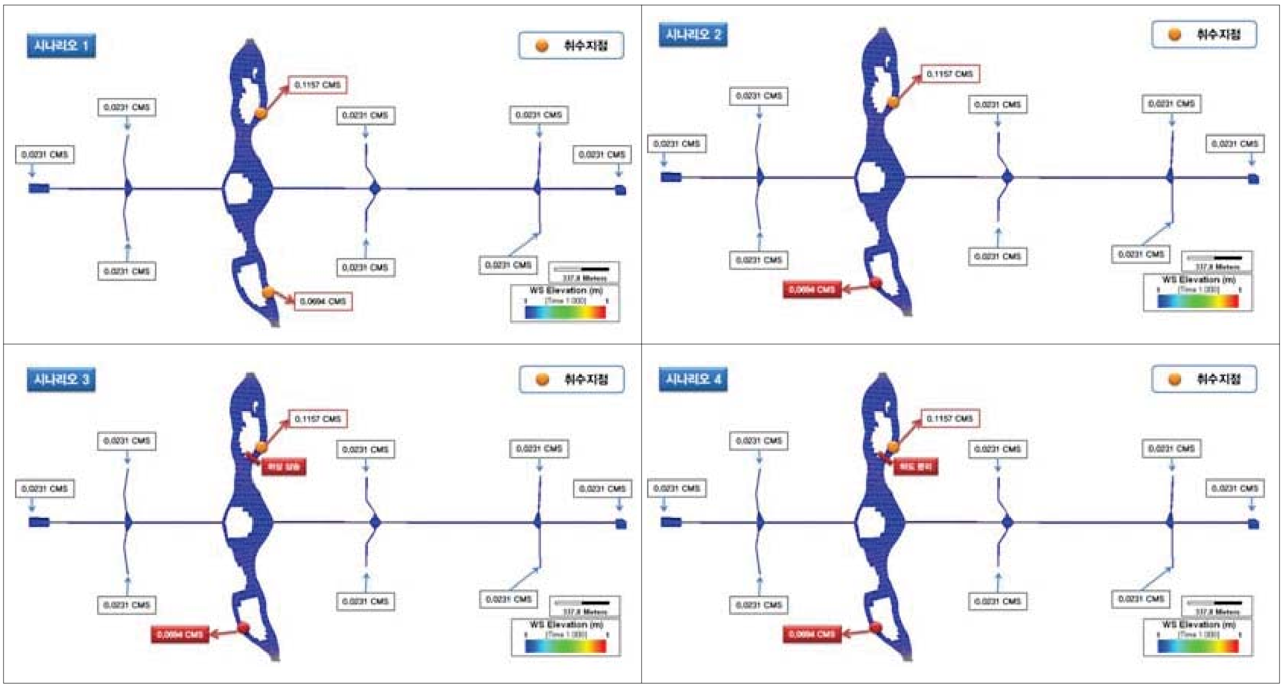
Initial Condition of Water Quality

- Water Quality of Circulation Inflow adopted Target quality
- Inflow water quality of rainfall adopted water quality concentration of road runoff

Item	BOD (mg/L)	COD (mg/L)	SS (mg/L)	T-P (mg/L)
Circulation W.Q.C	2.0	3.0	3.0	0.025
Rainfall Inflow W.Q.	24	103	141	0.430

Application of WASP Model

Scenarios of Original Plan and Alternative 1, 2, and 3



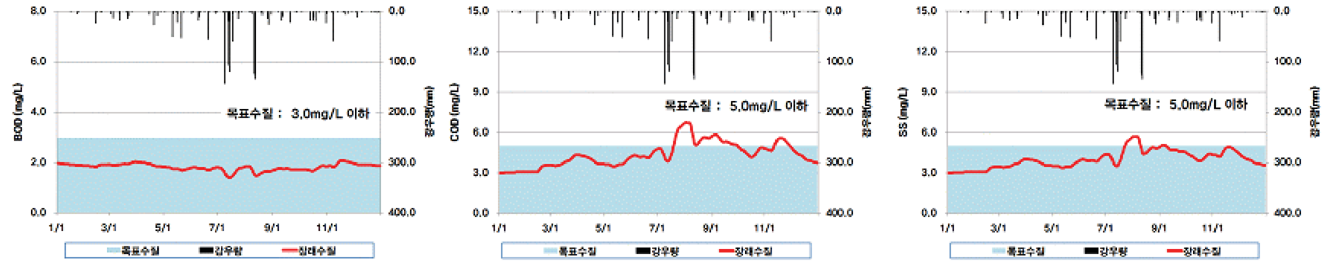
Application of WASP Model

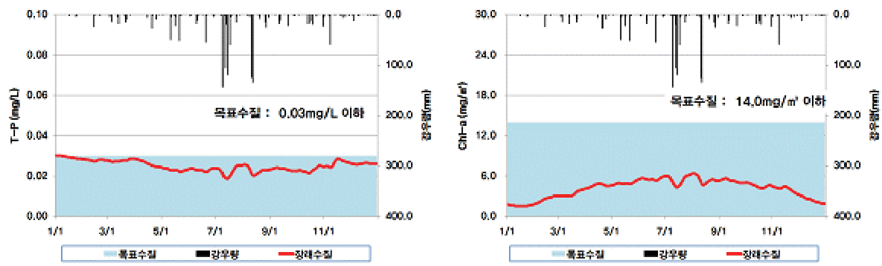
Results of Water Quality Simulation by WASP

- Compared Water Quality differences at 4 points in the Lake in terms of each scenario
- Point 2 and 3 show a little higher than point 1 and 4 because nonpoint pollutant transported from the waterways in the rainy season.
- Annual Average water quality satisfies target water quality except rainy season

Results of Simulation by WASP Model

Sample Results of Original Plan – Point 1





구 분	BOD	COD	SS	T-P	Chl-a
Average	1.83	4.37	4.0	0.025	4.2
Worst	2.09	6.74	5.7	0.030	6.4
Days satisfied target W.Q	365	274	339	357	365

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Results of Simulation by WASP Model

Comparison of BOD in terms of each scenario

구 분		Original Plan	Alternative 1	Alternative 2	Alternative 3
Point #1	Annual Average	1.83	1.83	1.83	1.93
	Worst Case	2.09	2.09	2.15	2.36
	Days satisfied with target W.Q.	365	365	365	365
Point #2	Annual Average	2.03	2.03	2.04	2.09
	Worst Case	2.66	2.66	2.77	3.01
	Days satisfied with target W.Q.	365	365	365	364
Point #3	Annual Average	2.03	2.03	2.03	2.05
	Worst Case	2.88	2.89	2.90	2.94
	Days satisfied with target W.Q.	365	365	365	365
Point #4	Annual Average	1.92	1.91	1.91	1.93
	Worst Case	2.29	2.26	2.27	2.30
	Days satisfied with target W.Q.	365	365	365	365

Results of Simulation by WASP Model

Comparison of COD in terms of each scenario

구 분		Original Plan	Alternative 1	Alternative 2	Alternative 3
Point #1	Annual Average	4.37	4.37	4.35	4.40
	Worst case	6.74	6.74	6.86	8.74
	Day satisfied with target WQ	274	274	283	283
Point #2	Annual Average	4.41	4.41	4.44	4.43
	Worst case	9.22	9.23	9.71	10.65
	Day satisfied with target WQ	285	283	282	286
Point #3	Annual Average	4.46	4.46	4.47	4.47
	Worst Case	10.31	10.34	10.38	10.50
	Day satisfied with target WQ	276	274	273	273
Point #4	Annual Average	4.46	4.48	4.48	4.49
	Worst Case	8.50	8.54	8.55	8.66
	Day satisfied with target WQ	284	282	282	281

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Results of Simulation by WASP Model

Comparison of T-P in terms of each scenario

구 분		Original Plan	Alternative 1	Alternative 2	Alternative 3
Point #1	Annual Average	0.025	0.025	0.025	0.027
	Worst case	0.030	0.030	0.030	0.034
	Days satisfied with target W.Q	357	357	358	334
Point #2	Annual Average	0.029	0.029	0.029	0.030
	Worst case	0.040	0.040	0.042	0.046
	Days satisfied with target W.Q	292	293	281	239
Point #3	Annual Average	0.029	0.029	0.029	0.029
	Worst case	0.044	0.044	0.044	0.045
	Days satisfied with target W.Q	283	285	286	273
Point #4	Annual Average	0.027	0.027	0.026	0.027
	Worst case	0.032	0.032	0.032	0.033
	Days satisfied with target W.Q	344	346	346	339

Results of Simulation by WASP Model

Comparison of Chl-a in terms of each scenario

구 분		Original Plan	Alternative 1	Alternative 2	Alternative 3
지점 #1	Annual Average	4.2	4.2	4.2	4.5
	Worst case	6.4	6.4	6.3	8.6
	Days satisfied with target W.Q	365	365	365	365
지점 #2	Annual Average	4.5	4.5	4.6	4.6
	Worst case	9.7	9.7	10.1	11.1
	Days satisfied with target W.Q	365	365	365	365
지점 #3	Annual Average	4.8	4.8	4.8	4.8
	Worst case	10.7	10.8	10.8	11.0
	Days satisfied with target W.Q	365	365	365	365
지점 #4	Annual Average	4.9	4.9	4.9	4.9
	Worst case	9.0	8.9	8.9	9.0
	Days satisfied with target W.Q	365	365	365	365

Summary of Flow Analysis and Water Quality for Water Circulation System

Flow Analysis

1. **For the original plan, the circulation water discharges directly to near intake facility**

   ☞ **Short cut phenomenon and bad mixing circulation**

   ☞ **Vortex and dead zone appear in the North and South area**

2. **Among alternatives, the 3rd one , Separation of the Bed near the North Intake Structure , Improved Vortex and Mixing Condition in the lake circulation**

3. **In the review of dilution rate and detention time, the alternative 3 is superior to original plan.**

Summary of Flow Analysis and Water Quality for Water Circulation System

Water Quality Analysis

1. For water quality control in terms of BOD, COD, SS, T-P, T-N and Chl-a, WASP7 model is used for the 2-D simulation

2. Point 2 and 3 show a little higher than point 1 and 4 because nonpoint pollutant transported from the waterways in the rainy season.

3. Annual Average water quality satisfies target water quality except rainy season in each plan

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We are still Concerning ;

1. **Water Quality Control**
2. **Water Quantity Control**
3. **Canal Operation Rules**

Due to Rare References


Thank You