APPLICATION OF AUTOMATIC STORMWATER MONITORING SYSTEMS FOR INTEGRATED MANAGEMENT OF URBAN STREAMS

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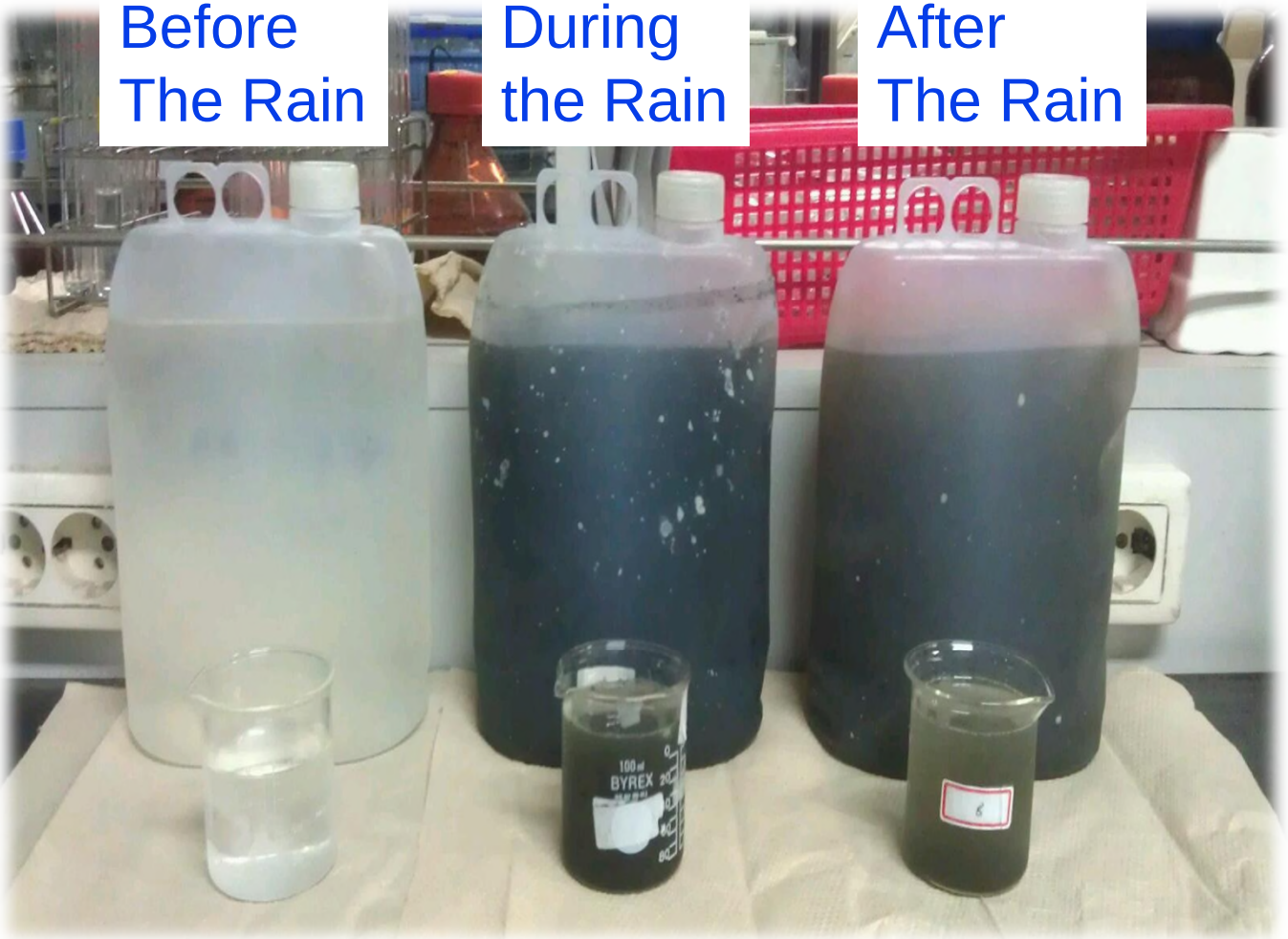
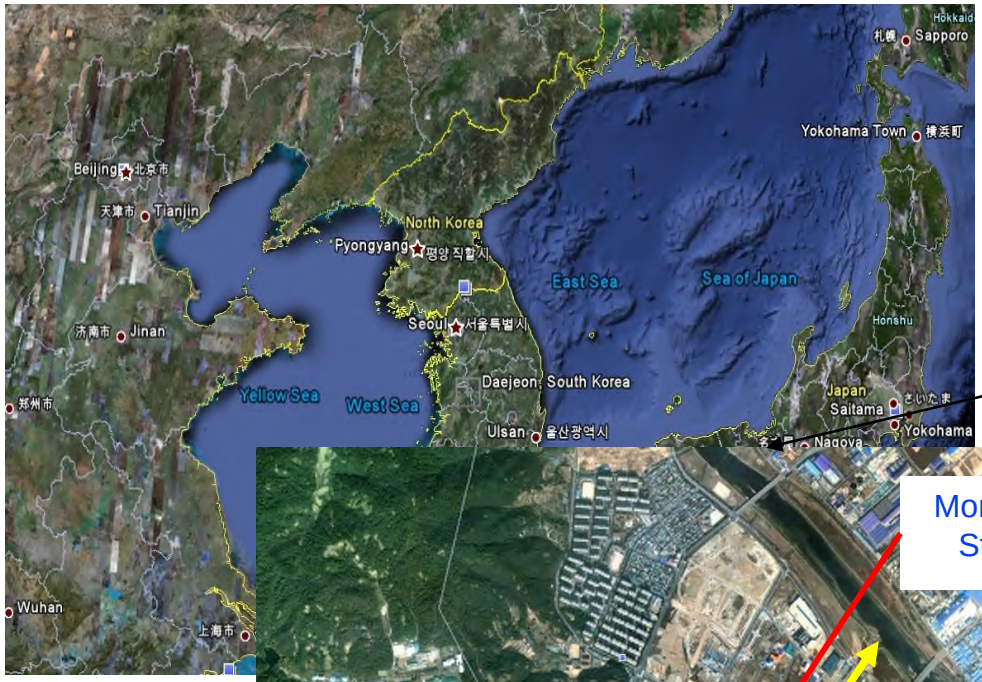
Stormwater Pollution

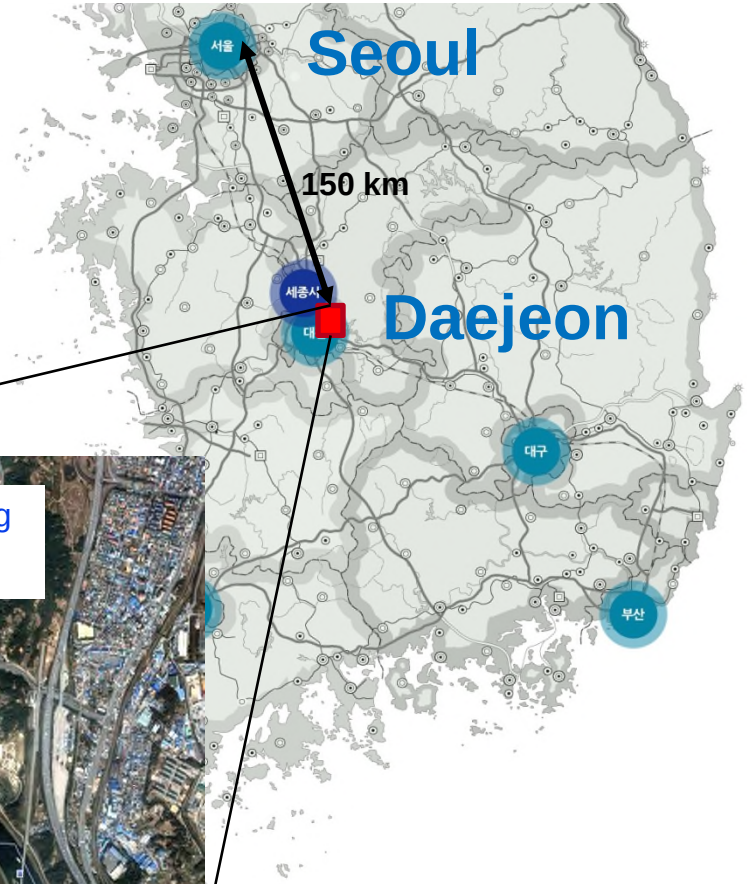


Backgrounds

- Urban Stream Management Requires
  - Management of Basin Water Resources
- Basin Water Resources Information Requires
  - Urban Hydrological Model
- Urban Hydrological Model Requires
  - Stormwater Related Information
  - Runoff and Pollutant Washoff
- Stormwater Information
  - ?

The Study Site:
DTV (Deaduk Tech Valley), Daejeon, Korea





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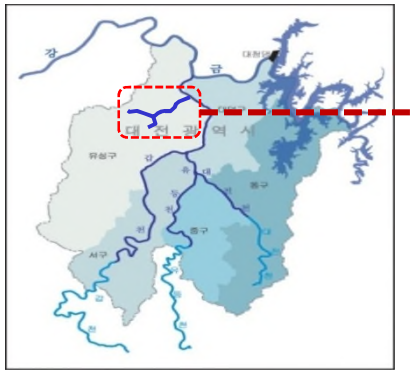
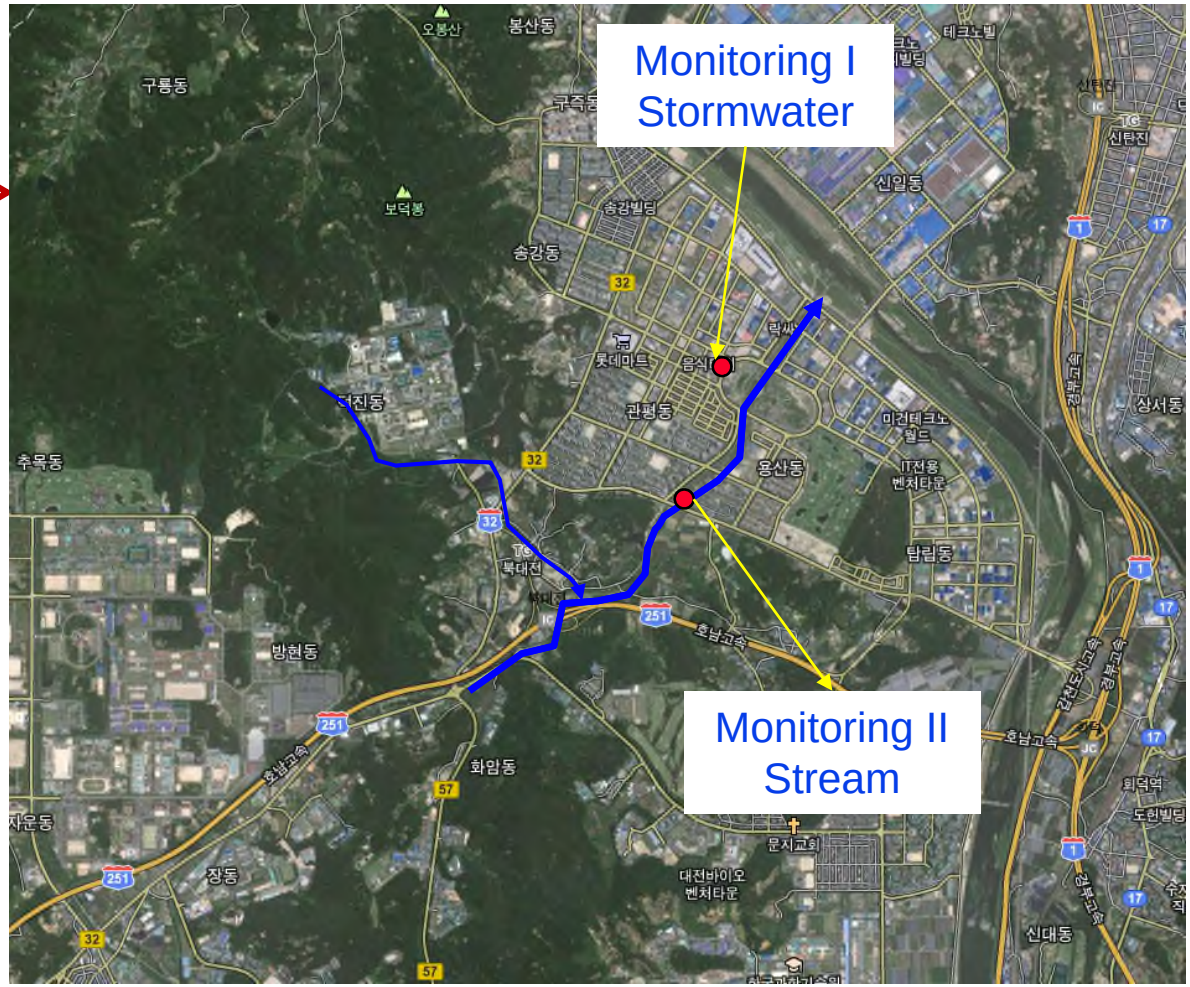
Two Monitoring Sites: Gwanpyung-Cheon, Daejeon, Korea





- Basin Area: 10.85km^2
- Stream Length : 5.45km
- Upper Stream Area
  - Non urban area
- Down Stream Area
  - Urban
  - industrial

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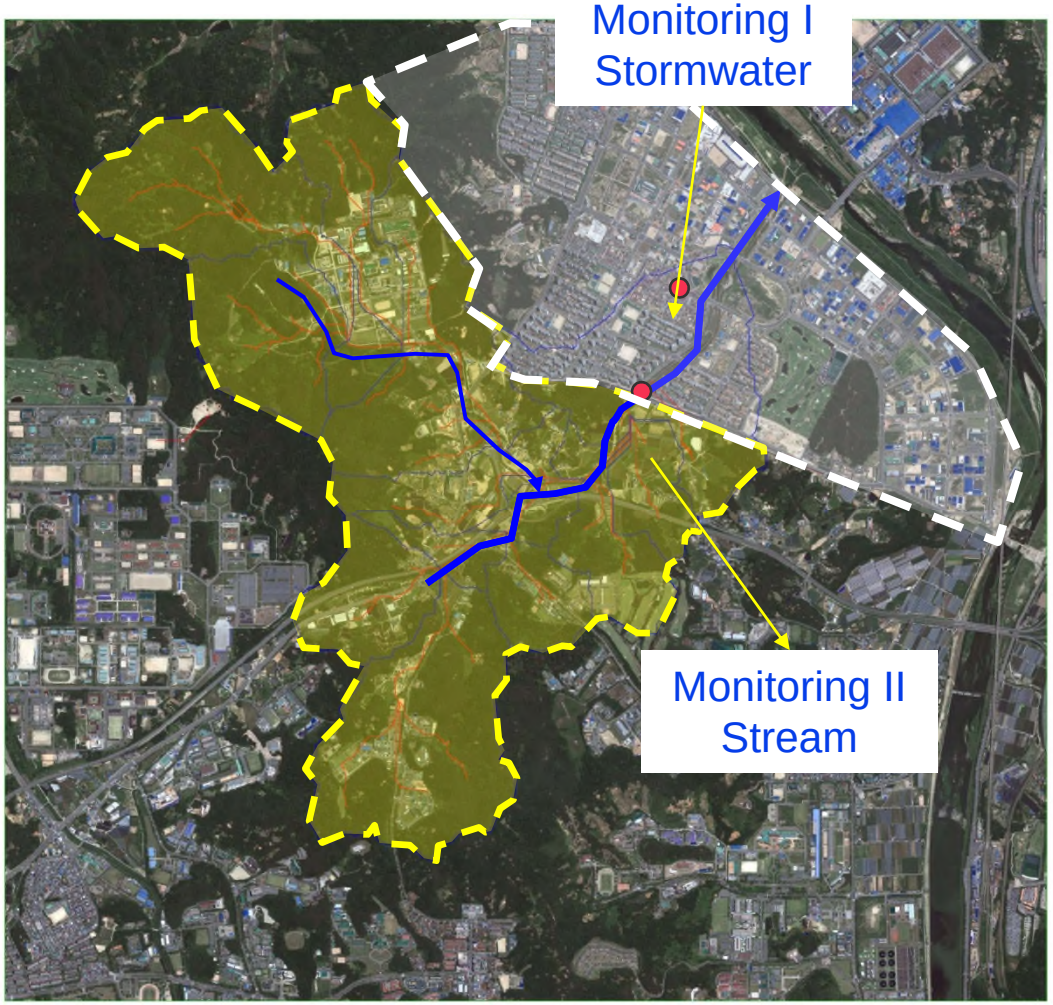
Upper and Down Stream Areas of the Study Site



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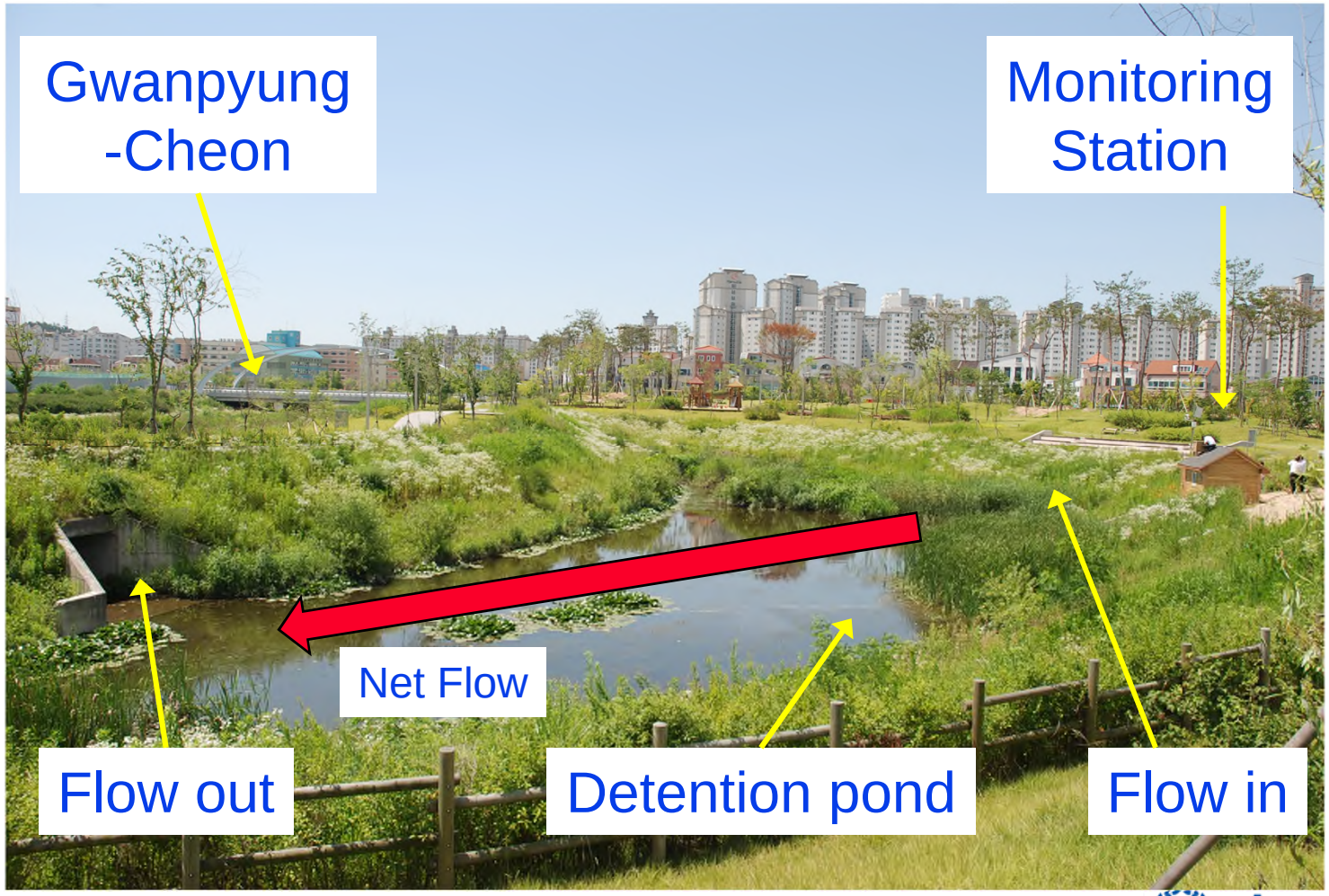
Monitoring I
At a Detention Pond and its Basin Area

Monitoring Site 1
The Entrance of Detention Pond



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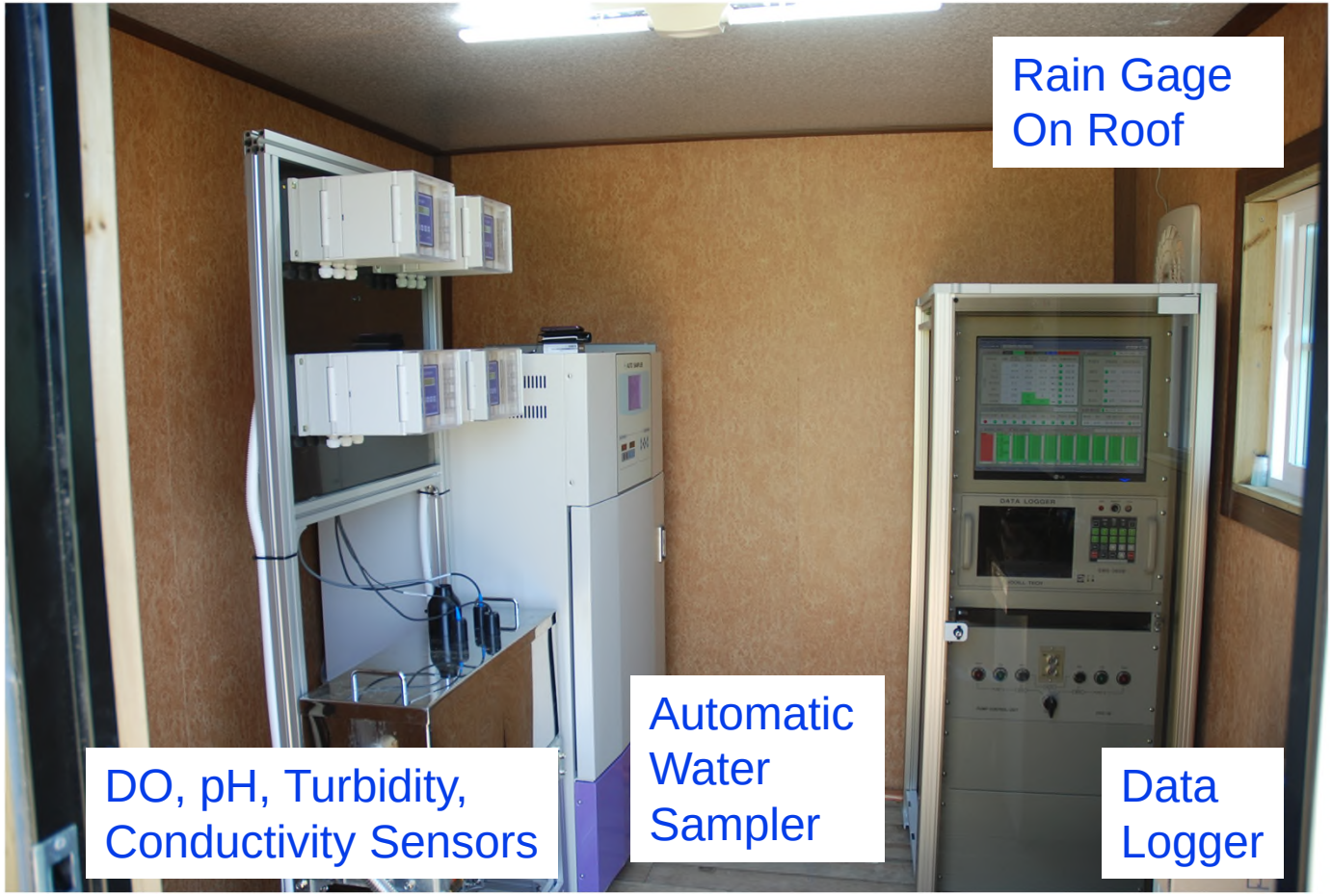
Before and After the Monitoring System Installation at the Study Site

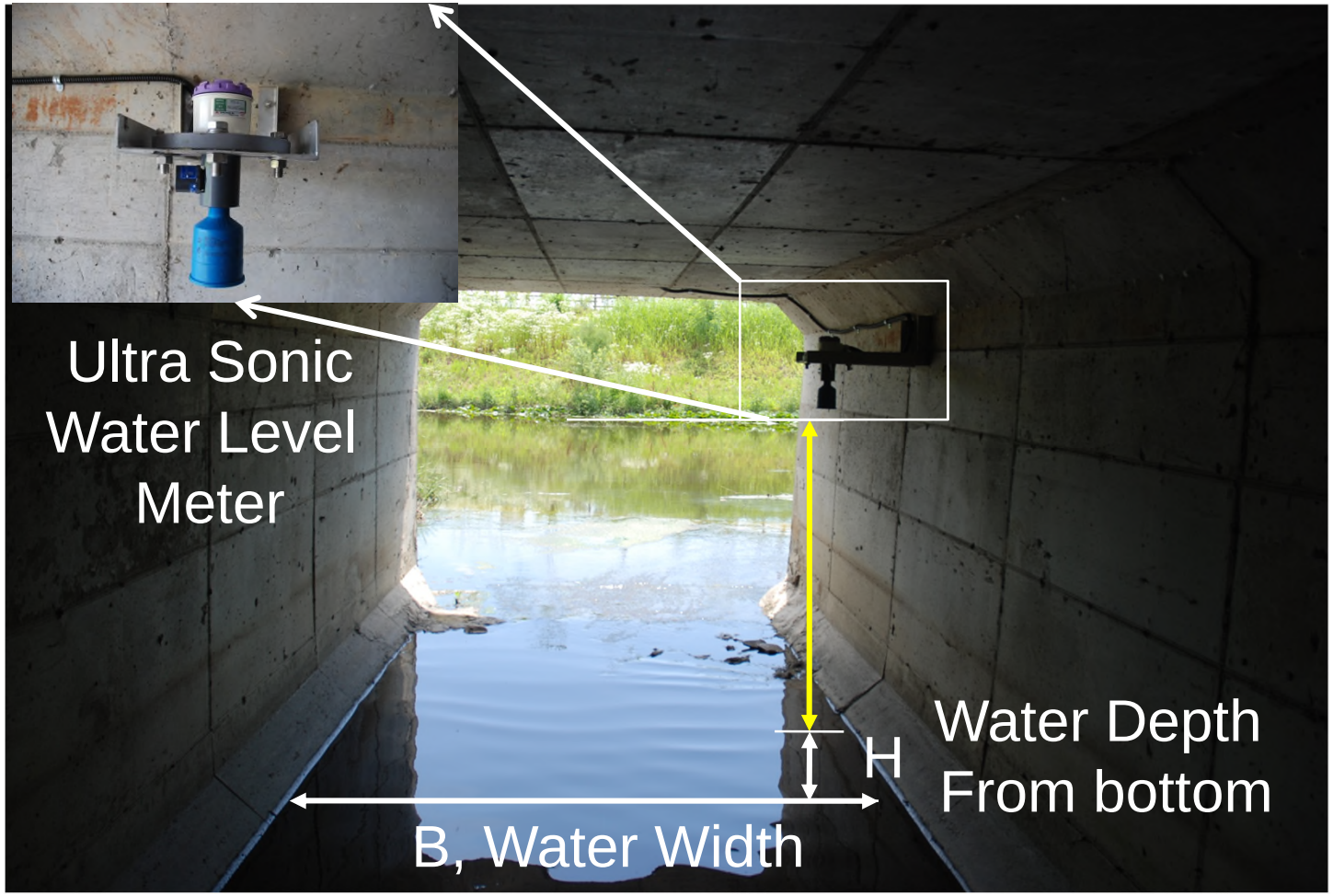
Inside of the Monitoring Station



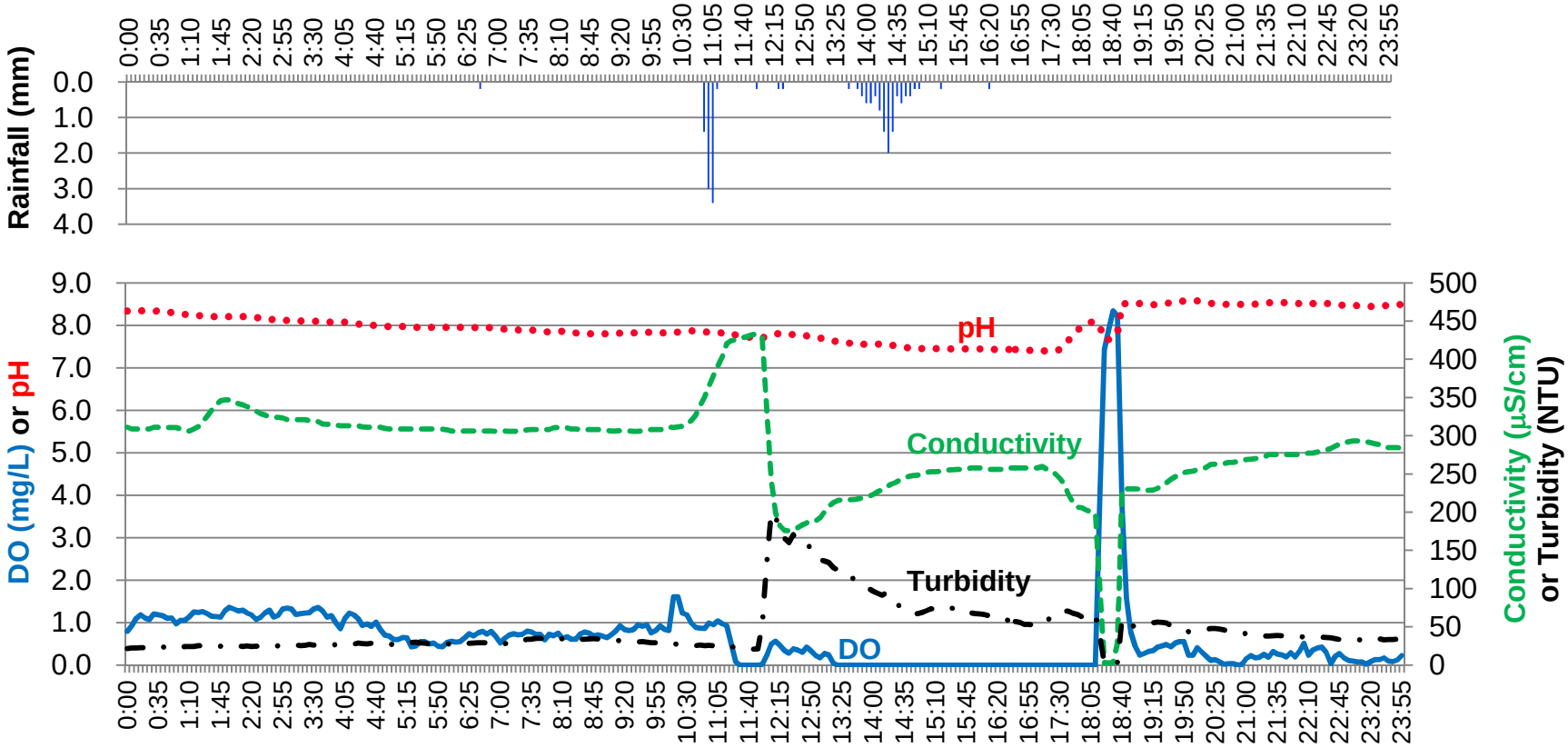
Automatic Sampler and Data Logger

Rain Gage on the Roof

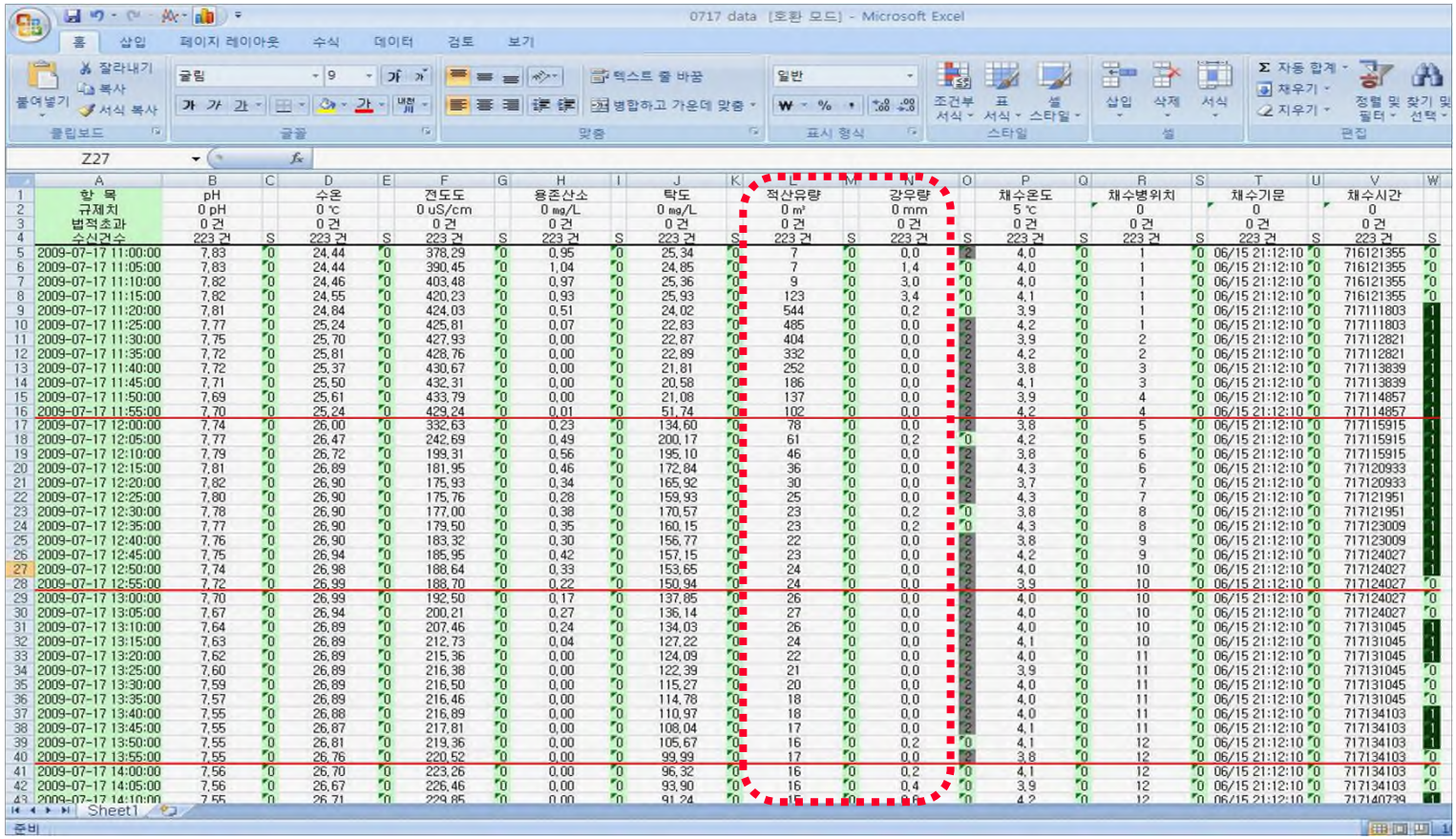
Ultra Sound Flow Monitoring System



Water Quality Variables by Automatic Sensors during a Storm Event



Real Time Data Read from the Laboratory, a Remote Site



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	항 목	pH		수온		전도도		용존산소		탁도		적산유량		강우량		채수온도		채수병위치		채수기문		채수시간	
2	규제치	0 pH		0 ℃		0 uS/cm		0 mg/L		0 mg/L		0 m³		0 mm		5 ℃		0		0		0	
3	법적초과	0 건		0 건		0 건		0 건		0 건		0 건		0 건		0 건		0 건		0 건		0 건	
4	수신건수	223 건	S	223 건	S	223 건	S	223 건	S	223 건	S	223 건	S	223 건	S	223 건	S	223 건	S	223 건	S	223 건	S
5	2009-07-17 11:00:00	7,83	0	24,44	0	378,29	0	0,95	0	25,34	0	7	0	0,0	2	4,0	0	1	0	06/15 21:12:10	0	716121355	0
6	2009-07-17 11:05:00	7,83	0	24,44	0	390,45	0	1,04	0	24,85	0	7	0	1,4	0	4,0	0	1	0	06/15 21:12:10	0	716121355	0
7	2009-07-17 11:10:00	7,82	0	24,46	0	403,48	0	0,97	0	25,36	0	9	0	3,0	0	4,0	0	1	0	06/15 21:12:10	0	716121355	0
8	2009-07-17 11:15:00	7,82	0	24,55	0	420,23	0	0,93	0	25,93	0	123	0	3,4	0	4,1	0	1	0	06/15 21:12:10	0	716121355	0
9	2009-07-17 11:20:00	7,81	0	24,84	0	424,03	0	0,51	0	24,02	0	544	0	0,2	0	3,9	0	1	0	06/15 21:12:10	0	717111803	1
10	2009-07-17 11:25:00	7,77	0	25,24	0	425,81	0	0,07	0	22,83	0	485	0	0,0	2	4,2	0	1	0	06/15 21:12:10	0	717111803	1
11	2009-07-17 11:30:00	7,75	0	25,70	0	427,93	0	0,00	0	22,87	0	404	0	0,0	2	3,9	0	2	0	06/15 21:12:10	0	717112821	1
12	2009-07-17 11:35:00	7,72	0	25,81	0	428,76	0	0,00	0	22,89	0	332	0	0,0	2	4,2	0	2	0	06/15 21:12:10	0	717112821	1
13	2009-07-17 11:40:00	7,72	0	25,37	0	430,67	0	0,00	0	21,81	0	252	0	0,0	2	3,8	0	3	0	06/15 21:12:10	0	717113839	1
14	2009-07-17 11:45:00	7,71	0	25,50	0	432,31	0	0,00	0	20,58	0	186	0	0,0	2	4,1	0	3	0	06/15 21:12:10	0	717113839	1
15	2009-07-17 11:50:00	7,69	0	25,61	0	433,79	0	0,00	0	21,08	0	137	0	0,0	2	3,9	0	4	0	06/15 21:12:10	0	717114857	1
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17	2009-07-17 12:00:00	7,74	0	26,00	0	332,63	0	0,23	0	134,60	0	78	0	0,0	2	3,8	0	5	0	06/15 21:12:10	0	717115915	1
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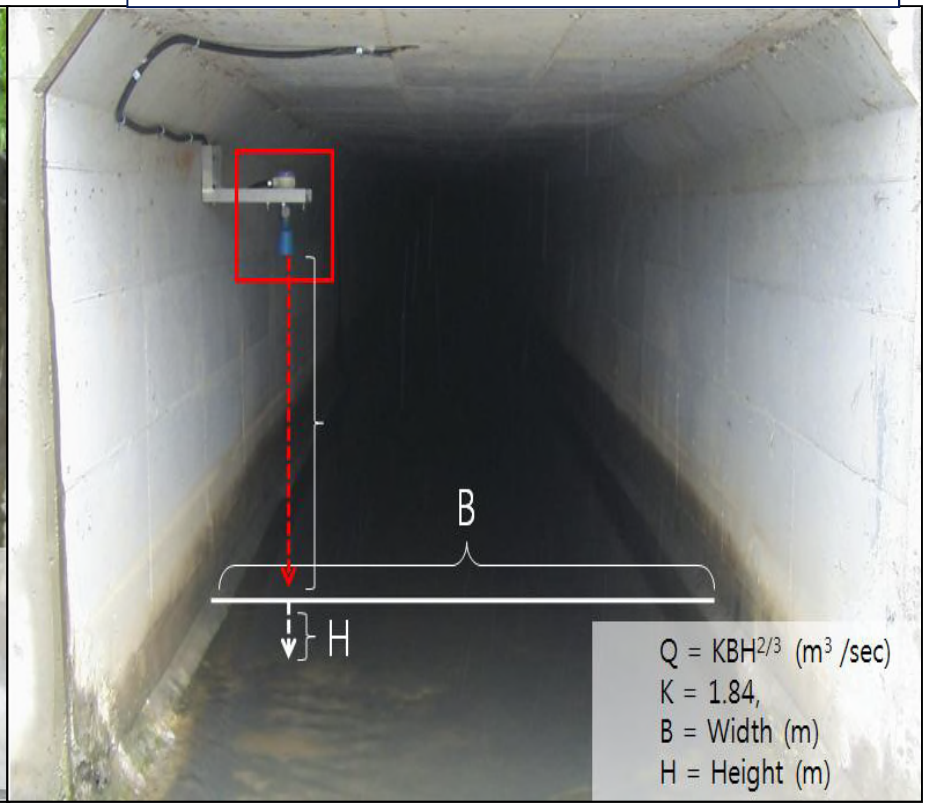
24	2009-07-17 12:35:00	7,77	0	26,90	0	179,50	0	0,35	0	160,15	0	23	0	0,2	0	4,3	0	8	0	06/15 21:12:10	0	717123009	1
25	2009-07-17 12:40:00	7,76	0	26,90	0	183,32	0	0,30	0	156,77	0	22	0	0,0	2	3,8	0	9	0	06/15 21:12:10	0	717123009	1
26	2009-07-17 12:45:00	7,75	0	26,94	0	185,95	0	0,42	0	157,15	0	23	0	0,0	2	4,2	0	9	0	06/15 21:12:10	0	717124027	1
27	2009-07-17 12:50:00	7,74	0	26,98	0	188,64	0	0,33	0	153,65	0	24	0	0,0	2	4,0	0	10	0	06/15 21:12:10	0	717124027	1
28	2009-07-17 12:55:00	7,72	0	26,99	0	188,70	0	0,22	0	150,94	0	24	0	0,0	2	3,9	0	10	0	06/15 21:12:10	0	717124027	0
29	2009-07-17 13:00:00	7,70	0	26,99	0	192,50	0	0,17	0	137,85	0	26	0	0,0	2	4,0	0	10	0	06/15 21:12:10	0	717124027	0
30	2009-07-17 13:05:00	7,67	0	26,94	0	200,21	0	0,27	0	136,14	0	27	0	0,0	2	4,0	0	10	0	06/15 21:12:10	0	717124027	0
31	2009-07-17 13:10:00	7,64	0	26,89	0	207,46	0	0,24	0	134,03	0	26	0	0,0	2	4,0	0	10	0	06/15 21:12:10	0	717131045	1
32	2009-07-17 13:15:00	7,63	0	26,89	0	212,73	0	0,04	0	127,22	0	24	0	0,0	2	4,1	0	10	0	06/15 21:12:10	0	717131045	1
33	2009-07-17 13:20:00	7,62	0	26,89	0	215,36	0	0,00	0	124,09	0	22	0	0,0	2	4,0	0	11	0	06/15 21:12:10	0	717131045	1
34	2009-07-17 13:25:00	7,60	0	26,89	0	216,38	0	0,00	0	122,39	0	21	0	0,0	2	3,9	0	11	0	06/15 21:12:10	0	717131045	0
35	2009-07-17 13:30:00	7,59	0	26,89	0	216,50	0	0,00	0	115,27	0	20	0	0,0	2	4,0	0	11	0	06/15 21:12:10	0	717131045	0
36	2009-07-17 13:35:00	7,57	0	26,89	0	216,46	0	0,00	0	114,78	0	18	0	0,0	2	4,0	0	11	0	06/15 21:12:10	0	717131045	0
37	2009-07-17 13:40:00	7,55	0	26,88	0	216,89	0	0,00	0	110,97	0	18	0	0,0	2	4,0	0	11	0	06/15 21:12:10	0	717134103	1
38	2009-07-17 13:45:00	7,55	0	26,87	0	217,81	0	0,00	0	108,04	0	17	0	0,0	2	4,1	0	11	0	06/15 21:12:10	0	717134103	1
39	2009-07-17 13:50:00	7,55	0	26,81	0	219,36	0	0,00	0	105,67	0	16	0	0,2	0	4,1	0	12	0	06/15 21:12:10	0	717134103	1
40	2009-07-17 13:55:00	7,55	0	26,76	0	220,52	0	0,00	0	99,99	0	17	0	0,0	2	3,8	0	12	0	06/15 21:12:10	0	717134103	0
41	2009-07-17 14:00:00	7,56	0	26,70	0	223,26	0	0,00	0	96,32	0	16	0	0,2	0	4,1	0	12	0	06/15 21:12:10	0	717134103	0
42	2009-07-17 14:05:00	7,56	0	26,67	0	226,46	0	0,00	0	93,90	0	16	0	0,4	0	3,9	0	12	0	06/15 21:12:10	0	717134103	0
43	2009-07-17 14:10:00	7,55	0	26,71	0	229,85	0	0,00	0	91,24	0	15	0	0,6	0	4,2	0	12	0	06/15 21:12:10	0	717140739	1

Flow Monitoring System Confirmation

Field Measurements
Q = AU

Automatic Measurements
Q [m^3/sec] = $1.84BH^{2/3}$

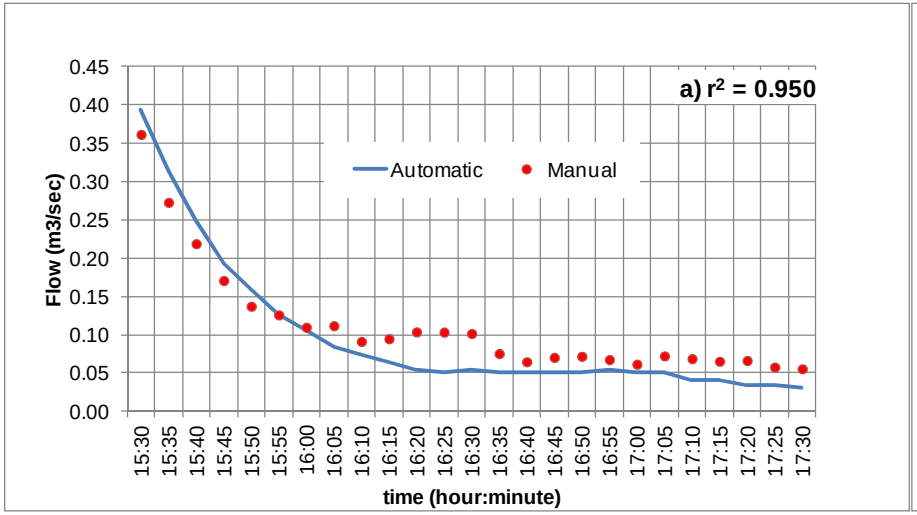


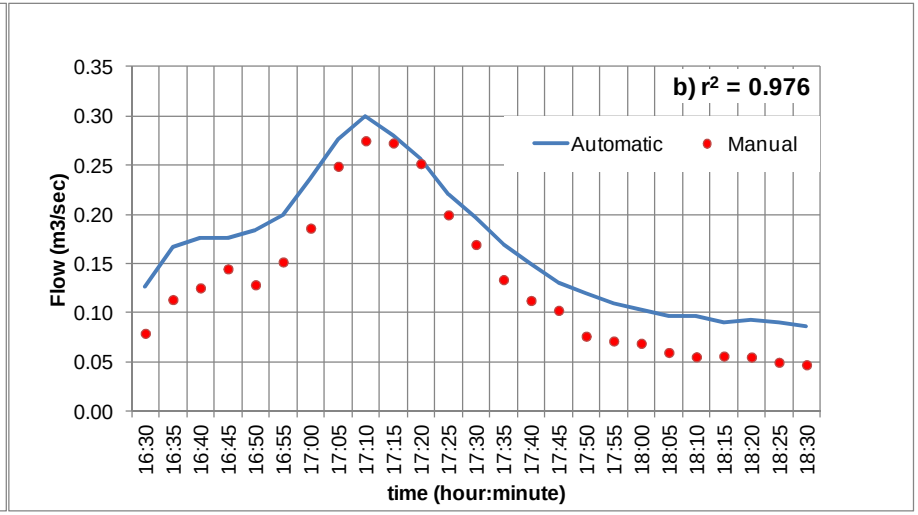
Weir Equation for Flow Rate Estimation

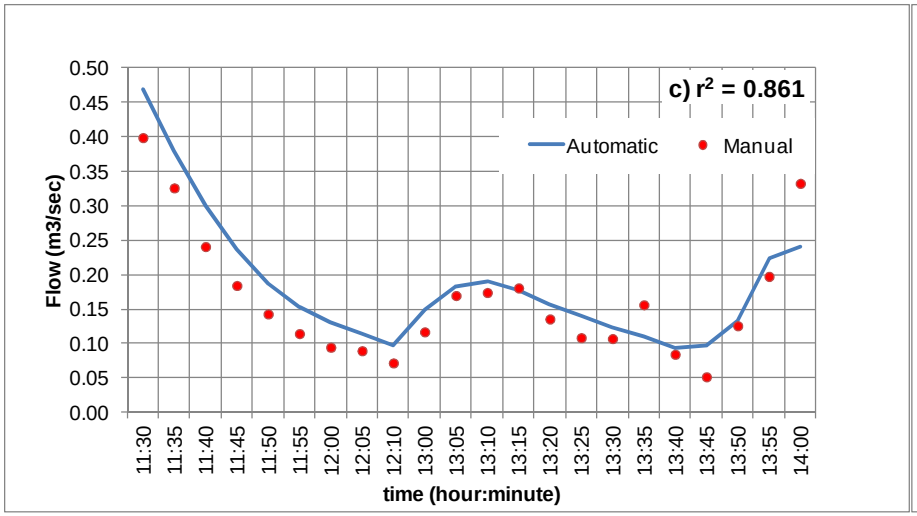
$$Q = KBH^{2/3}$$

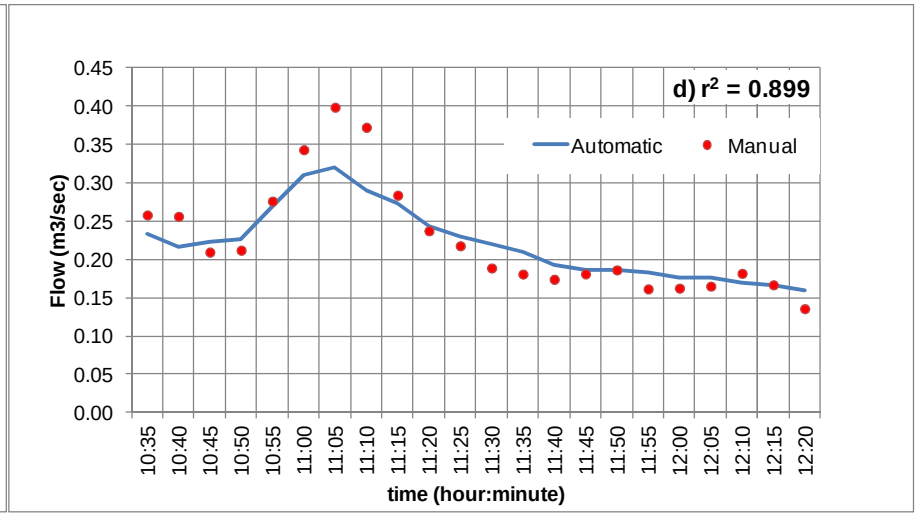
Q = Flow rate (m^3/sec),
K = coefficient (m/sec), 1.84 in this study
B = width of weir (m),
H = water depth (m)

Correlation of Automatic and Manual Flow Measurements









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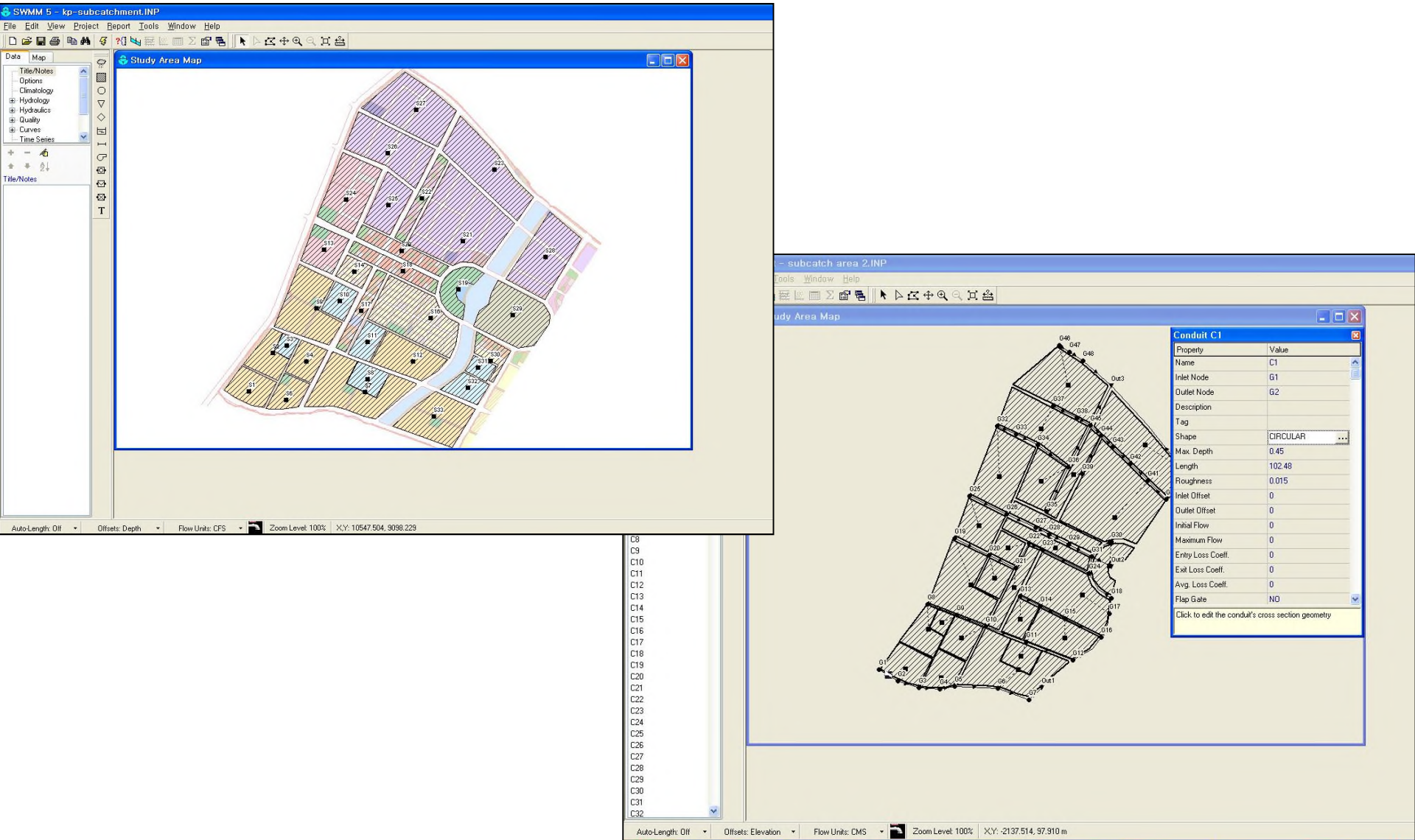
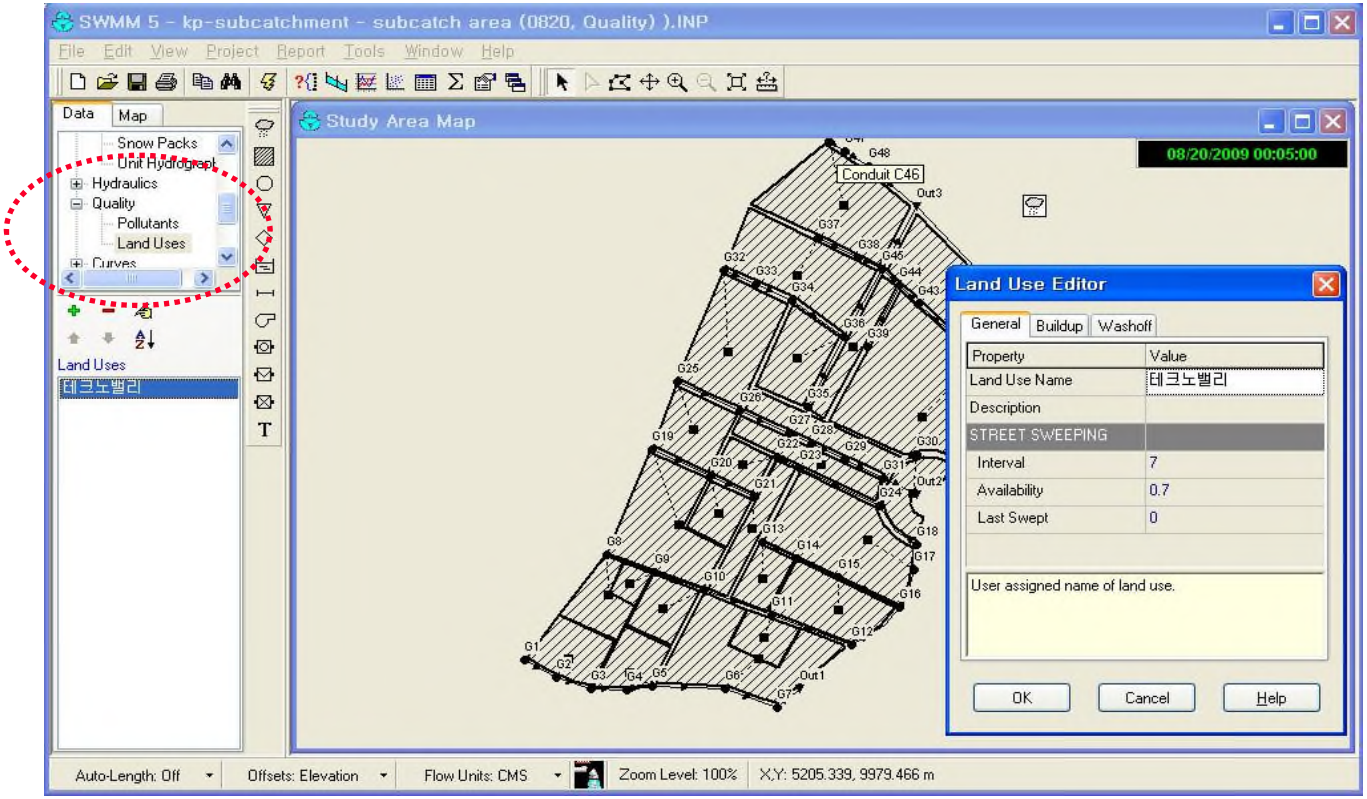
SWMM Model Development of the Study Site



SWMM(Storm Water Management Model)

- Land Uses – Build up, Washoff



Pollutant Buildup

- Power Function:
  - C_1 = maximum buildup possible
  - C_2 = buildup rate constant
  - C_3 = time exponent

$$B = Min\left(C_1, C_2 t^{C_3}\right)$$

- Exponential Function:
  - C_1 = maximum buildup possible
  - C_2 = buildup rate constant

$$B = C_1\left(1 - e^{-C_2 t}\right)$$

- Saturation Function
  - C_1 = maximum buildup possible
  - C_2 = half saturation coefficient

$$B = \frac{C_1 t}{C_2 + t}$$

Wash-off

- Exponential Washoff:
  - C_1 = washoff coefficient
  - C_2 = washoff exponent
  - q = runoff rate per unit area (mm/hr)

$$W = C_1 q^{C_2} B$$

- Rating Curve Washoff:
  - C_1 = washoff coefficient
  - C_2 = washoff exponent
  - Q = runoff rate in user-defined flow units

$$W = C_1 Q^{C_2}$$

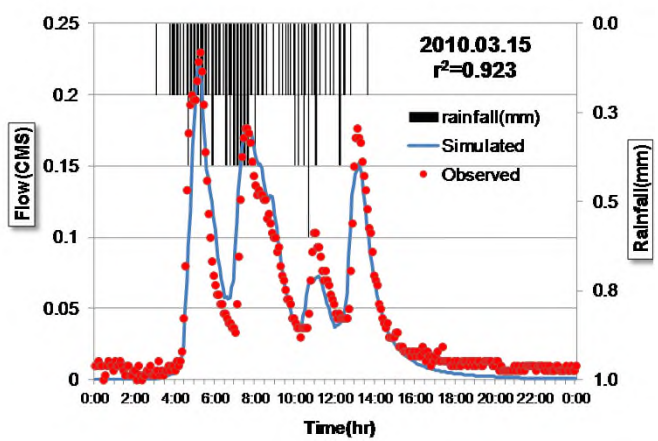
- Event Mean Concentration:
  - C_1 = maximum buildup possible
  - C_2 = half saturation coefficient

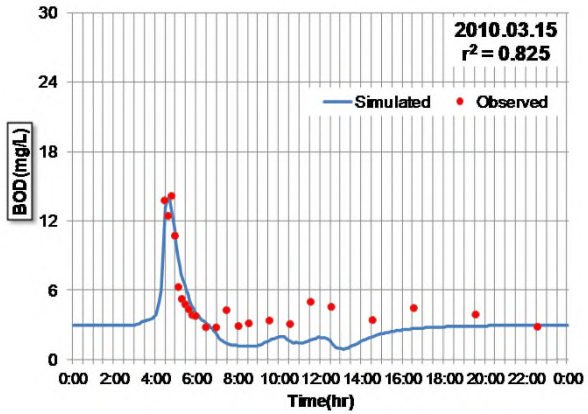
$$\overline{C} = \frac{\sum C_i Q_i}{\sum Q_i}$$

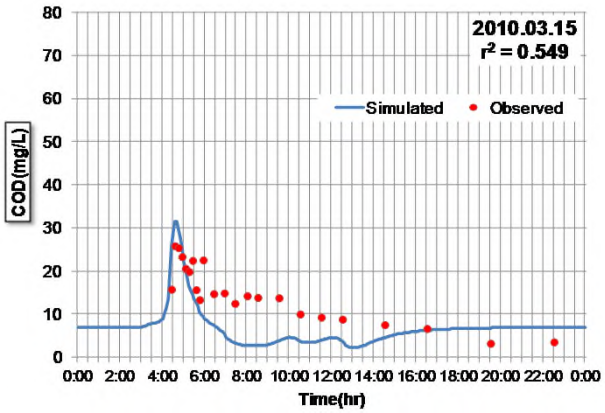
Calibrated Coefficients for Pollutant Buildup and Washoff

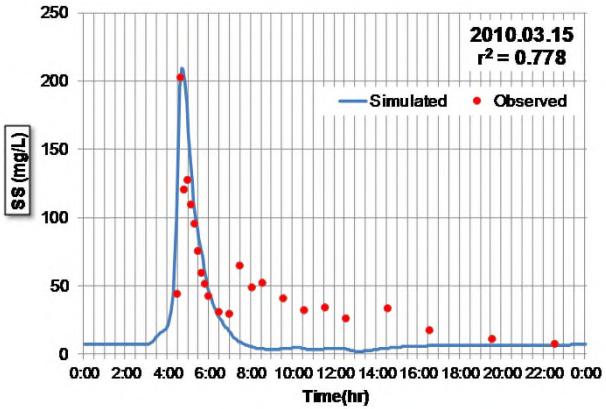
Pollutant	Buildup			Washoff		
	Function	C_2	C_3	Function	C_1	C_2
SS	Power	30	0.05	Exponential	1.8	1.2
BOD		0.5	0.05		1.6	1.2
COD		1.5	0.05		1.6	1.2
TN		0.18	0.05		1.6	1.2
TP		0.09	0.05		1.6	1.2

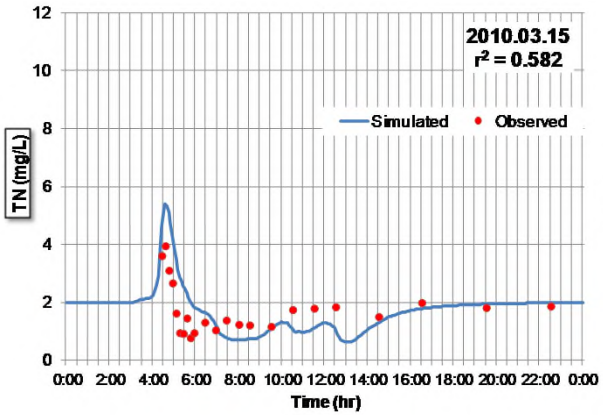
SWMM Flow and Water Quality Calibration Result (2010.03.15)

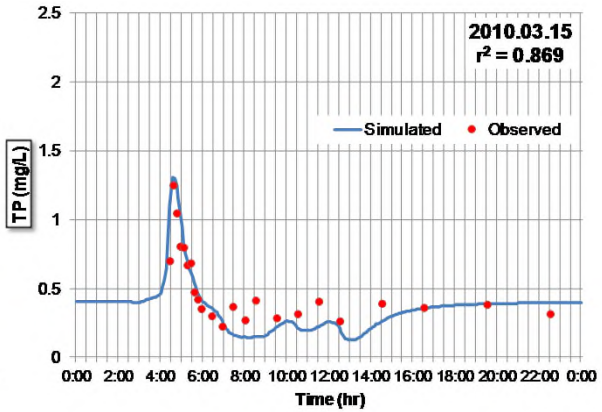












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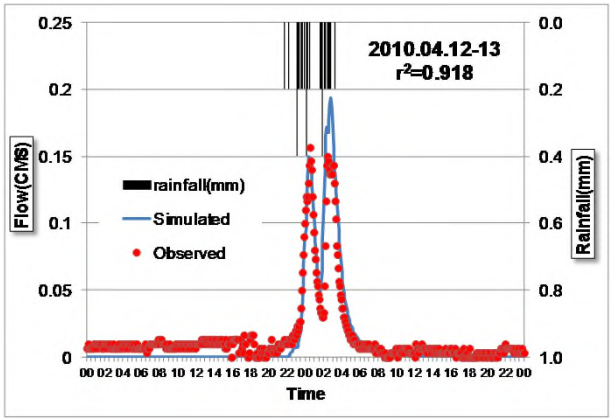
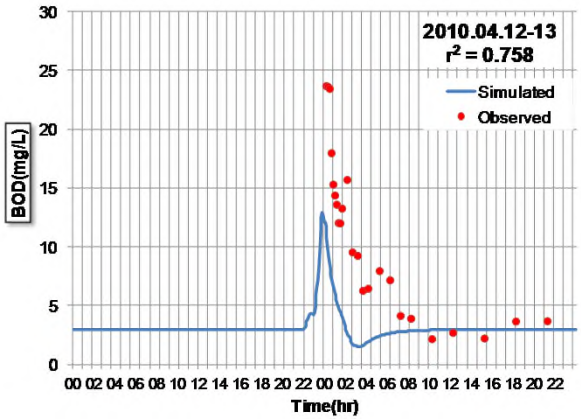
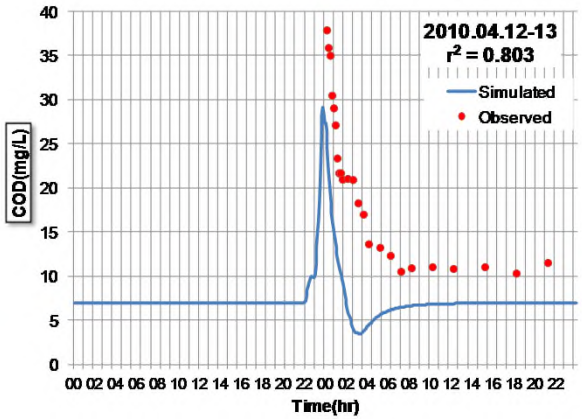
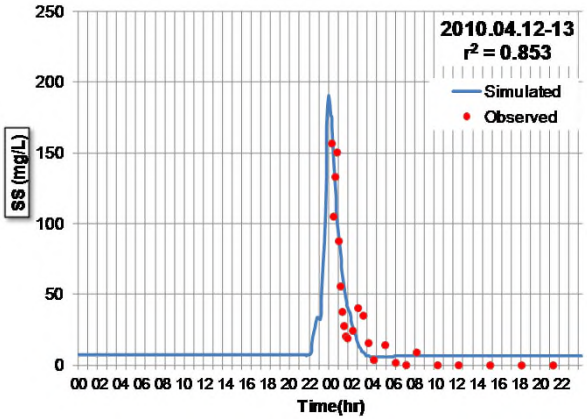
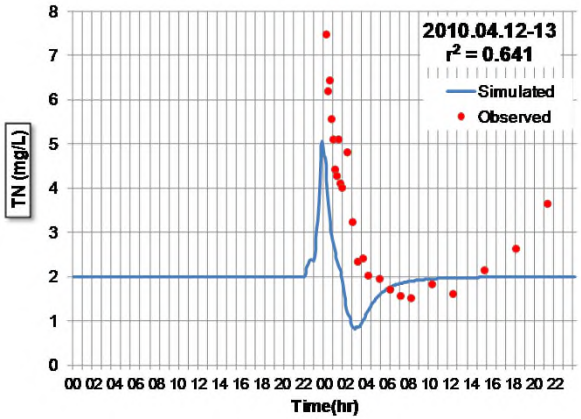
SWMM Flow and Water Quality Calibration Result (2010.04.12-13)

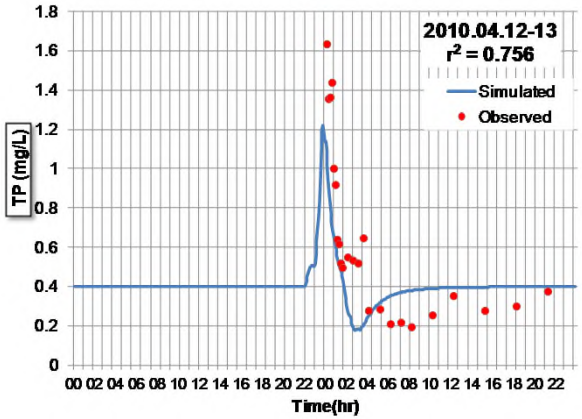












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Correlation Coefficients between SWMM Predictions vs. Observations

Date	Flow	SS	BOD	COD	TN	TP	Precipi-tation mm	Rainfall Intensity mm/hr	Duration (hr)	Dry Days (day)
03.15	0.92	0.78	0.83	0.55	0.58	0.87	8.80	0.80	11	3
04.12.-13	0.92	0.85	0.76	0.80	0.63	0.76	5.40	0.90	6	11
04.21.-22	0.96	0.87	0.51	0.48	0.68	0.34	8.40	1.68	5	9
04.26.-27	0.99	0.61	0.87	0.82	0.89	0.70	33.8	3.07	11	4
05.17-18	0.97	0.37	0.34	0.59	0.59	0.48	47.4	2.50	19	11
Average	**0.96**	**0.68**	**0.62**	**0.67**	**0.70**	**0.57**				

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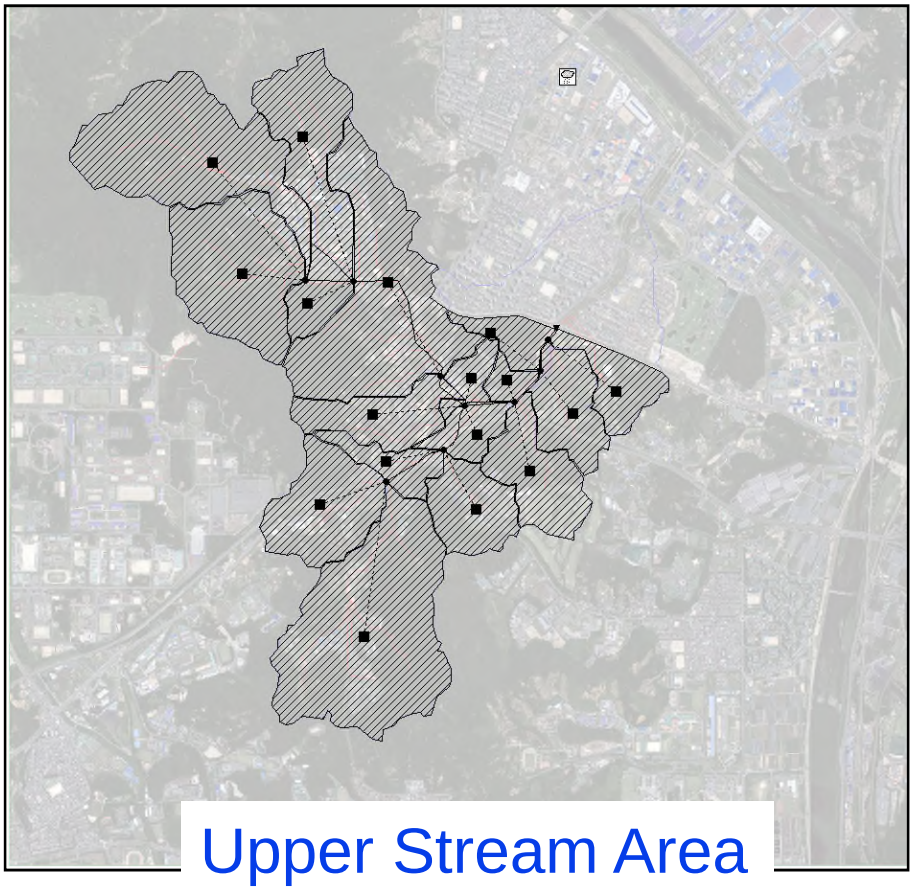
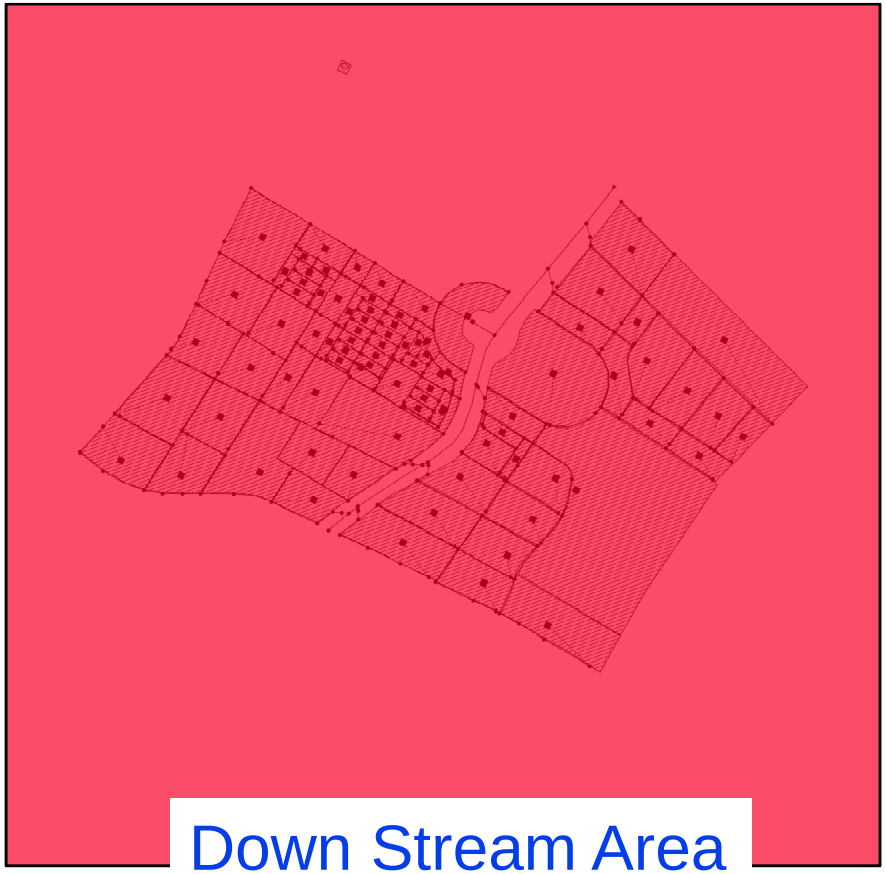
Rest of the Basin Areas

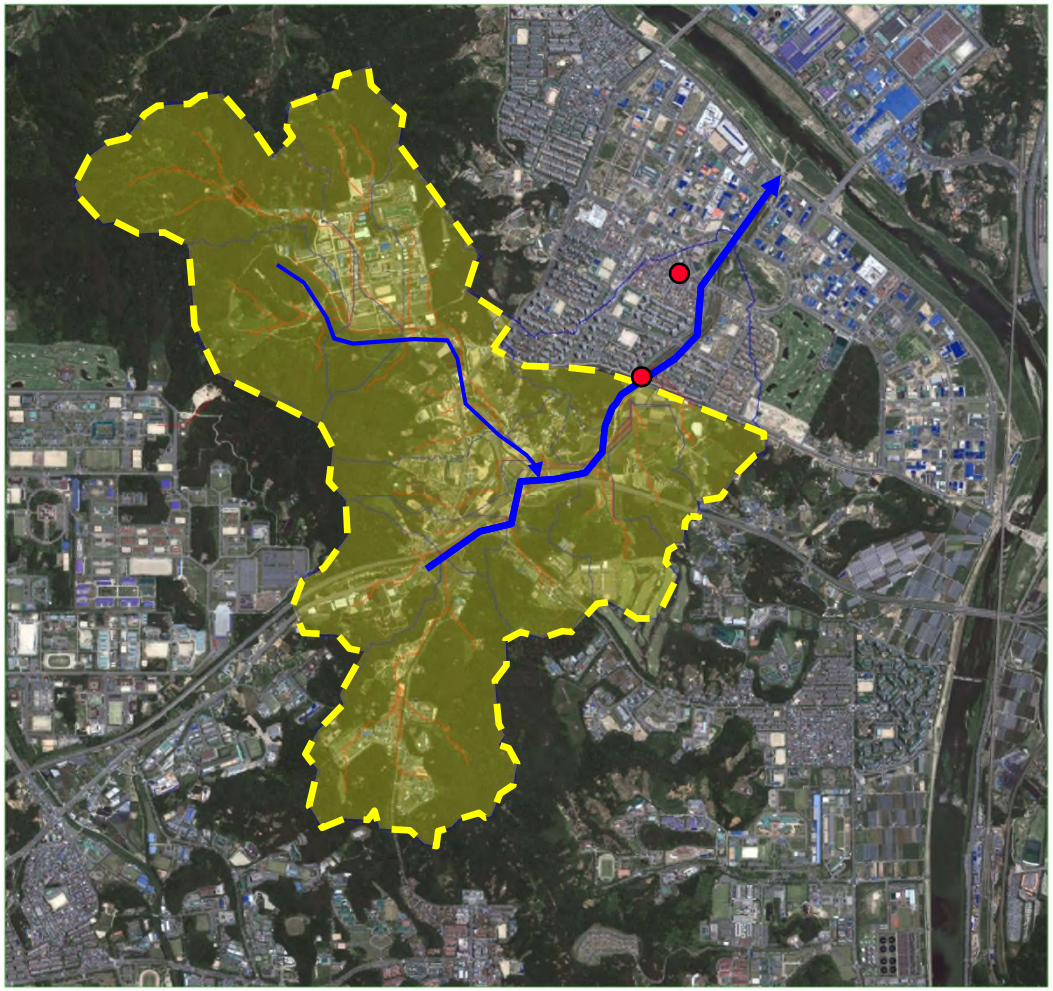


Upper Stream Area



Down Stream Area

Monitoring II
for Upper Stream and its Basin Area



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Monitoring II
New Installation and Web Page

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Monitoring II Equipments

Before Installation	After Installation	Ultrasonic Water Level Meter	Auto Sampler
Rain Gage	Data Logger	Water Quality Sensors	Water Quality Display

Real Time Water Information via Internet: http://ummm.cnu.ac.kr

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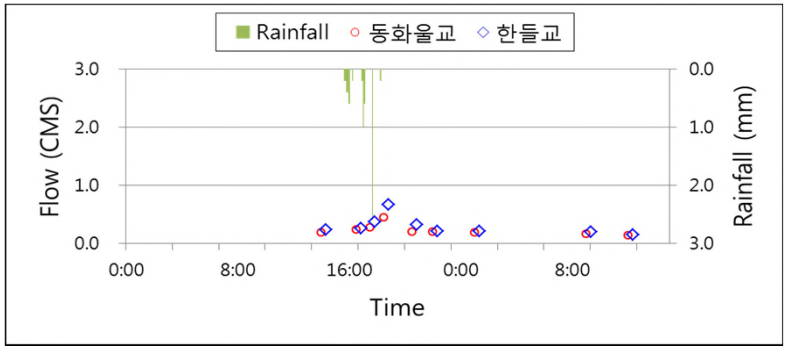
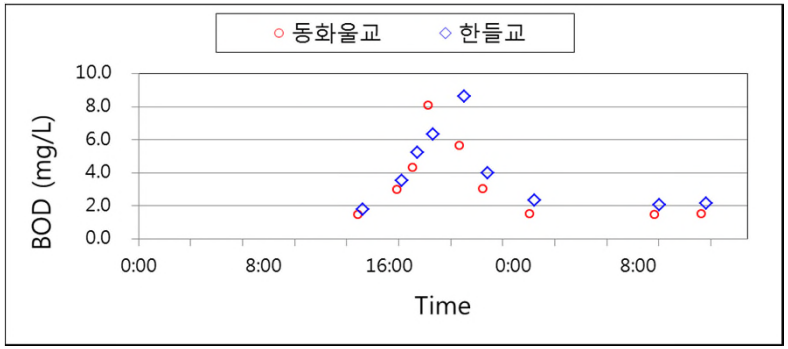
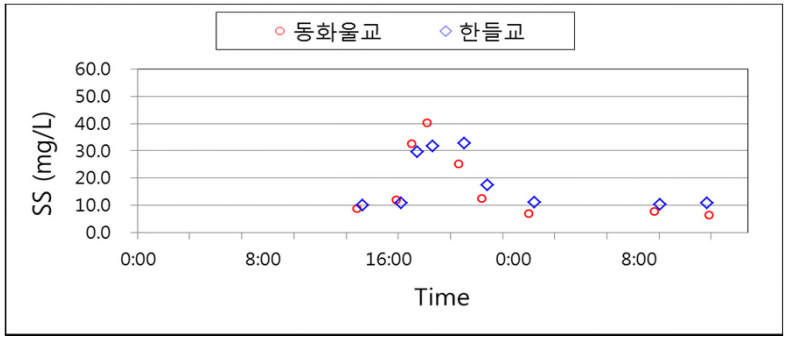
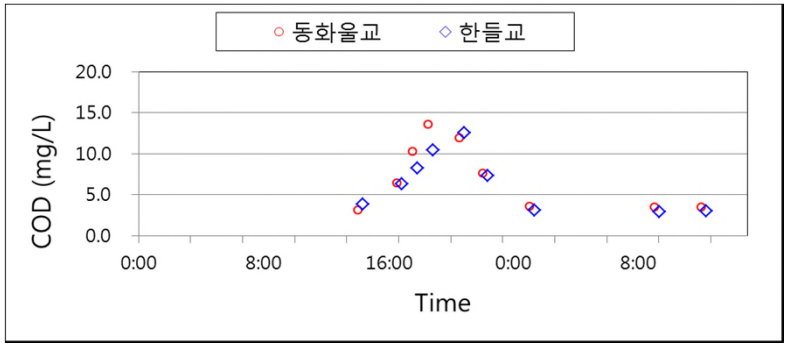
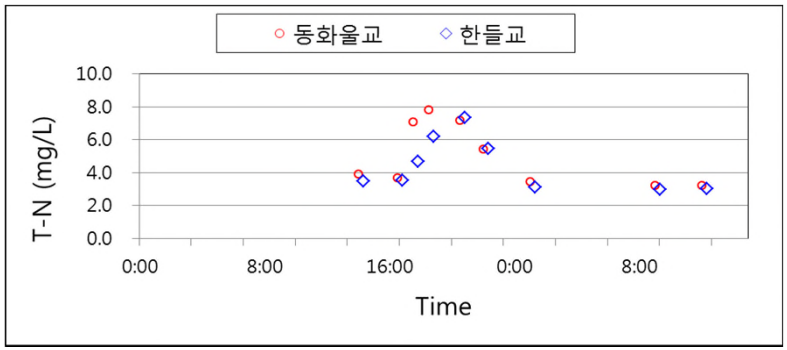
Field Measurements (2013. 08. 05~06)

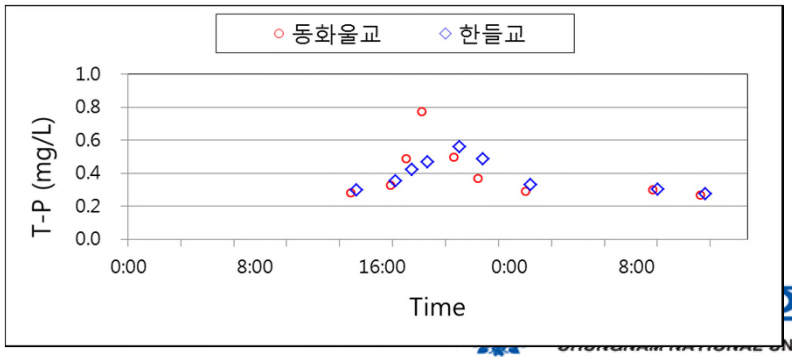




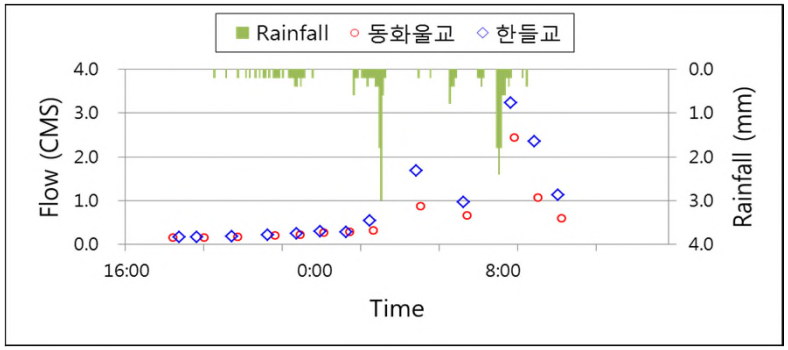


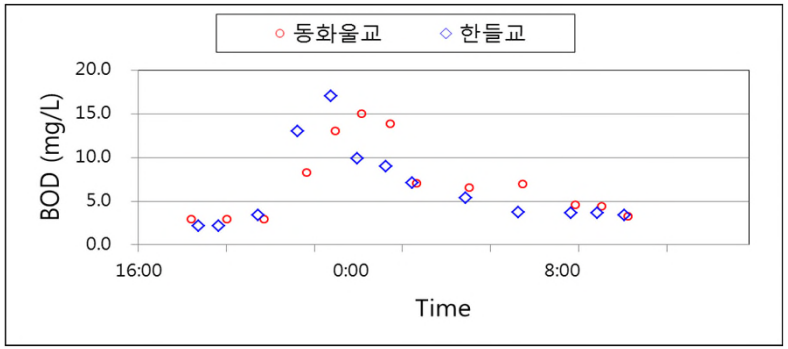


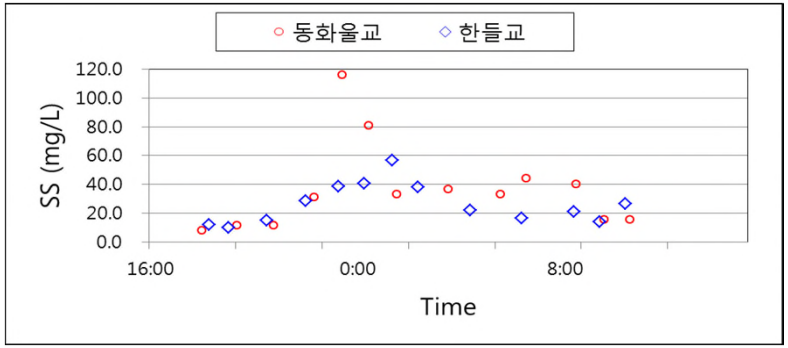


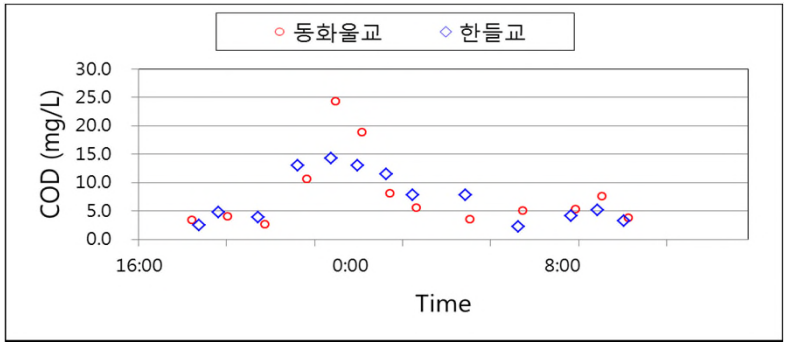


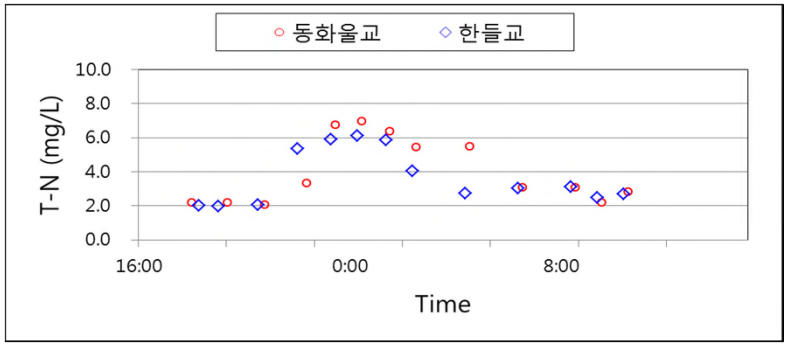
Field Measurements(2013. 09. 10~11)

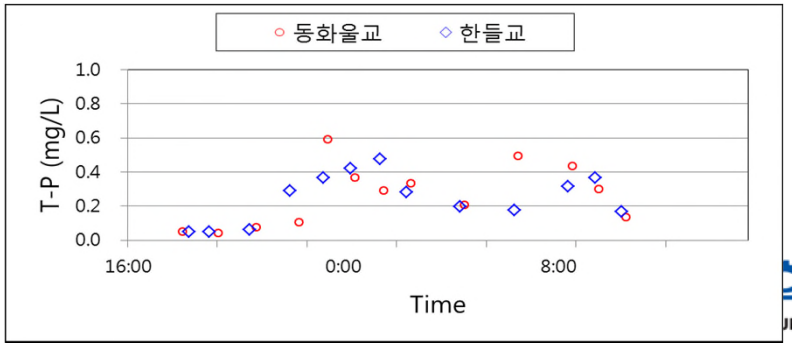




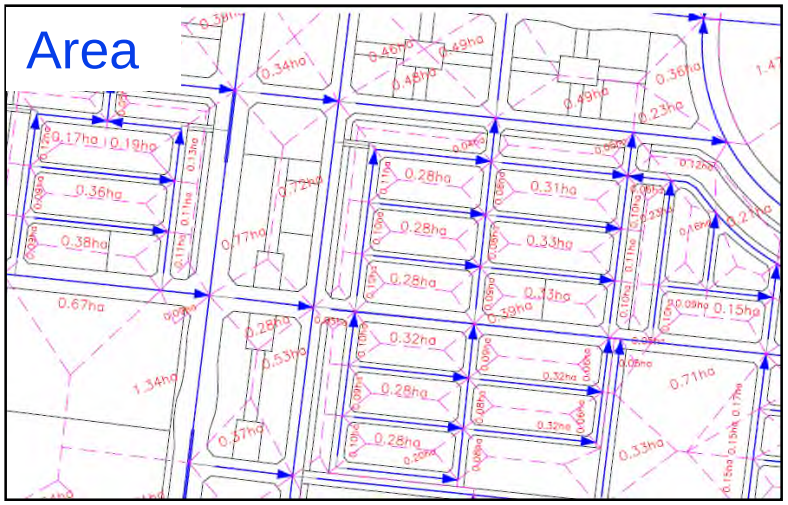


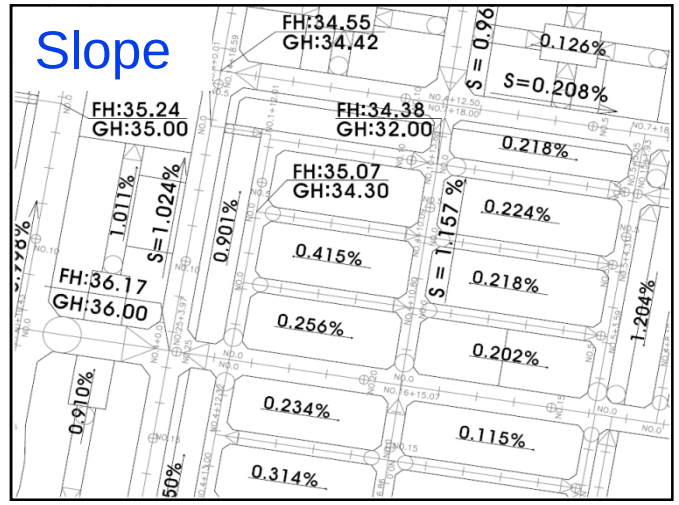


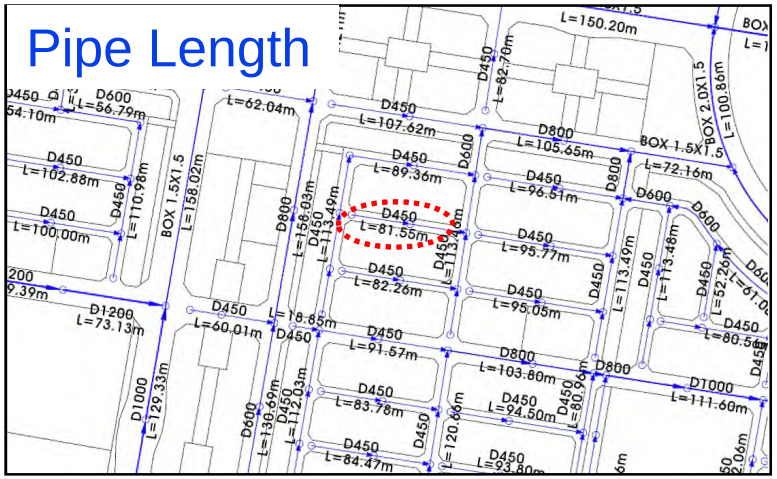


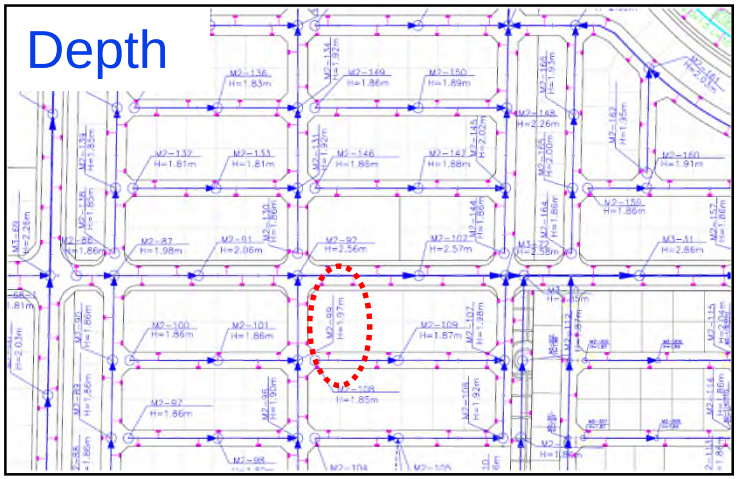


Information for SWMM









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Calibrated Coefficients for Pollutant Buildup and Washoff_Upper Stream

Pollutant	Buildup			Washoff		
	Function	C_2	C_3	Function	C_1	C_2
SS	Power	0.50	0.30	Exponential	0.60	0.050
BOD		0.18	0.15		0.30	0.015
COD		0.21	0.18		0.30	0.015
TN		0.10	0.12		0.30	0.115
TP		0.01	0.08		0.30	0.015

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Calibrated Coefficients for Pollutant Buildup and Washoff_Down Stream

Pollutant	Buildup			Washoff		
	Function	C_2	C_3	Function	C_1	C_2
SS	Power	0.40	0.30	Exponential	0.60	0.050
BOD		0.30	0.50		0.30	0.015
COD		0.30	0.50		0.30	0.015
TN		0.25	0.15		0.15	0.115
TP		0.015	0.02		0.30	0.115

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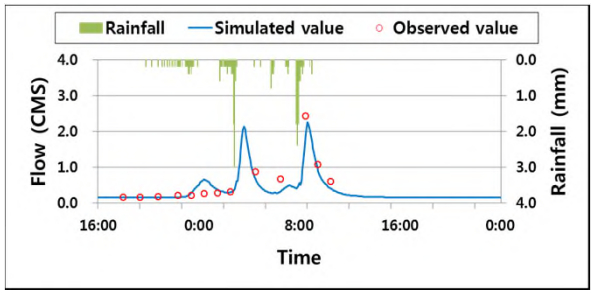
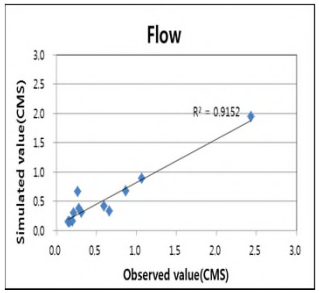
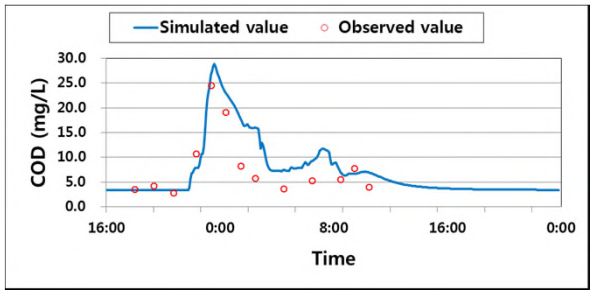
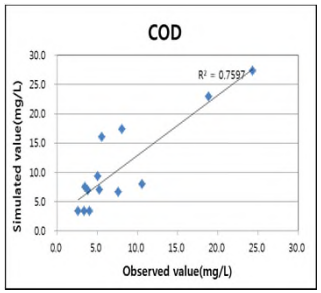
Calibration of Upper Stream Area

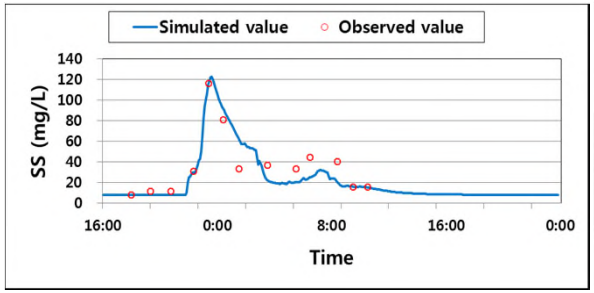
SITE 1. 2013.09.10~11

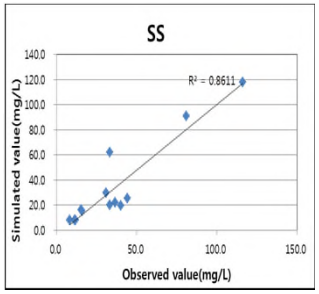


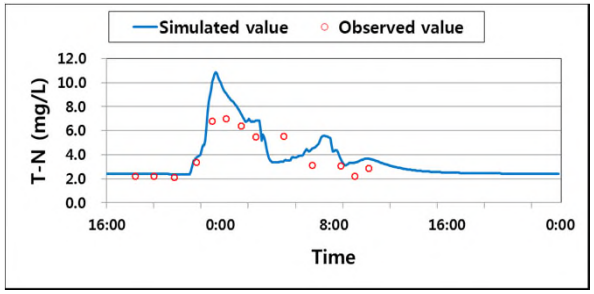


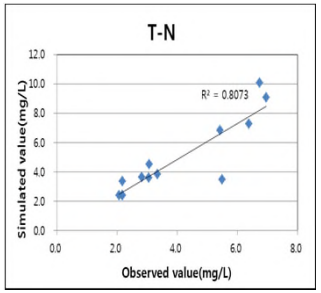


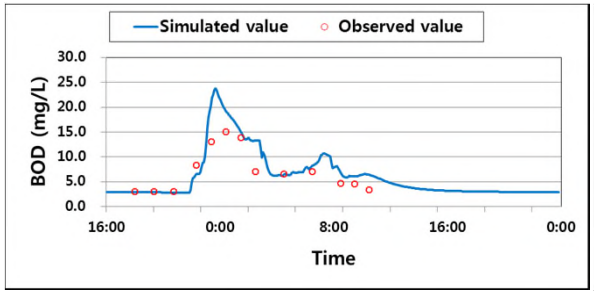


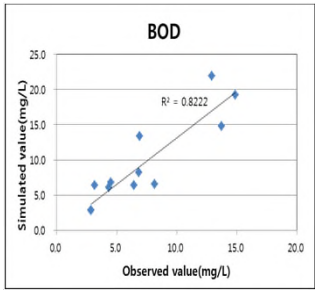


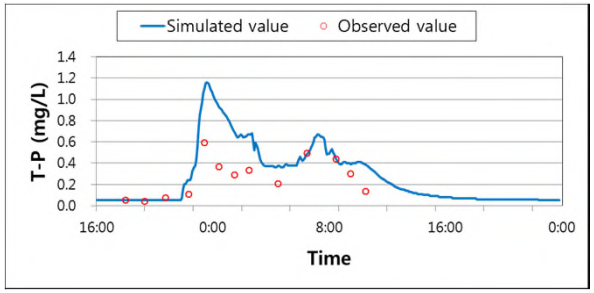


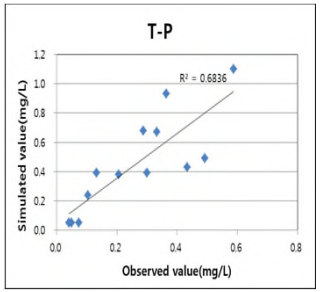












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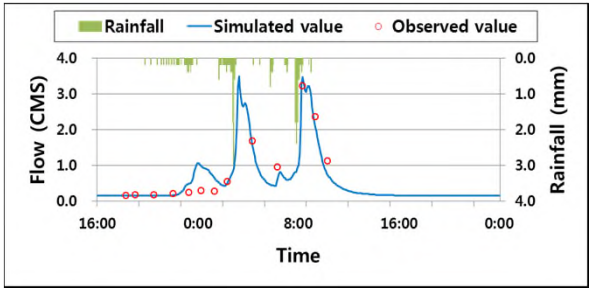
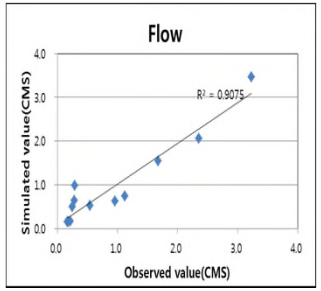
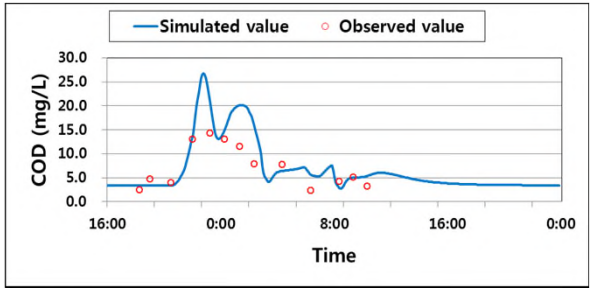
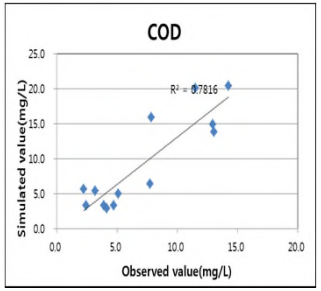
Calibration of Upper Stream Area

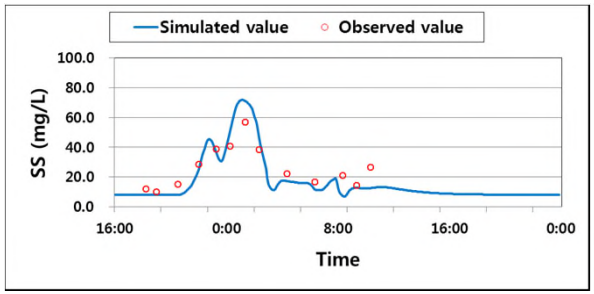
SITE 2. 2013.09.10~11

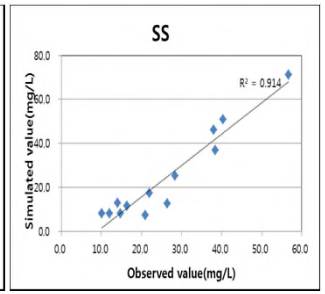


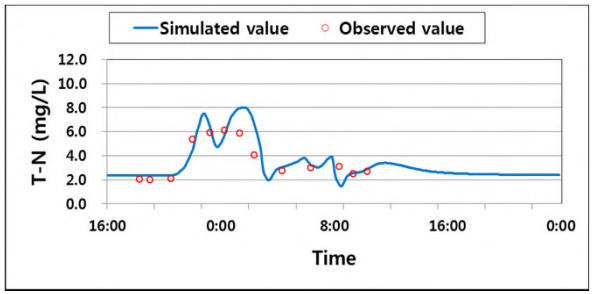


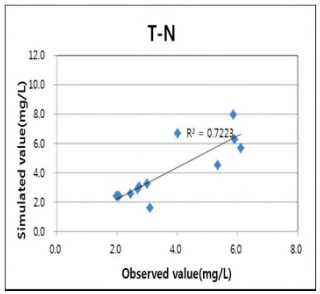


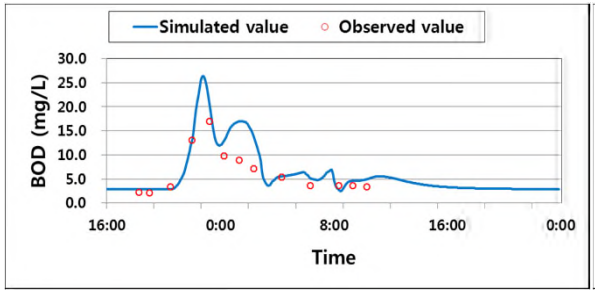


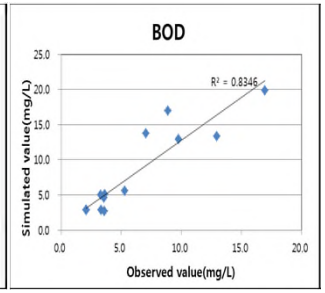


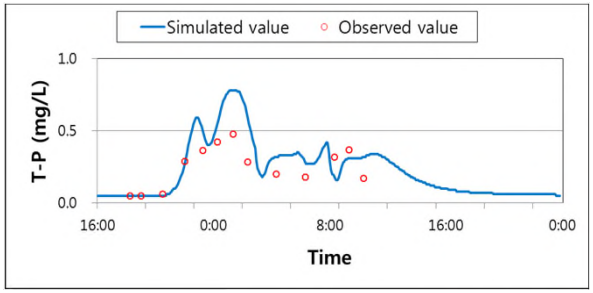


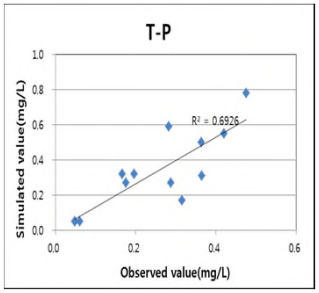












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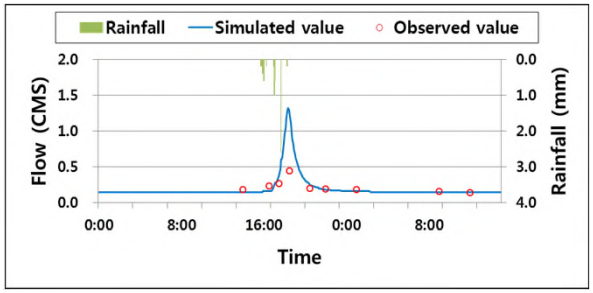
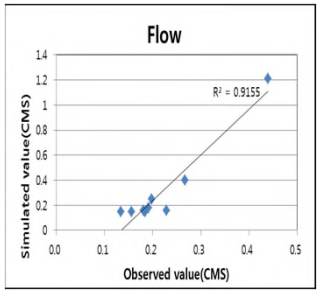
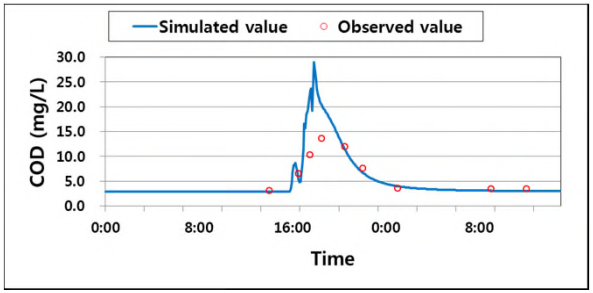
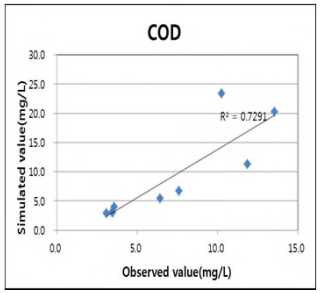
Verification of Upper Stream Area

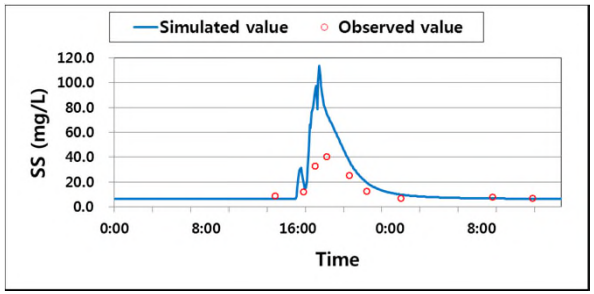
SITE 1. 2013.08.05~06

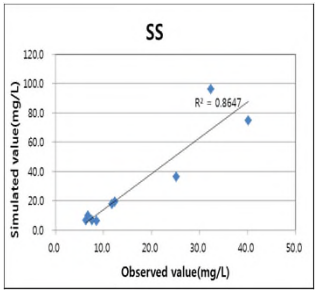


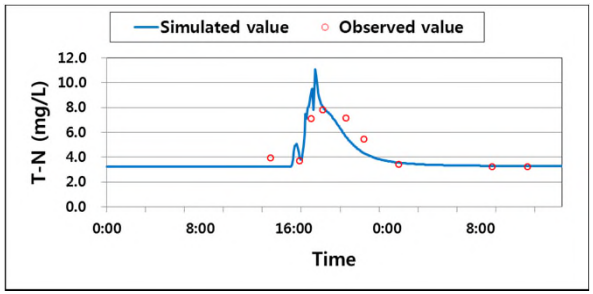


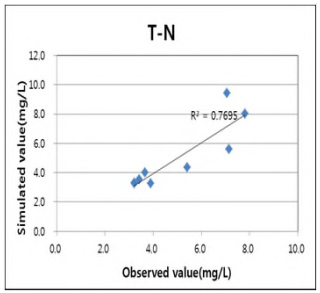


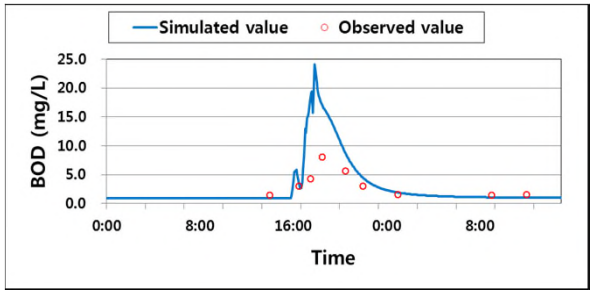


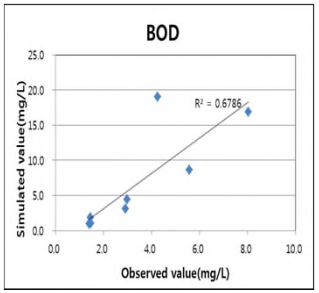


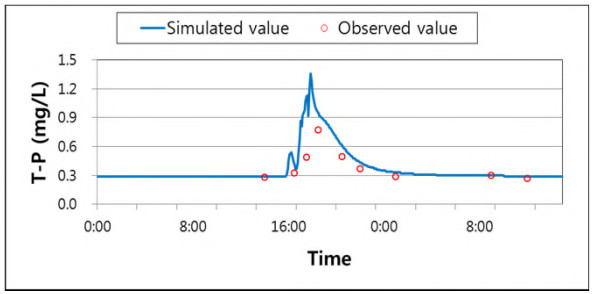


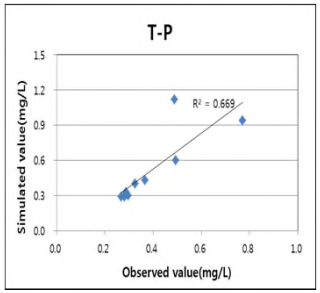












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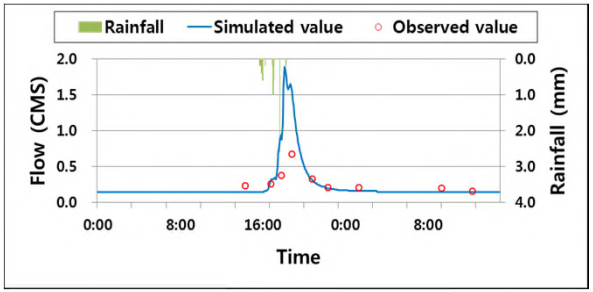
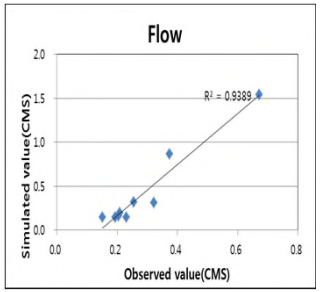
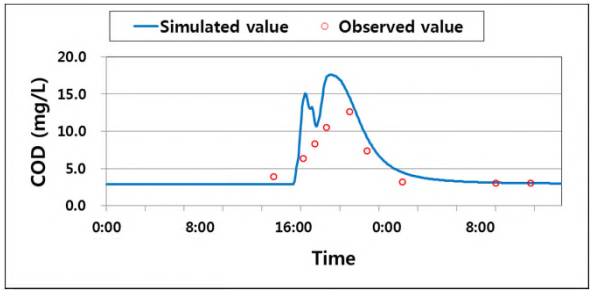
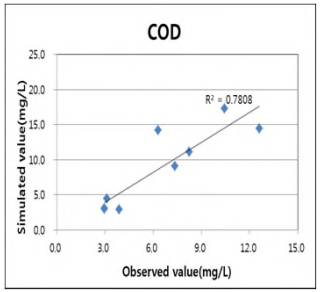
Verification of Upper Stream Area

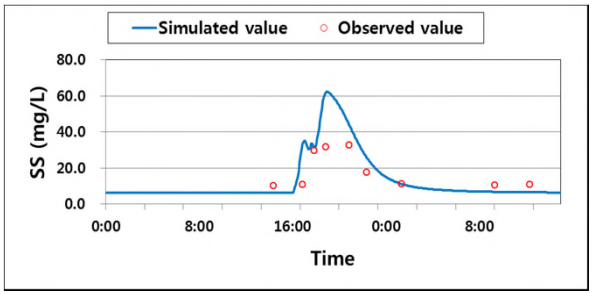
SITE 2. 2013.08.05~06

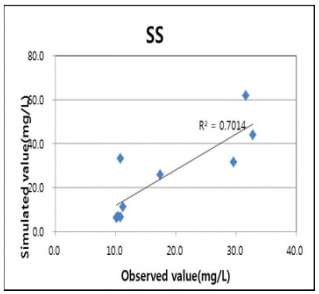


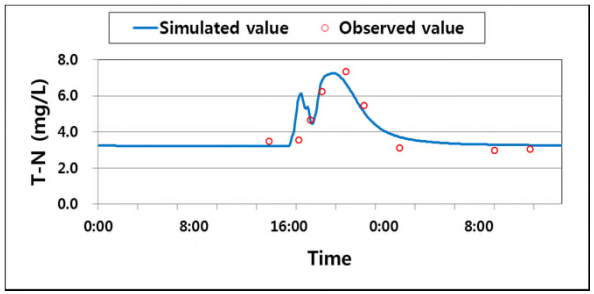


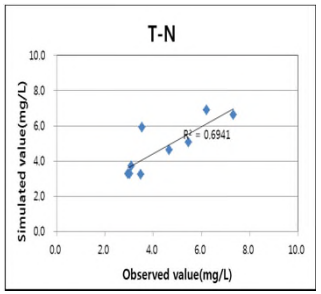


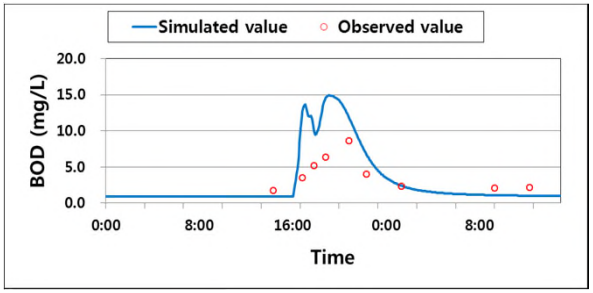


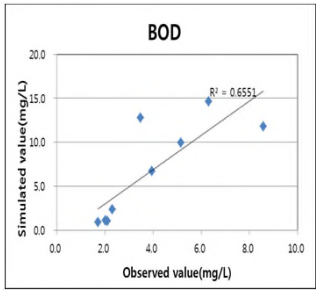


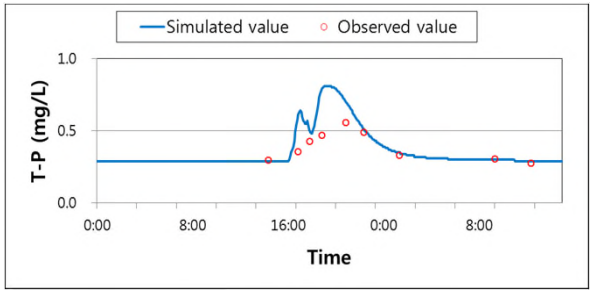


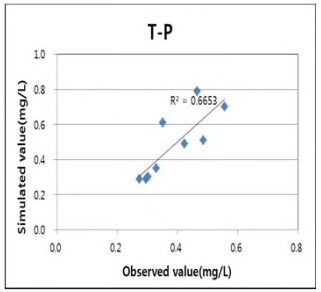












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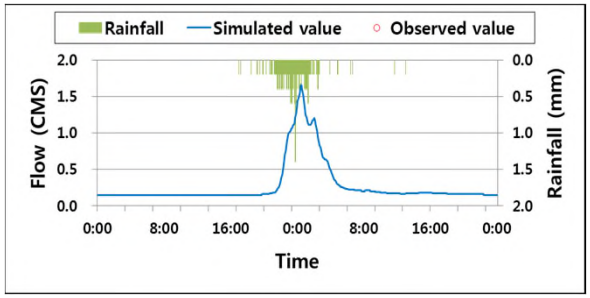
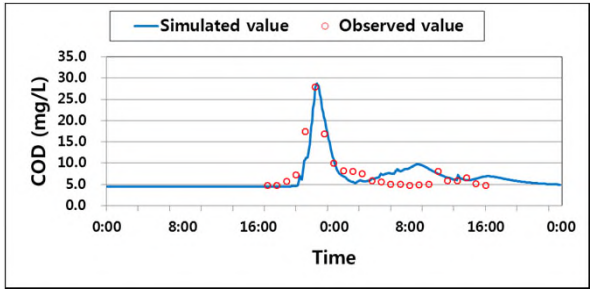
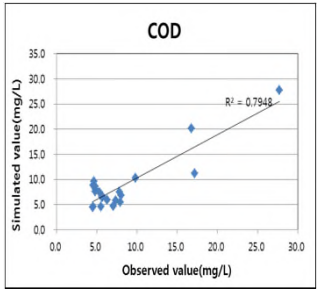
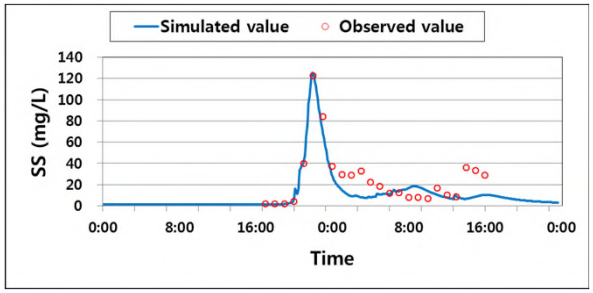
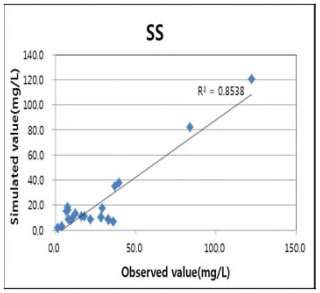
SITE 2. 2013.11.24~25

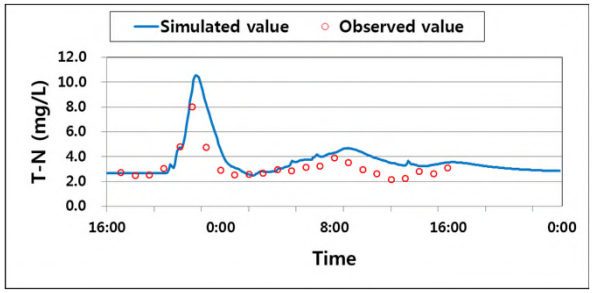


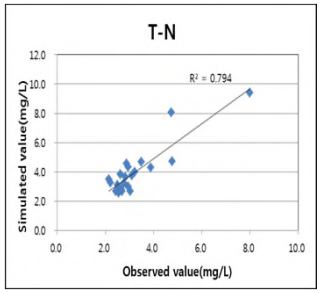


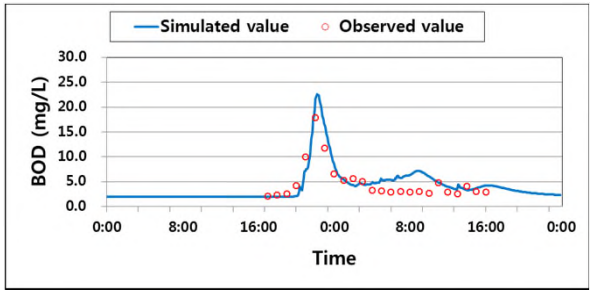


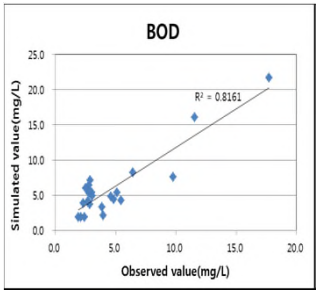


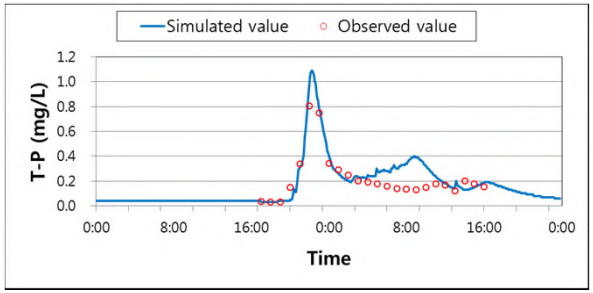


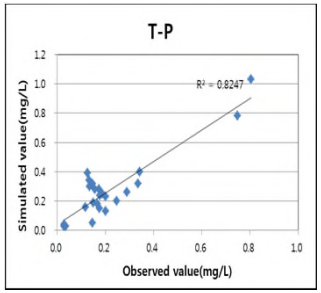












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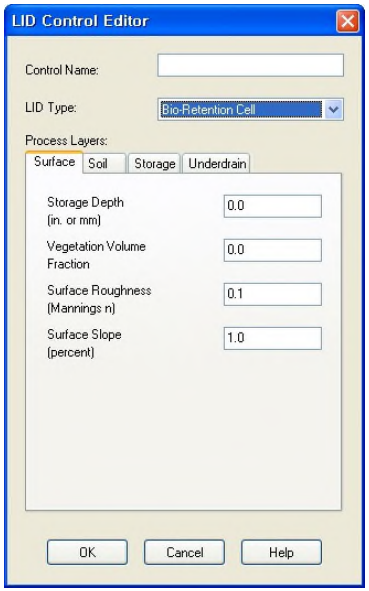
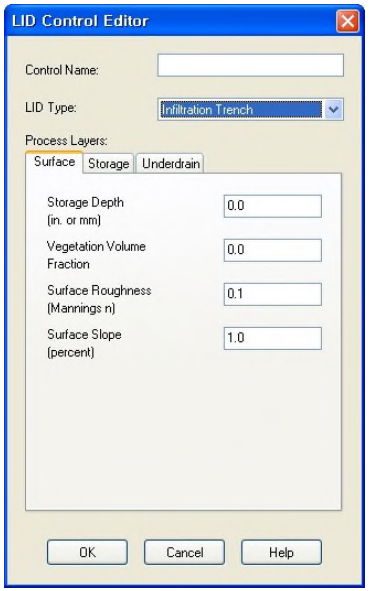
Calibration and Verification

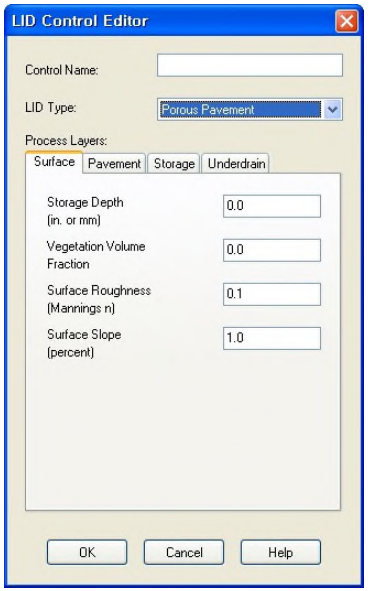
R^2			Flow	SS	BOD	COD	T-N	T-P
Calibration	Site 1	2013. 09. 10~11	0.915	0.861	0.822	0.760	0.807	0.684
	Site 2	2013. 09. 10~11	0.908	0.914	0.835	0.782	0.722	0.693
	Average		**0.912**	**0.888**	**0.829**	**0.771**	**0.765**	**0.689**

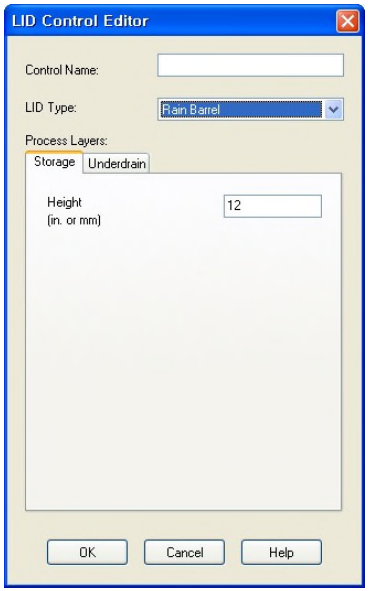
R^2			Flow	SS	BOD	COD	T-N	T-P
Verification	Site 1	2013. 08. 05~06	0.916	0.865	0.679	0.729	0.769	0.669
		2013. 11. 24~25	-	0.854	0.816	0.797	0.795	0.825
	Site 2	2013. 08. 05~06	0.939	0.701	0.655	0.781	0.694	0.665
	Average		**0.928**	**0.807**	**0.717**	**0.768**	**0.753**	**0.720**

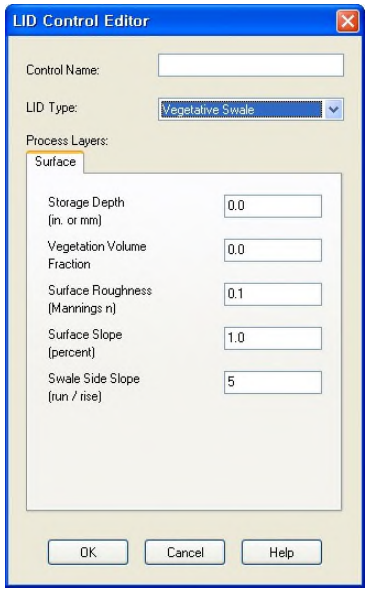
LID Control Options in SWMM











Research Team

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U-Eco City 사업단 Ubiquitous & Ecological City R&D Center

Conclusions

- Automatic Monitoring System Development for
  - Stormwater Events Flow Rates and Pollution Loading Rates
  - Continuous Stream Water Flow and Water Quality
  - Real Time Hydrograph and Pollutograph Possible
  - Internet Broadcast
- Data Confirmation with
  - Field Measurements
- SWMM Model Constructed
  - For Flow Rate and Water Quality Model Forecast
  - For Evaluation of Water Quality Management Alternatives
- Fusion Technologies
  - Future of Environmental Engineering Industry

Questions?

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