HYDROLOGICAL SURVEY CENTER

Hydrometric measurements with quality and accuracy

Oct. 25~27, 2016

Youngsin Roh
(rohys@hsc.re.kr)

Hydrological Survey Center, HSC
Republic of Korea

Background

- In order to improve accuracy of field measurement, it is necessary to improve relevant techniques and use of adequate instrument and analysis method for specific flow conditions.
- Both of Application of advanced techniques and improvement of existing method(measurement, data analysis and QC, assessment) are important
- The main objective of the activities is to provide a technical report or guideline about three parts of hydrological observation technique
  - Real-time discharge measurement (IRDIMS, Integrated Real-time Discharge Measurement System)
  - Sediment measurement
  - development of rating curve
- Each action was based on case study for various conditions and practical experience of HSC

Overview of Hydrological measurements in HSC

- Since 2007, HSC has been conducting hydrological measurement in Korea
  - Discharge measurement and rating curve development in over 150 sites every year
  - Construction and operation of IRDIMS(55 sites have been operating)
  - Sediment measurement in 15~20 sites every year

year	Number of sites						Remarks
	Development of H-Q rating	IRDIMS	Sediment	Soil moisture	Evapotran-spiration	Survey river-bed	
2004	69	-	-	-	-	-	HSC
2005	73	1	-	-	-	-	
2006	99	4	6	-	-	-	
2007	107	8	6	1	1	-	
2008	109	11	6	2	2	-	
2009	114	13	7	2	2	-	
2010	126	16	20	2	2	-	
2011	121	26	20	2	2	-	
2012	123	46	15	2	2	690km	
2013	146	49	15	2	2	530km	
2014	152	52	15	2	2	690km	
2015	153	55	17				
2016	154	58	16				
Plan*	380	104	138	25	25		

* National hydrological observation network in Korea

ACTIVITIES and OUTCOME

- Hydrometric measurements with quality and accuracy

- **Provide guidance on the use of appropriate instruments and methods of observation in diverse conditions**

  - In terms of use of appropriate instruments and methods of observation in diverse conditions, IRDIMS(Integrated Real-time discharge Measurement System) would be a great model and example for real-time discharge measurement in diverse conditions such as backwater and tidally effected area

  - The main purpose of this action is providing technical information and guidance on application of real-time discharge measurement

  - There are two sub actions have been conducted in this action plan,

    (1) Collection of the technical information of IRDIMS

    (2) Case study on measurement of IRDIMS

ACTIVITIES and OUTCOME

(1) Collection of the technical information of IRDIMS

- Technical information related to real-time measurement, which include (a) measuring instruments, (b) discharge calculation and (c) construction and operation of IRDIMS

(a) Analysis on measurement conditions of various types of ADVM by its specifications and flow condition have been carried out based on results from IRDIMS stations.

(b) The information related to discharge calculation using IVM(Index Velocity Method) and its development procedure considering flow condition, characteristics of measuring instrument

(c) The technical information of a proper installation considering development of IVM

- Selection of measuring instrument and type of installation
- Analysis on flow condition to proper installation
- Available range of ADVM measurement to be more accurate measurement

ACTIVITIES and OUTCOME

(2) Case study on measurement of IRDIMS

- Analysis on result of measurement by IRDIMS have been conducted and it contained the procedure on development of index rating. The details are

(a) Measurement in tidally effected area

(b) Measurement in backwater area caused by weir, sluice gate, junction

(c) Evaluation of the result of measurement

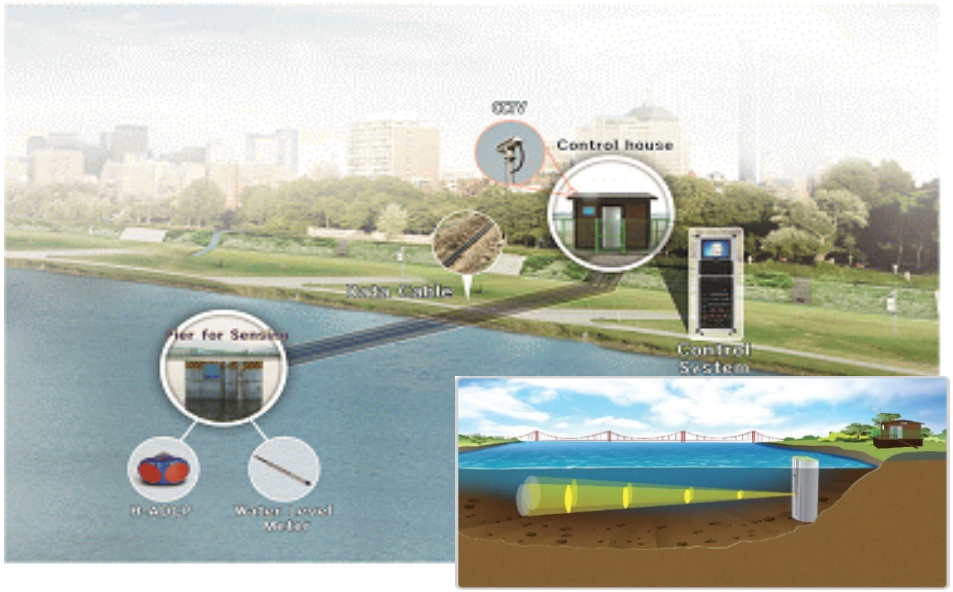
- Comparative analysis using individual measurements
- Assessment of runoff between up and down stream

(d) Development of index rating

- Analysis on available measurement range of ADVM to calculate index velocity properly
- Procedure of index rating development and its software tool
- Analysis of index ratings developed for various conditions

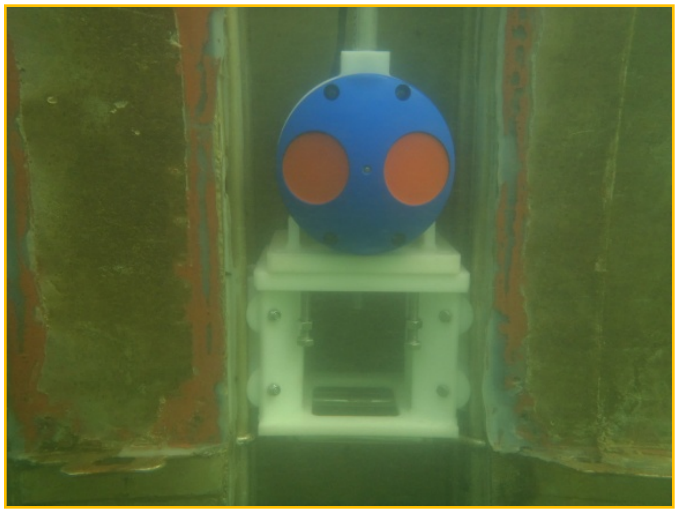
Construction and operation of IRDIMS in Korea

- Integrated River Discharge Measurement System, IRDIMS is widely used to measure real-time flow discharge in Korea
- IRDIMS mainly have been installed in difficult stations to measure discharge due to backwater or tidal effect and key stations to flood forecast
- 55 sts. have been constructed and operating now and it will be extended to more than 100



Total	Han river	Nakdong river	Geum river	Yeongsan river
55	16	22	7	10

Measurement of ADVM



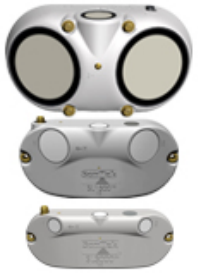
CM-1200kHz

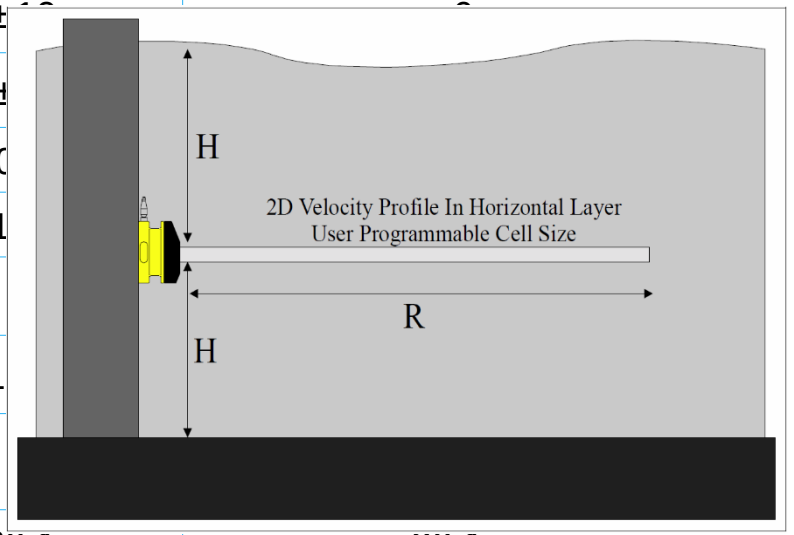
CM-300, 600kHz

ADP-250, 500kHz

ArgonautSL-500, 1500kHz

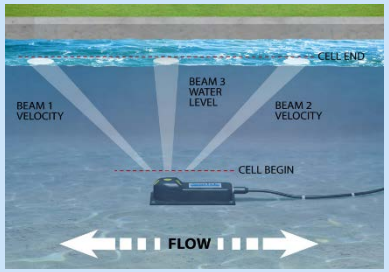
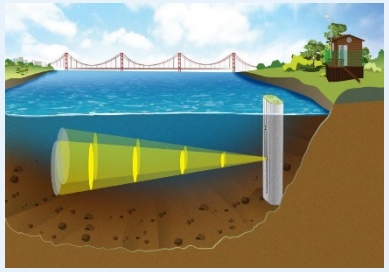
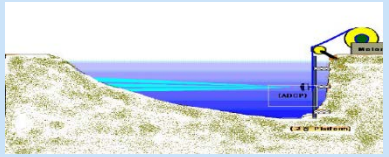
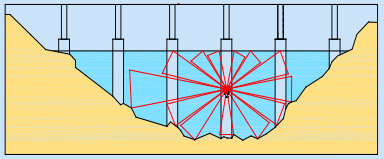
Specification of ADVM

	Specification							
Model	Channel Master			ADP-SL		ARG-SL		
								
Manufacturer	RD Instruments			SonTek				
Frequency(kHz)	300	600	1,200	250	500	500	1,500	3,000
Max. range(m)	300	90	20	180	100	1.5~120	0.2~20	0.2~5
Range of velocity(m/s)	default ±5, max. ±20			±				
Accuracy(%, cm/s)	±0.5%(±0.2㎝/s)			±1%(±				
Resolution(cm/s)	0.1			0				
Number of Cell	128			1				
Cell size(m)	1~16	0.5~8	0.25~4	1~20				
Beam Angle(°)	2.2	1.5	1.5	1				
Min. Blanking distance(m)	1	0.5	0.2	1.5				
Aspect Ratio(R:H)	35:1			20:1		20:1		



Measurement of ADVM

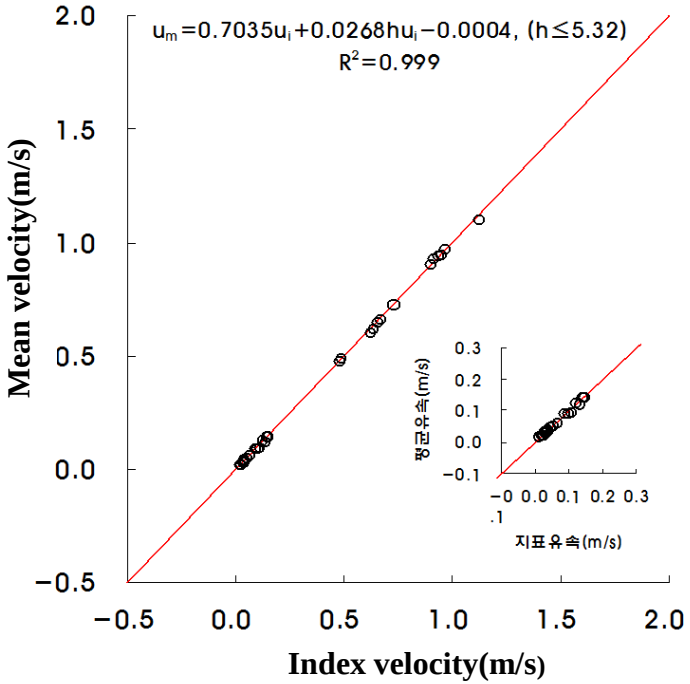
- **Types of measurement**
  - 3 types of installation of ADVM depending on measuri
  - It's important to select the proper position of ADVM t
    cross-section (central core of flow, away from the influ

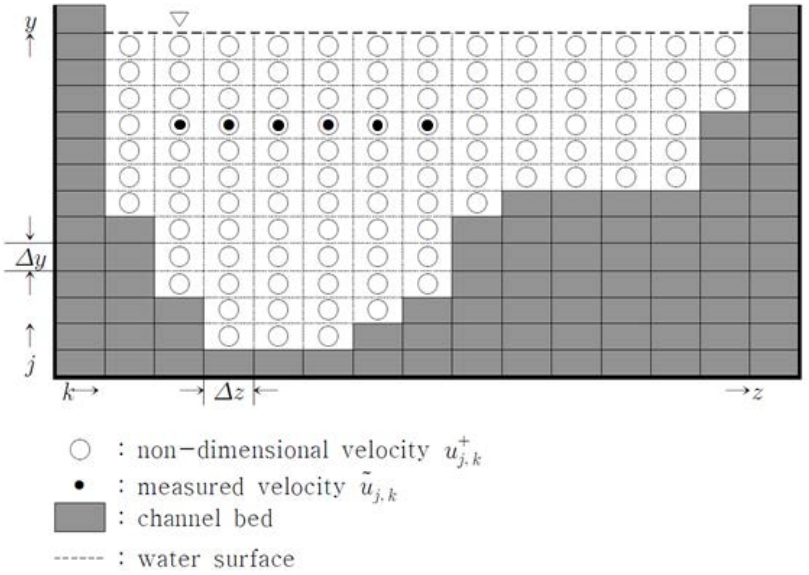
Types	Concept	Examp installa
Up-looking		
Side-looking		
Moving type up and down rotation	 	

- Expensive and complex to install because additional equipment are required to move ADVM

Calculation of Discharge

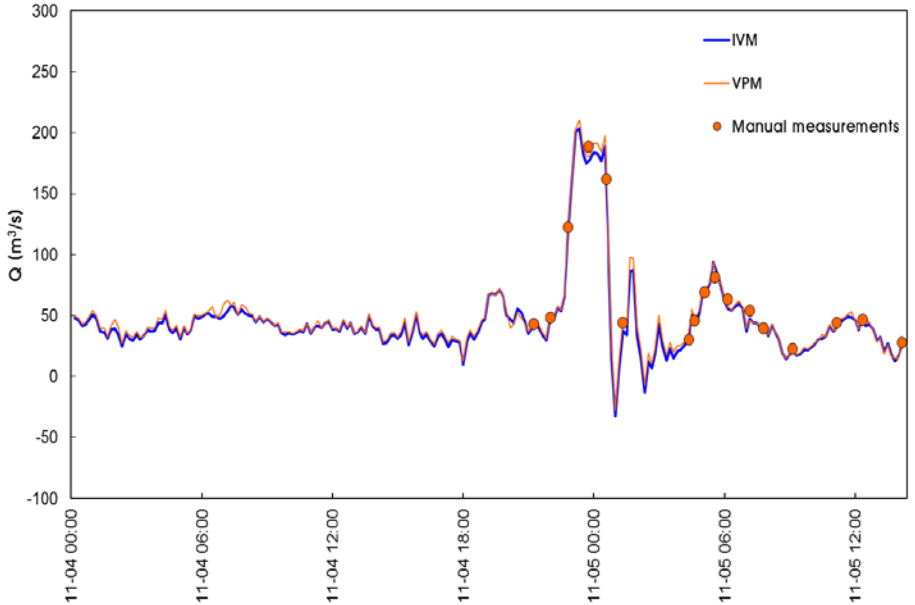
- For real-time discharge measurement by ADVM, it is necessary to calculate mean velocity from ADVM measurement in order to calculate discharge
- **IVM(Index Velocity Method)**
  - Mean velocity is calculated by relationship between index- and mean velocity
  - A number of individual discharge measurements are needed to develop relationship between index- and mean velocity throughout the expected range in stage or mean velocity.
- **VPM(Velocity Profile Method)**
  - Velocity distribution of cross section is estimated by applying theoretical velocity profile

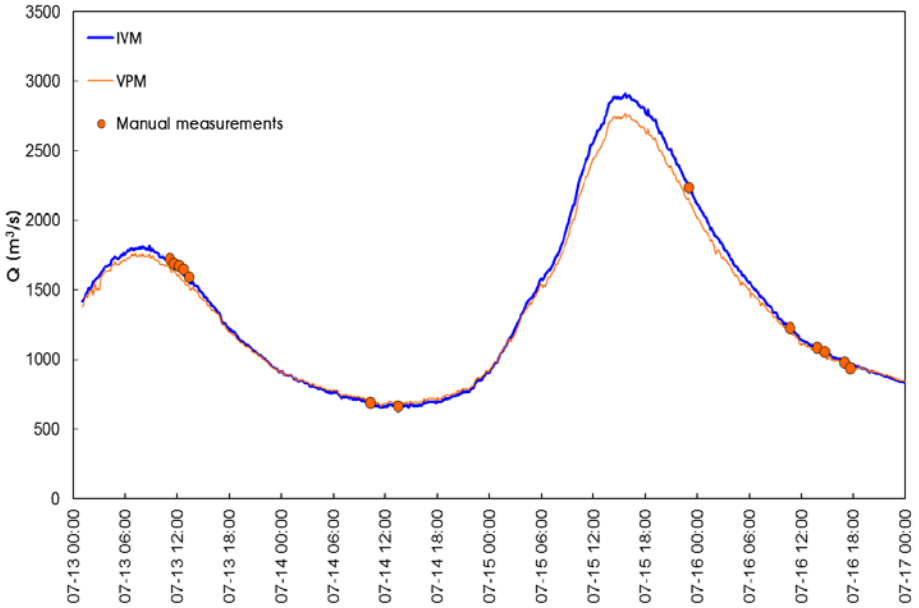




Calculation of Discharge

- Comparison between **IVM and VPM**
  - Results of discharge by IVM and VPM during low and high flow were compared with manual measurements
  - Both method showed a similar result and accuracy
  - Comparative error with manual meas. :
    IVM(average 4.4%, 0.2~21.6%), VPM(average 5.9%, 0.7~17.7%)





Standard procedures of IVM

Selection of site	• Field investigation to select the site including survey of cross-section, discharge measurement and check velocity profile • Temporary operation of ADVM to check measurement
Selection of ADVM location & position	• Identify optimum location and position at the chosen site • Selection of optimum alignment of the ADVM
Configuring the ADVM	• Check the available measurement range(setting of cell) • Setting of Measurement Interval(MI) & Averaging Period(AP) • Setting of raw data configuration
Discharge measurement to get V_m	• Discharge measurements considering variant V_m range
Check of continuous data from ADVM	• Examination of ADVM data : Velocity , Temperature, Cell end, Signal amplitudes & instruments noise, etc.
Calculation of cross-section area	• Identify and survey of standard cross-section used for calculation of discharge • Development of stage-area rating • Checking of change of cross-section
Development of Index rating & discharge calculation	• Extracting of V_i and checking of relation between V_m • Development of index rating • Checking on correlation of index rating between V_i and V_m and evaluate possible shift • Separation of the rating for applicable period depend on cross-section change • Discharge calculation

Development of software tool for IVM

- **EDPad(Extracting Data Pad)**

- Data extracting from ADVM

- Data checking (available range of meas., signal amplitude etc.)

- Calculation of V_i

- Data processing of missing or abnormal data

- **MCDPad(Multi-Computing Discharge Pad)**

- Calculation of cross-section area(H-A rating or coordination of cross-section)

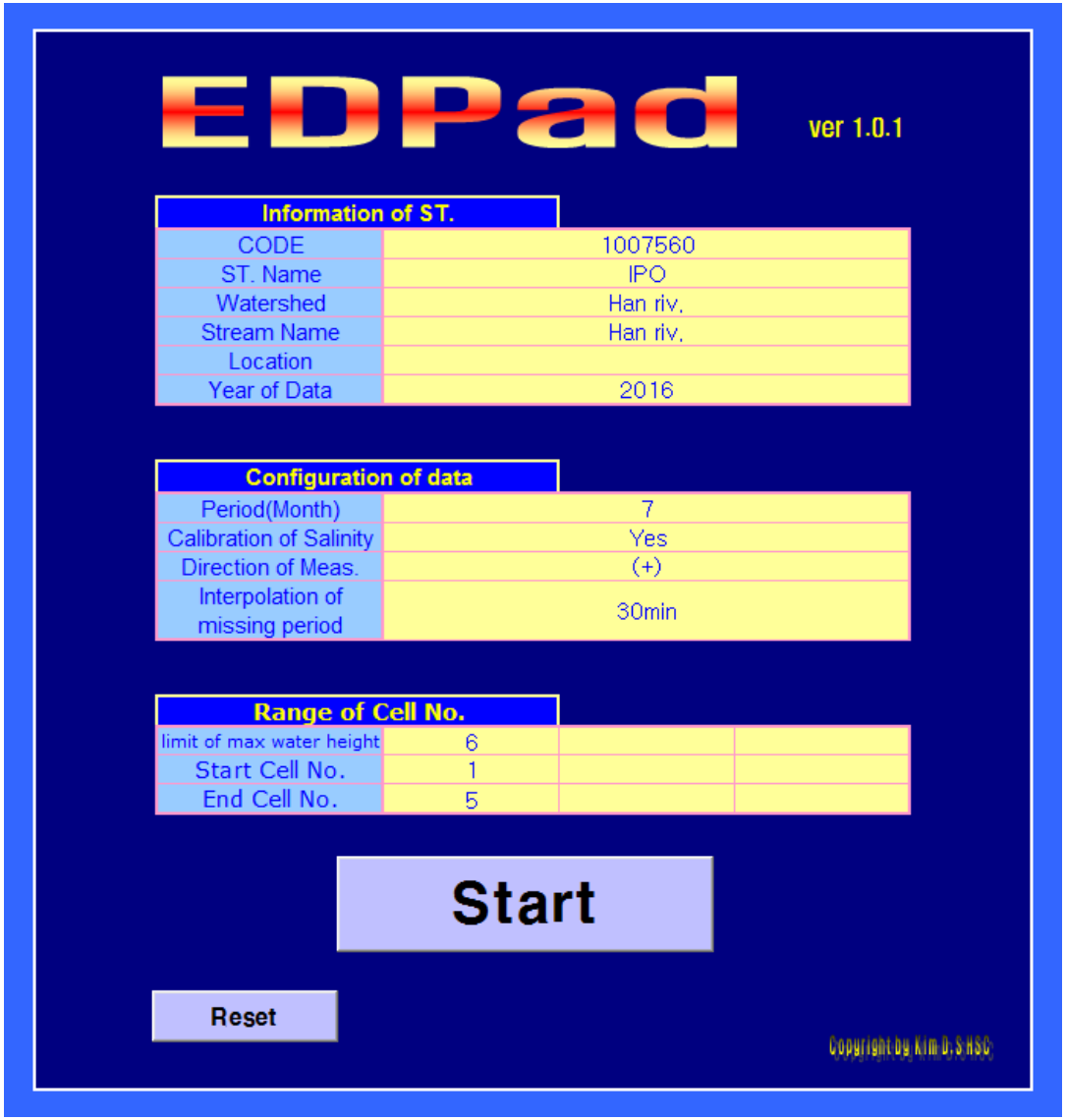
- Development of relationship between V_i and V_m

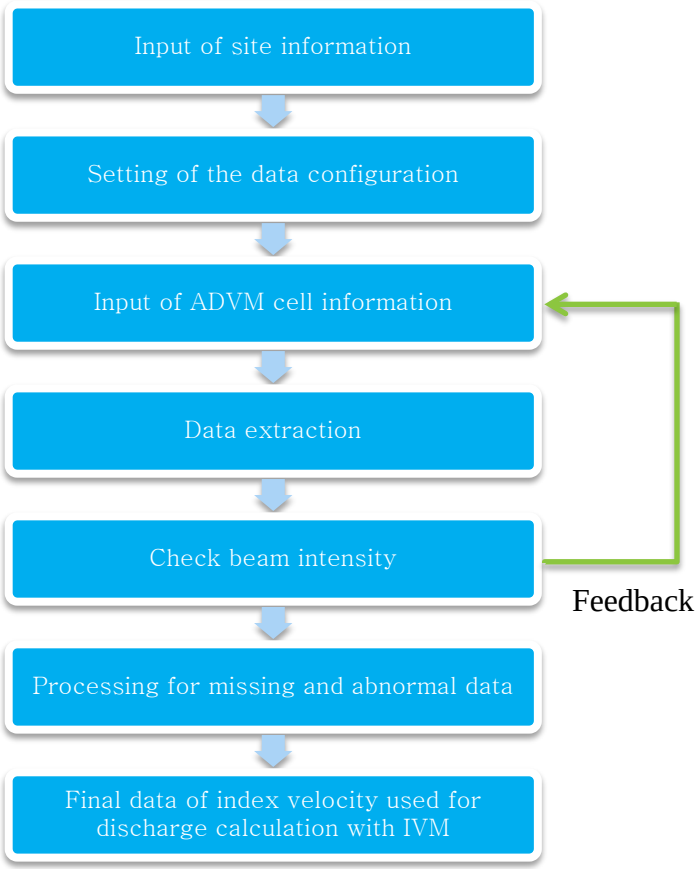
- Checking of correlation of index rating and evaluate possible shift

- Separation of the rating for applicable period depend on cross-section change

- Calculation of discharge

Development of software tool for IVM





Development of software tool for IVM

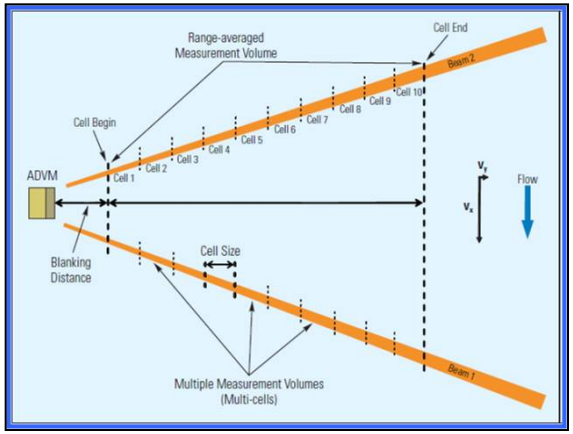
- **Data extracting from ADVM**

- Time series of water height, 2-D velocity vector and signal amplitude(or intensity) along the transvers line of ADVM

Data extracting

Extracting ◄ 1.Load data | 2.Extracting | 3.Data processing

	H	Cell No.	aEW	aNS	aE1	aE2					
201607010000	2,129	1	-5	28	154	142	2	-31	23	134	132
201607010010	2,125	1	-65	26	153	143	2	-79	7	135	133
201607010020	2,126	1	-83	49	154	141	2	-80	1	139	134
201607010030	2,124	1	-70	46	154	142	2	-30	-23	137	135
201607010040	2,122	1	-48	26	154	143	2	64	-32	138	133
201607010050	2,121	1	-5	-29	154	144	2	-30	-43	137	132
201607010100	2,12	1	32	-6	154	145	2	83	-22	140	133
201607010110	2,118	1	-21	-10	157	145	2	54	-41	140	134
201607010120	2,115	1	5	-21	157	145	2	67	-22	140	135
201607010130	2,113	1	29	-6	158	146	2	106	-58	141	134
201607010140	2,111	1	7	-19	154	146	2	-31	13	137	137
201607010150	2,108	1	21	-11	156	146	2	17	-32	139	136
201607010200	2,104	1	37	-13	157	146	2	-22	1	138	138
201607010210	2,098	1	44	-26	159	143	2	-14	-29	141	135
201607010220	2,098	1	104	-39	157	144	2	-14	28	142	136
201607010230	2,094	1	22	1	156	147	2	-7	5	139	138
201607010240	2,091	1	17	-38	157	145	2	87	-10	137	135
201607010250	2,087	1	8	-29	157	146	2	20	-14	136	135
201607010300	2,093	1	2	-32	160	149	2	-14	11	140	135
201607010310	2,089	1	28	-29	159	150	2	37	-21	138	134
201607010320	2,088	1	28	-28	158	148	2	28	-25	140	134
201607010330	2,088	1	51	-16	158	146	2	61	-31	138	134
201607010340	2,09	1	104	-31	158	146	2	47	-32	137	132
201607010350	2,088	1	67	-22	156	145	2	45	-44	137	133
201607010400	2,091	1	4	-15	156	146	2	24	-18	138	134
201607010410	2,091	1	42	-8	155	146	2	25	-25	136	133
201607010420	2,094	1	42	-9	156	144	2	11	-29	135	131
201607010430	2,095	1	7	-4	157	141	2	47	-2	135	131
201607010440	2,096	1	45	0	156	144	2	15	38	132	132
201607010450	2,097	1	35	-15	159	143	2	74	2	136	130
201607010500	2,099	1	-66	29	159	144	2	54	-20	134	133
201607010510	2,1	1	-25	49	158	144	2	-21	55	139	133
201607010520	2,101	1	-14	14	156	148	2	34	15	142	134
201607010530	2,102	1	-24	36	157	145	2	101	-76	136	134
201607010540	2,105	1	-14	9	160	146	2	-15	-3	142	136
201607010550	2,112	1	-60	22	156	149	2	50	-27	140	134
201607010600	2,117	1	52	-6	157	147	2	25	-20	138	135
201607010610	2,118	1	5	1	157	145	2	44	-32	136	136
201607010620	2,116	1	-1	-3	158	146	2	40	-34	137	137
201607010630	2,116	1	31	-12	157	145	2	19	-17	138	136



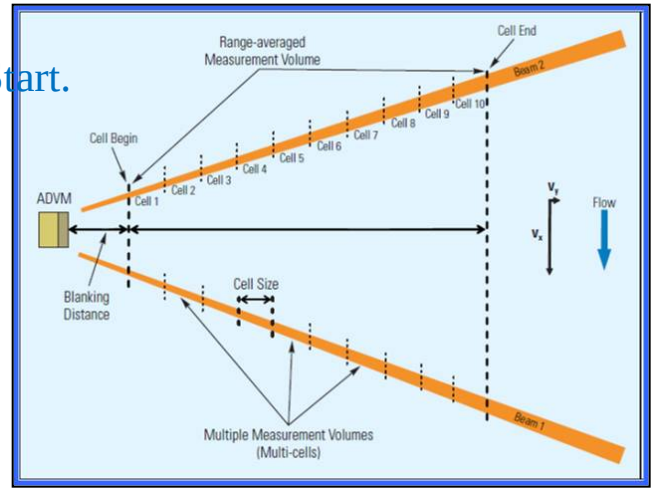
Development of software tool for IVM

- **Checking of signal intensity**

  - Determination of available range of measurement used as V_i
  - Examination of decreasing pattern of signal intensity

  ⇒ Available range : section that SI gradually decrease

  ⇒ If it shows difference with initial setup, it should be changed in Start.

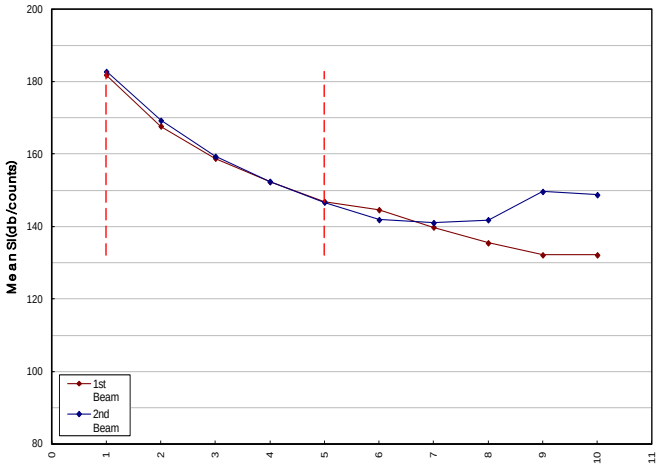


Signal Intensity

Copylight by Kim D.S., HSC

Mean SI		
Cell No.	1st Beam	2nd Beam
1	181,9	182,8
2	167,7	169,3
3	158,8	159,4
4	152,3	152,4
5	146,9	146,7
6	144,6	141,9
7	139,8	141,1
8	135,5	141,9
9	132,2	149,7
10	132,2	148,8
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		

유효셀신호강도	하한선	0,2	상한선	0,3	평균	
시간	1st Beam	2nd Beam	1st Beam	2nd Beam	1st Beam	2nd Beam
201607010000	101,6	96,3	165,1	156,5	127,0	120,4
201607010010	102,1	96,6	165,9	157,0	127,6	120,8
201607010020	103,2	96,3	167,7	156,5	129,0	120,4
201607010030	102,4	97,1	166,4	157,8	128,0	121,4
201607010040	102,4	97,3	166,4	158,1	128,0	121,6
201607010050	104,0	97,0	169,0	157,6	130,0	121,2
201607010100	105,0	98,2	170,6	159,6	131,2	122,8
201607010110	105,1	98,7	170,8	160,4	131,4	123,4
201607010120	105,6	98,9	171,6	160,7	132,0	123,6
201607010130	106,4	98,1	172,9	159,4	133,0	122,6
201607010140	104,5	99,8	169,8	162,2	130,6	124,8
201607010150	103,8	99,0	168,7	160,9	129,8	123,8
201607010200	104,8	99,4	170,3	161,5	131,0	124,2
201607010210	105,8	97,9	171,9	159,1	132,2	122,4
201607010220	105,6	98,2	171,6	159,6	132,0	122,8
201607010230	105,4	98,7	171,3	160,4	131,8	123,4
201607010240	104,5	98,1	169,8	159,4	130,6	122,6
201607010250	104,2	98,6	169,3	160,2	130,2	123,2
201607010300	105,9	99,0	172,1	160,9	132,4	123,8
201607010310	104,8	98,1	170,3	159,4	131,0	122,6
201607010320	105,1	98,4	170,8	159,9	131,4	123,0



Development of software tool for IVM

Final data of V_i

- V_i is calculated by averaging velocities within available range of cell
- Interpolation of Missing or abnormal data within 30min

⇒ Final time series data of Vi used for development of index rating and calculation of discharge

Extracted V_i

Copyright by Kim D.S., HSC

Available No.	Total No.
	4464

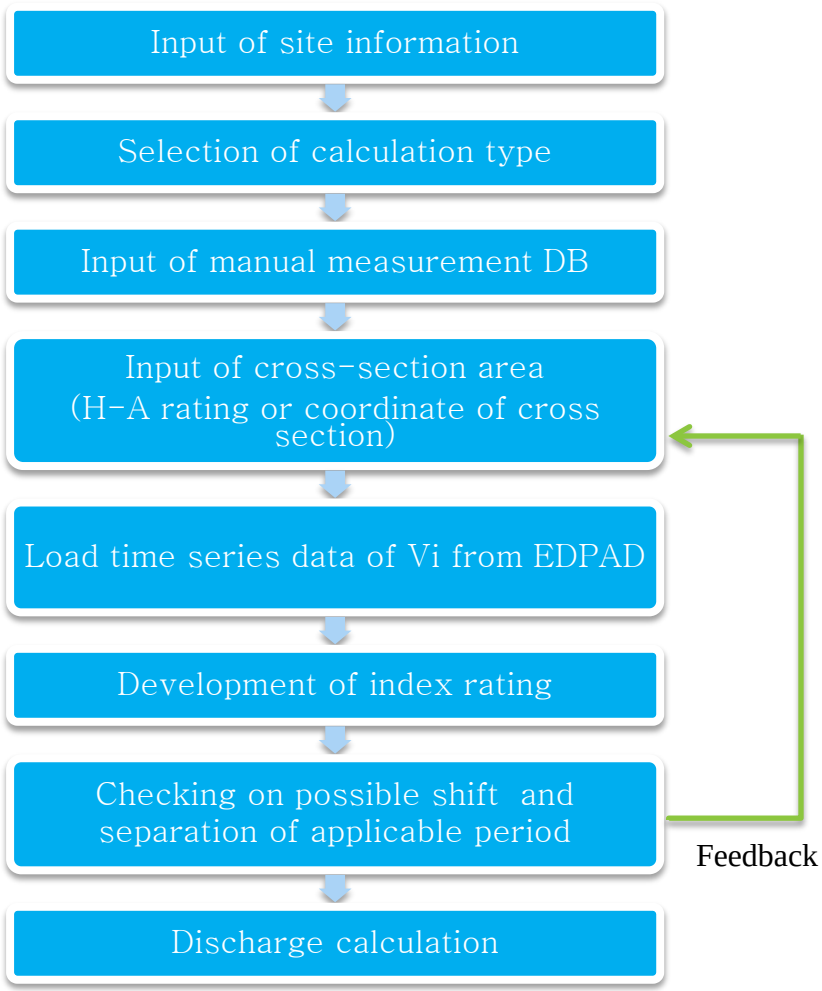
Raw Data / Final data / Salinity

Raw Data: Time	H	Vi	Final data: Time	H	Vi	Salinity
201607010000	2.13	-0.031	201607010000	2.13	-0.031	0
201607010010	2.13	-0.051	201607010010	2.13	-0.051	0
201607010020	2.13	-0.058	201607010020	2.13	-0.058	0
201607010030	2.12	-0.01	201607010030	2.12	-0.01	0
201607010040	2.12	-0.011	201607010040	2.12	-0.011	0
201607010050	2.12	0.019	201607010050	2.12	0.019	0
201607010100	2.12	0.032	201607010100	2.12	0.032	0
201607010110	2.12	-0.002	201607010110	2.12	-0.002	0
201607010120	2.12	0.011	201607010120	2.12	0.011	0
201607010130	2.11	0.029	201607010130	2.11	0.029	0
201607010140	2.11	0.007	201607010140	2.11	0.007	0
201607010150	2.11	0.021	201607010150	2.11	0.021	0
201607010200	2.1	-0.017	201607010200	2.1	-0.017	0
201607010210	2.1	-0.014	201607010210	2.1	-0.014	0
201607010220	2.1	-0.011	201607010220	2.1	-0.011	0
201607010230	2.09	0.012	201607010230	2.09	0.012	0
201607010240	2.09	0.017	201607010240	2.09	0.017	0
201607010250	2.09	0.008	201607010250	2.09	0.008	0
201607010300	2.09	0.034	201607010300	2.09	0.034	0
201607010310	2.09	0.022	201607010310	2.09	0.022	0
201607010320	2.09	0	201607010320	2.09	0	0
201607010330	2.09	0.021	201607010330	2.09	0.021	0
201607010340	2.09	0.007	201607010340	2.09	0.007	0
201607010350	2.09	0.012	201607010350	2.09	0.012	0
201607010400	2.09	0.004	201607010400	2.09	0.004	0
201607010410	2.09	0.025	201607010410	2.09	0.025	0
201607010420	2.09	-0.002	201607010420	2.09	-0.002	0
201607010430	2.1	0.007	201607010430	2.1	0.007	0
201607010440	2.1	0.015	201607010440	2.1	0.015	0
201607010450	2.1	0.007	201607010450	2.1	0.007	0
201607010500	2.1	0.007	201607010500	2.1	0.007	0
201607010510	2.1	-0.021	201607010510	2.1	-0.021	0
201607010520	2.1	0.004	201607010520	2.1	0.004	0
201607010530	2.1	-0.001	201607010530	2.1	-0.001	0
201607010540	2.11	-0.011	201607010540	2.11	-0.011	0
201607010550	2.11	0.017	201607010550	2.11	0.017	0

Status of ADVM

Water Temp.	Pitch	Roll
26.99	0.1	0
26.98	0.1	0
26.97	0.1	0
26.96	0.1	0
26.96	0.1	0
26.96	0.1	0
26.95	0.1	0
26.95	0.1	0
26.94	0.1	0
26.94	0.1	0
26.93	0.1	0
26.92	0.1	0
26.92	0.1	0
26.91	0.1	0
26.9	0.1	0
26.89	0.1	0
26.89	0.1	0
26.88	0.1	0
26.87	0.1	0
26.86	0.1	0
26.84	0.1	0
26.83	0	0
26.82	0.1	0
26.81	0.1	0
26.8	0.1	0
26.8	0.1	0
26.79	0.1	0
26.79	0.1	0
26.78	0.1	0
26.77	0.1	0
26.77	0.1	0
26.76	0.1	0
26.75	0.1	0
26.75	0.1	0
26.74	0.1	0
26.74	0.1	0

Development of software tool for IVM



Development of software tool for IVM

- **Manual measurements to obtain V_m**
  - Manual Measurements should be conducted in variant V_m range
  - Measurement data are managed by DBPAD

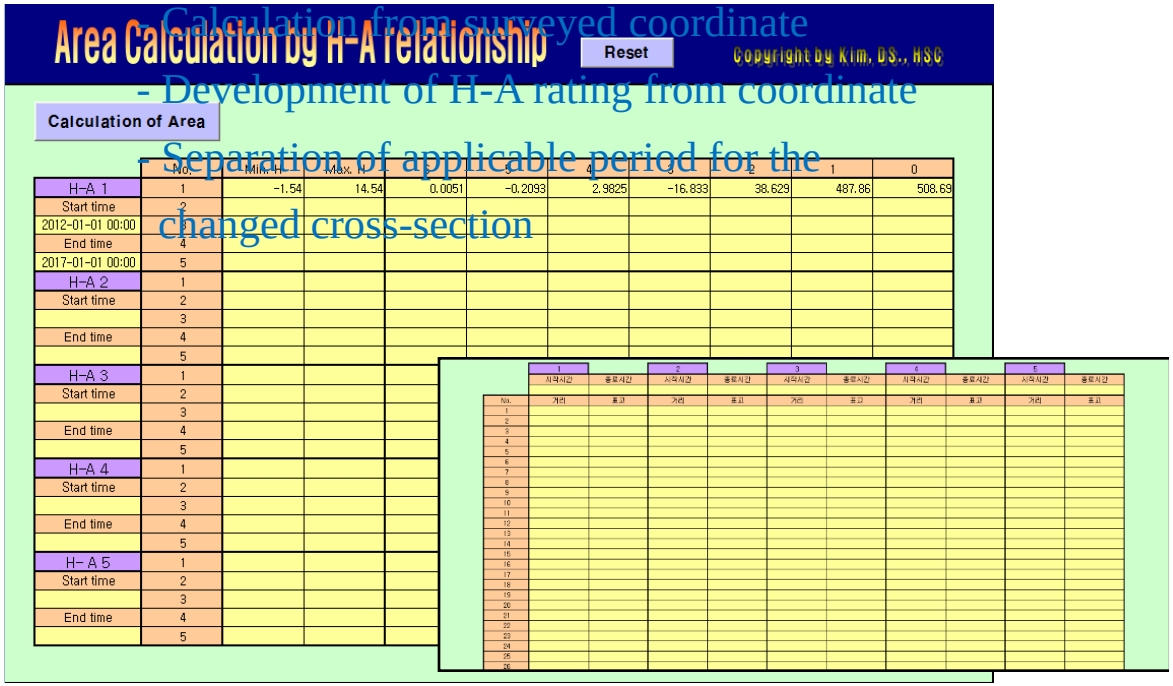
DB of Individual Meas.

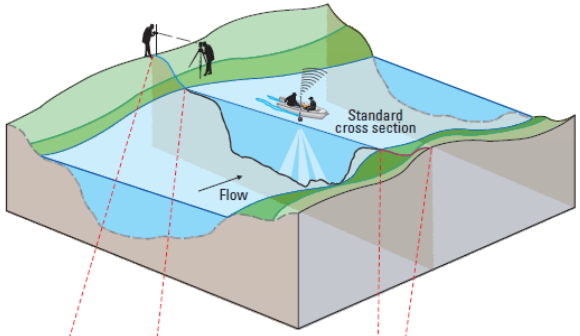
Reset

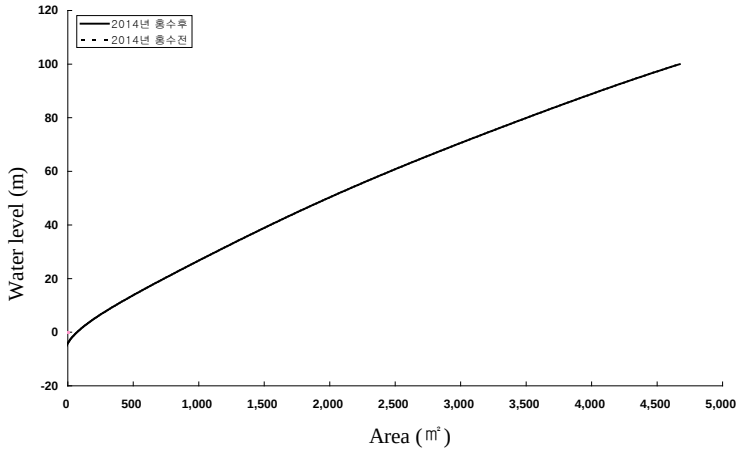
DM No	측정 일시 (yy-mm-dd hh:mm)	수위 H (m)	수면폭 W (m)	단면적 A (m²)	평균유속 Vm (m/sec)	유량 Q (m³/sec)	측정장비 (Meas. Type)	시작-종료 시간 Start-End time	시작수위 H_{start}	종료수위 H_{end}	Available past data H	Vi	A
1007660_12_001	2012-10-12 09:58	2,31				168,04	ADVM	12-10-12 09:58 ~ 11:11	2,31	2,31	100,00		
1007660_12_002	2012-10-30 14:22	2,42				190,26	ADVM	12-10-30 14:22 ~15:29	2,42	2,42	100,00		
1007660_12_003	2012-11-15 10:00	2,37				212,50	ADVM	12-11-15 10:00 ~ 11:06	2,37	2,37	100,00		
1007660_13_001	2013-03-11 16:39	2,26	522,72	1573,35	0,10	156,93	ADVM	13-03-11 16:39 ~ 17:50	2,24	2,27	100,00		
1007660_13_002	2013-03-18 15:10	2,40	548,32	1771,96	0,14	245,57	ADVM	13-03-18 15:10 ~ 16:20	2,40	2,40	100,00		
1007660_13_003	2013-04-01 14:01	2,42	544,78	1751,13	0,22	380,87	ADVM	13-04-01 14:01 ~ 14:30	2,42	2,42	100,00		
1007660_13_005	2013-04-10 13:59	1,92	523,31	1427,50	0,26	369,42	ADVM	13-04-10 13:59 ~ 14:17	1,95	1,88	100,00		
1007660_13_009	2013-04-10 15:00	2,07	504,71	1499,40	0,07	105,40	ADVM	13-04-10 15:00 ~ 15:20	2,05	2,09	100,00		
1007660_13_011	2013-04-10 15:30	2,08	508,10	1503,60	0,26	397,03	ADVM	13-04-10 15:30 ~ 15:37	2,08	2,08	100,00		
1007660_13_013	2013-04-10 16:00	2,01	516,54	1452,07	0,23	328,95	ADVM	13-04-10 16:00 ~ 16:50	2,01	2,00	100,00		
1007660_13_015	2013-05-08 15:30	2,38	513,77	1634,43	0,11	177,15	ADVM	13-05-08 15:30 ~ 16:40	2,38	2,37	100,00		
1007660_13_016	2013-05-28 14:00	2,53	524,89	1731,08	0,27	463,02	ADVM	13-05-28 14:00 ~ 15:10	2,54	2,52	100,00		
1007660_13_017	2013-06-27 07:45	2,24	527,96	1564,64	0,22	338,27	ADVM	13-06-27 07:45 ~ 08:55	2,20	2,27	100,00		
1007660_13_018	2013-07-03 10:53	2,22	528,67	1616,70	0,22	350,86	ADVM	13-07-03 10:53 ~ 12:15	2,21	2,22	100,00		
1007660_13_019	2013-07-14 08:14	2,54	515,02	1725,13	0,54	936,56	ADVM	13-07-14 08:14 ~ 08:45	2,52	2,56	100,00		
1007660_13_020	2013-07-14 13:54	2,39	521,41	1620,25	0,54	876,30	ADVM	13-07-14 13:54 ~ 14:25	2,39	2,39	100,00		
1007660_13_021	2013-07-15 11:34	2,75	523,44	1829,43	0,81	1472,80	ADVM	13-07-15 11:34 ~ 12:05	2,75	2,75	100,00		
1007660_13_023	2013-07-16 10:56	3,35	520,63	2136,23	1,08	2317,20	ADVM	13-07-16 10:56 ~ 11:25	2,22	2,19	100,00		
1007660_13_024	2013-07-16 12:34	3,22	517,36	2075,95	1,08	2236,81	ADVM	13-07-16 12:34 ~ 13:05	2,12	2,07	100,00		
1007660_13_025	2013-07-16 14:26	3,10	507,81	1989,85	1,06	2116,96	ADVM	13-07-16 16:37 ~ 17:05	2,95	2,90	100,00		
1007660_13_026	2013-07-16 16:37	2,93	508,41	1907,33	1,03	1971,40	ADVM	13-07-16 18:25 ~ 18:55	2,80	2,76	100,00		
1007660_13_027	2013-07-16 18:25	2,78	521,65	1857,93	0,99	1834,91	ADVM	13-07-16 18:25 ~ 18:55	2,80	2,76	100,00		
1007660_13_028	2013-07-19 11:35	2,14	510,19	1530,25	0,88	1350,32	ADVM	13-07-19 11:35 ~ 12:05	2,14	2,14	100,00		
1007660_13_037	2013-07-24 10:24	2,97	513,07	1899,53	1,04	1979,42	ADVM	13-07-24 10:24 ~ 10:55	2,98	2,96	100,00		
1007660_13_038	2013-08-06 16:24	2,37	510,26	1628,13	0,35	566,06	ADVM	13-08-06 16:24 ~ 16:55	2,38	2,36	100,00		
1007660_13_039	2013-08-21 10:45	2,39	516,23	1632,83	0,09	143,44	ADVM	13-08-21 10:45 ~ 12:05	2,40	2,38	100,00		
1007660_13_040	2013-08-28 10:05	2,40	511,47	1653,02	0,13	212,31	ADVM	13-08-28 10:05 ~ 10:45	2,40	2,39	100,00		
1007660_13_041	2013-08-28 10:55	2,36	511,50	1614,98	0,10	156,02	ADVM	13-08-28 10:55 ~ 11:25	2,39	2,32	100,00		
1007660_13_042	2013-09-11 16:57	2,32	509,87	1611,74	0,15	245,36	ADVM	13-09-11 16:57 ~ 18:05	2,32	2,31	100,00		
1007660_13_043	2013-09-25 16:25	2,21	520,40	1560,36	0,12	189,43	ADVM	13-09-25 16:25 ~ 17:45	2,21	2,21	100,00		
1007660_13_044	2013-10-23 17:05	2,33	513,40	1607,75	0,10	153,43	ADVM	13-10-23 17:05 ~ 18:15	2,34	2,31	100,00		
1007660_13_045	2013-11-28 12:55	2,21	521,14	1537,88	0,09	130,23	ADVM	13-11-28 12:55 ~ 13:25	2,21	2,21	100,00		
1007660_13_046	2013-12-05 14:34	2,20	527,42	1542,90	0,08	120,86	ADVM	13-12-05 14:34 ~ 15:45	2,20	2,20	100,00		

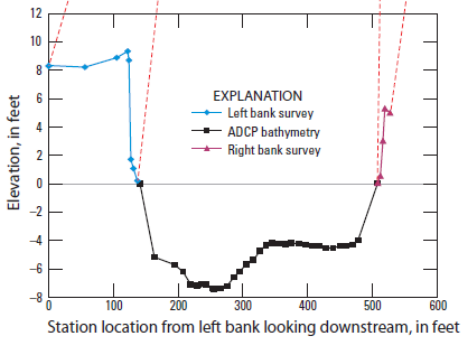
Development of software tool for IVM

- **Calculation of cross-section area**









Development of software tool for IVM

- **Input time series data of V_i from EDpad**

  - Final data of V_i from EDpad are input into the MCDpad to develop relationship with V_m

Input of H, V_i

Reset

Copyright by Kim, DS., HSC

Selection of H: H1(main)

Input

No.	Time	H_1	$H_{1rev.}$	H_2	$H_{2rev.}$	V_i	$V_{irev.}$
1	2016-01-01 00:00	1.99	1.99	2.14	2.14	0.043	0.043
2	2016-01-01 00:10	1.99	1.99	2.15	2.15	0.030	0.030
3	2016-01-01 00:20	2.00	2.00	2.15	2.15	0.033	0.033
4	2016-01-01 00:30	2.00	2.00	2.15	2.15	0.029	0.029
5	2016-01-01 00:40	2.00	2.00	2.15	2.15	0.033	0.033
6	2016-01-01 00:50	2.00	2.00	2.15	2.15	0.033	0.033
7	2016-01-01 01:00	2.01	2.01	2.16	2.16	0.040	0.040
8	2016-01-01 01:10	2.01	2.01	2.16	2.16	0.044	0.044
9	2016-01-01 01:20	2.01	2.01	2.16	2.16	0.035	0.035
10	2016-01-01 01:30	2.01	2.01	2.16	2.16	0.036	0.036
11	2016-01-01 01:40	2.01	2.01	2.16	2.16	0.028	0.028
12	2016-01-01 01:50	2.01	2.01	2.16	2.16	0.043	0.043
13	2016-01-01 02:00	2.01	2.01	2.16	2.16	0.045	0.045
14	2016-01-01 02:10	2.01	2.01	2.16	2.16	0.036	0.036
15	2016-01-01 02:20	2.00	2.00	2.16	2.16	0.044	0.044
16	2016-01-01 02:30	2.00	2.00	2.16	2.16	0.039	0.039
17	2016-01-01 02:40	1.99	1.99	2.16	2.16	0.037	0.037
18	2016-01-01 02:50	2.00	2.00	2.16	2.16	0.043	0.043
19	2016-01-01 03:00	2.00	2.00	2.16	2.16	0.044	0.044
20	2016-01-01 03:10	2.00	2.00	2.16	2.16	0.044	0.044
21	2016-01-01 03:20	2.01	2.01	2.16	2.16	0.041	0.041
22	2016-01-01 03:30	2.01	2.01	2.16	2.16	0.039	0.039
23	2016-01-01 03:40	2.01	2.01	2.16	2.16	0.039	0.039
24	2016-01-01 03:50	2.01	2.01	2.16	2.16	0.037	0.037
25	2016-01-01 04:00	2.00	2.00	2.15	2.15	0.035	0.035
26	2016-01-01 04:10	2.00	2.00	2.15	2.15	0.041	0.041
27	2016-01-01 04:20	2.00	2.00	2.15	2.15	0.033	0.033
28	2016-01-01 04:30	2.00	2.00	2.15	2.15	0.045	0.045
29	2016-01-01 04:40	2.00	2.00	2.15	2.15	0.047	0.047
30	2016-01-01 04:50	1.99	1.99	2.15	2.15	0.041	0.041
31	2016-01-01 05:00	1.99	1.99	2.15	2.15	0.033	0.033
32	2016-01-01 05:10	1.99	1.99	2.15	2.15	0.036	0.036
33	2016-01-01 05:20	1.99	1.99	2.15	2.15	0.036	0.036
34	2016-01-01 05:30	2.00	2.00	2.15	2.15	0.043	0.043
35	2016-01-01 05:40	2.00	2.00	2.15	2.15	0.035	0.035
36	2016-01-01 05:50	2.00	2.00	2.15	2.15	0.039	0.039

Development of software tool for IVM

- **Matching of V_i and V_m**

  - In order to match V_i and V_m, it is necessary to interpolate V_i at the 1min intervals
  - Averaging of the interpolated V_i during the manual measurement
  - Using of V_i at the meantime between start and end of manual measurement

Develeopment of V_i and V_m relation

Reset

Load data(all) | Load data(selection) | Calc. | 측정방법 및 년도구분

Indiv. Meas. | Start No. of indiv. Meas. | 59

제외성과는 수위에 "100" 입력!!, 지표유속식개발에만 제외는 수위에 "200" 입력!!

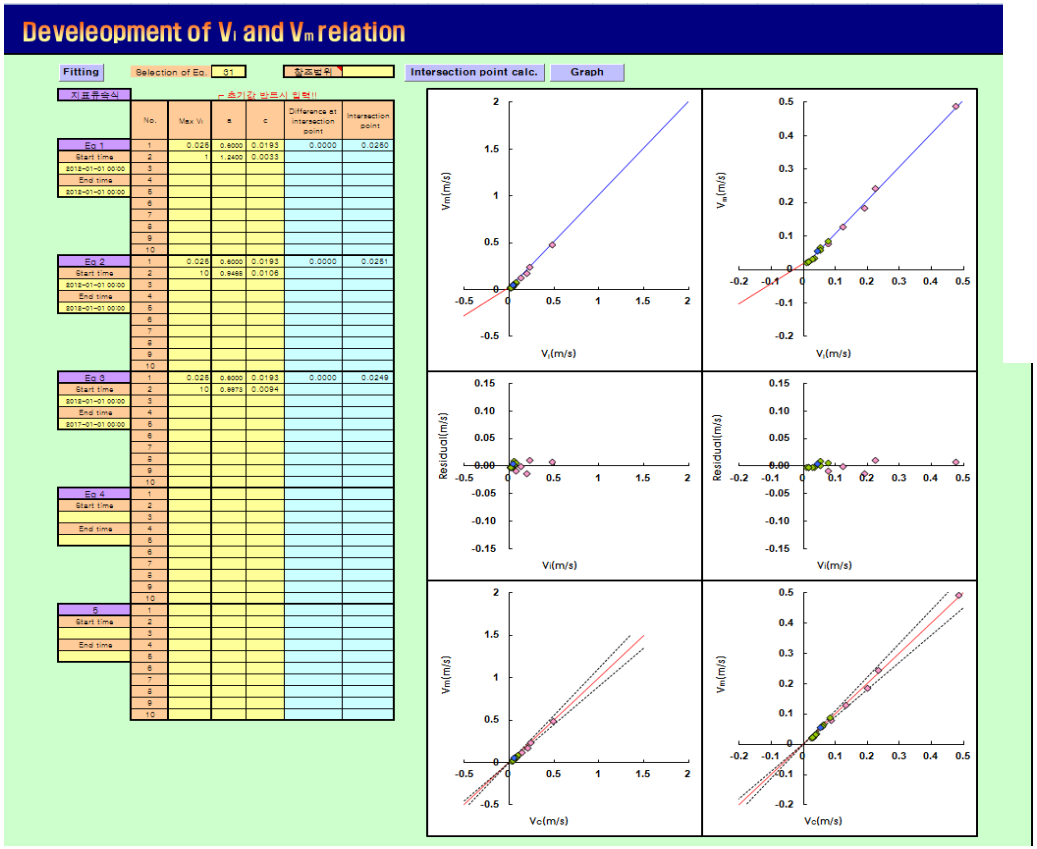
No.	Start time	End time	Mean time	수위	지표유속 (V)	단면적(A)	평균유속 (V_m) Q_m/A	환산평균유속 (V_c)	측정유량 (Q_m)	환산유량 (Q_c) V_c*A	유량편차 Q_m-Q_c	편차율(%) $(Q_m-Q_c)/Q_m$	V_i and V_m Matching	Applied Eq.	Meas. Type
1	2014-12-10 11:49	2014-12-10 12:39	2014-12-10 12:14	2.20	0.043	1649.37	0.057	0.052	93.49	85.77	7.72	8.3%		320	ADVM
2	2015-02-04 14:55	2015-02-04 15:39	2015-02-04 15:17	2.15	0.049	1623.48	0.068	0.058	110.99	94.16	16.83	15.2%		320	ADVM
3	2015-03-20 10:43	2015-03-20 11:08	2015-03-20 10:55	2.17	0.073	1633.84	0.089	0.082	144.76	133.97	10.79	7.5%		320	ADVM
4	2015-04-08 15:57	2015-04-08 16:49	2015-04-08 16:23	2.29	0.048	1695.89	0.060	0.057	101.13	96.67	4.46	4.4%		320	ADVM
5	2015-05-14 15:20	2015-05-14 16:09	2015-05-14 15:44	2.23	0.03	1664.89	0.038	0.039	63.51	64.93	(1.42)	-2.2%		320	ADVM
6	2015-06-08 13:46	2015-06-08 14:23	2015-06-08 14:04	2.15	0.014	1623.48	0.027	0.028	43.06	45.46	(2.40)	-5.6%		310	ADVM
7	2015-07-03 10:38	2015-07-03 11:47	2015-07-03 11:12	2.13	0.013	1613.11	0.027	0.027	44.35	43.55	0.80	1.8%		310	ADVM
8	2015-07-12 15:52	2015-07-12 17:03	2015-07-12 16:27	2.15	0.024	1623.48	0.033	0.034	53.39	55.20	(1.81)	-3.4%		310	ADVM
9	2015-07-26 10:23	2015-07-26 10:54	2015-07-26 10:38	100.00											ADVM
10	2015-08-12 12:16	2015-08-12 12:49	2015-08-12 12:32	100.00											ADVM
11	2015-09-17 10:29	2015-09-17 11:03	2015-09-17 10:46	100.00											ADVM
12	2015-11-11 14:31	2015-11-11 15:08	2015-11-11 14:49	2.12	0.008	1607.93	0.023	0.024	37.65	38.59	(0.94)	-2.5%		310	ADVM
13	2015-12-16 16:17	2015-12-16 17:31	2015-12-16 16:54	2.12	0.012	1607.93	0.027	0.027	43.40	43.41	(0.01)	0.0%		310	ADVM
14	2016-03-17 14:48	2016-03-17 15:26	2016-03-17 15:07	2.14	0.077	1618.29	0.080	0.086	128.72	139.17	(10.45)	-8.1%		320	ADVM
15	2016-04-27 16:21	2016-04-27 17:33	2016-04-27 16:57	2.38	0.189	1742.32	0.186	0.198	324.71	344.98	(20.27)	-6.2%		320	ADVM
16	2016-05-11 15:09	2016-05-11 15:47	2016-05-11 15:28	2.27	0.121	1685.56	0.131	0.130	220.37	219.12	1.25	0.6%		320	ADVM
17	2016-07-13 17:59	2016-07-13 18:44	2016-07-13 18:21	2.38	0.474	1742.32	0.492	0.482	858.08	839.80	18.28	2.1%		320	ADVM
18	2016-07-14 16:43	2016-07-14 17:21	2016-07-14 17:02	2.17	0.224	1633.84	0.245	0.233	399.56	380.68	18.88	4.7%		320	ADVM
19															
20															
21															
22															
23															

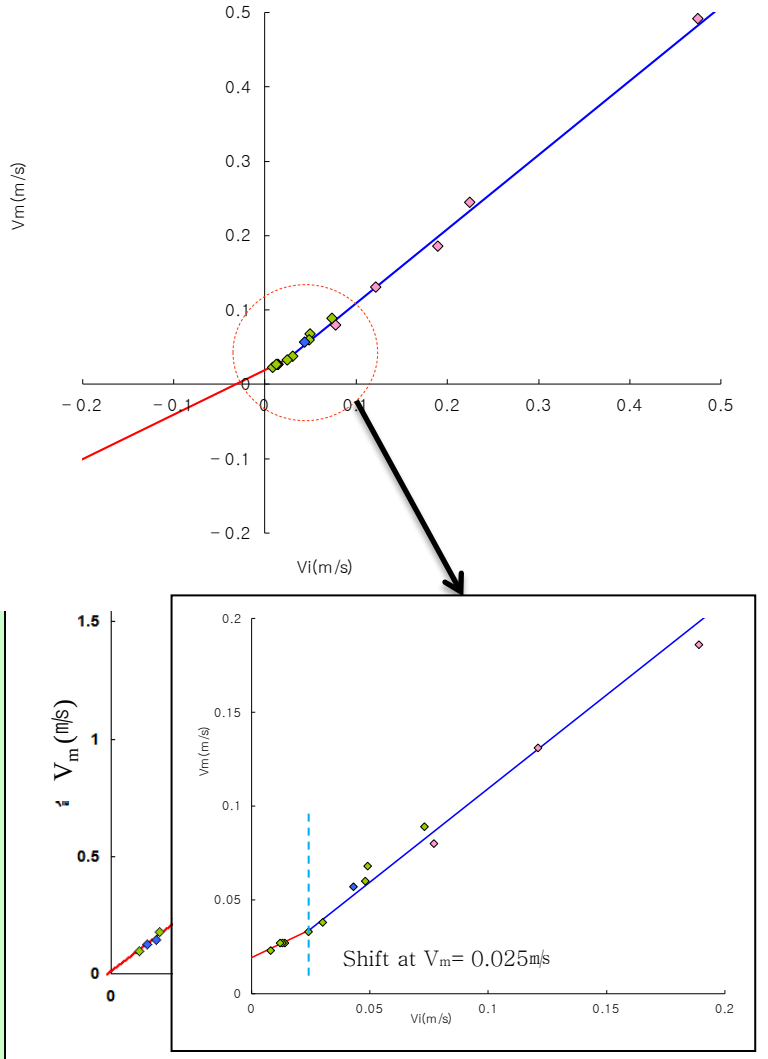
Development of software tool for IVM

- **Development of relationship between Vi**

Model Name	Equation
Compound	$V = b_1 + b_2 V_I \quad V_I \leq V_C$ $V = b_3 + b_4 V_I \quad V_I > V_C$

- Regression of determined Vi and Vm and calculation of
- Checking on possible shift
  ⇒ Development of compound curve considering shift at t
- Separation of index rating by applicable period
  ⇒ It is necessary to develop index ratings for each period





Development of software tool for IVM

- **Discharge calculation**

  - Final discharge data is calculated by applying Vi to index rating determined from MCpad

Discharge Calculation

189.3042 Reset Copyright by Kim, DS., HSC

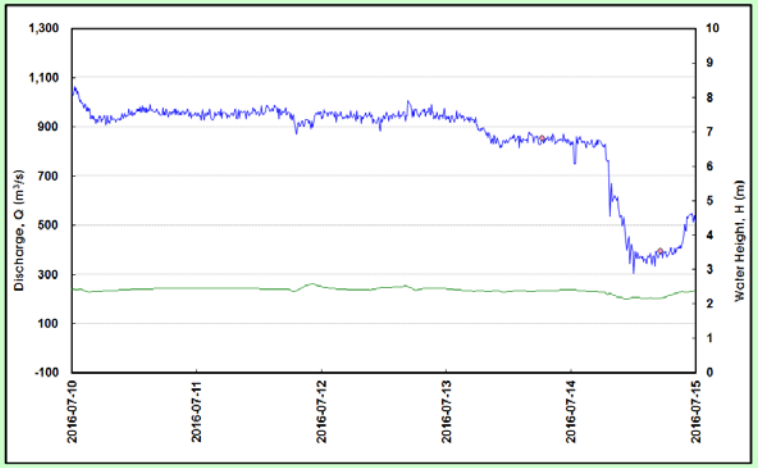
Calculation | Start 2016-01-01 00:00 | End 2017-01-01 00:00 | 결측기간 확인 | Selection of H | H1(main)

No.	Time	H	H_{adv}	Q	Q_{adv}	A	V_m	비고	결측보완
1	2016-01-01 00:00	2.14	2.14	84.15	84.15	1618.29	0.052		
2	2016-01-01 00:10	2.15	2.15	63.32	63.32	1623.48	0.039		
3	2016-01-01 00:20	2.15	2.15	68.19	68.19	1623.48	0.042		
4	2016-01-01 00:30	2.15	2.15	61.69	61.69	1623.48	0.038		
5	2016-01-01 00:40	2.15	2.15	68.19	68.19	1623.48	0.042		
6	2016-01-01 00:50	2.15	2.15	68.19	68.19	1623.48	0.042		
7	2016-01-01 01:00	2.16	2.16	79.80	79.80	1628.66	0.049		
8	2016-01-01 01:10	2.16	2.16	86.32	86.32	1628.66	0.053		
9	2016-01-01 01:20	2.16	2.16	71.66	71.66	1628.66	0.044		
10	2016-01-01 01:30	2.16	2.16	73.29	73.29	1628.66	0.045		
11	2016-01-01 01:40	2.16	2.16	60.26	60.26	1628.66	0.037		
12	2016-01-01 01:50	2.16	2.16	84.69	84.69	1628.66	0.052		
13	2016-01-01 02:00	2.16	2.16	87.95	87.95	1628.66	0.054		
14	2016-01-01 02:10	2.16	2.16	73.29	73.29	1628.66	0.045		
15	2016-01-01 02:20	2.16	2.16	86.32	86.32	1628.66	0.053		
16	2016-01-01 02:30	2.16	2.16	78.18	78.18	1628.66	0.048		
17	2016-01-01 02:40	2.16	2.16	74.92	74.92	1628.66	0.046		
18	2016-01-01 02:50	2.16	2.16	84.69	84.69	1628.66	0.052		
19	2016-01-01 03:00	2.16	2.16	86.32	86.32	1628.66	0.053		
20	2016-01-01 03:10	2.16	2.16	86.32	86.32	1628.66	0.053		
21	2016-01-01 03:20	2.16	2.16	81.43	81.43	1628.66	0.050		
22	2016-01-01 03:30	2.16	2.16	78.18	78.18	1628.66	0.048		
23	2016-01-01 03:40	2.16	2.16	78.18	78.18	1628.66	0.048		
24	2016-01-01 03:50	2.16	2.16	74.92	74.92	1628.66	0.046		
25	2016-01-01 04:00	2.15	2.15	71.43	71.43	1623.48	0.044		
26	2016-01-01 04:10	2.15	2.15	81.17	81.17	1623.48	0.050		
27	2016-01-01 04:20	2.15	2.15	68.19	68.19	1623.48	0.042		
28	2016-01-01 04:30	2.15	2.15	87.67	87.67	1623.48	0.054		
29	2016-01-01 04:40	2.15	2.15	90.91	90.91	1623.48	0.056		
30	2016-01-01 04:50	2.15	2.15	81.17	81.17	1623.48	0.050		
31	2016-01-01 05:00	2.15	2.15	68.19	68.19	1623.48	0.042		
32	2016-01-01 05:10	2.15	2.15	73.06	73.06	1623.48	0.045		
33	2016-01-01 05:20	2.15	2.15	73.06	73.06	1623.48	0.045		
34	2016-01-01 05:30	2.15	2.15	84.42	84.42	1623.48	0.052		
35	2016-01-01 05:40	2.15	2.15	71.43	71.43	1623.48	0.044		
36	2016-01-01 05:50	2.15	2.15	77.93	77.93	1623.48	0.048		
37	2016-01-01 06:00	2.15	2.15	77.93	77.93	1623.48	0.048		
38	2016-01-01 06:10	2.15	2.15	81.17	81.17	1623.48	0.050		

Result of Discharge

Reset Copyright by Kim, DS., HSC

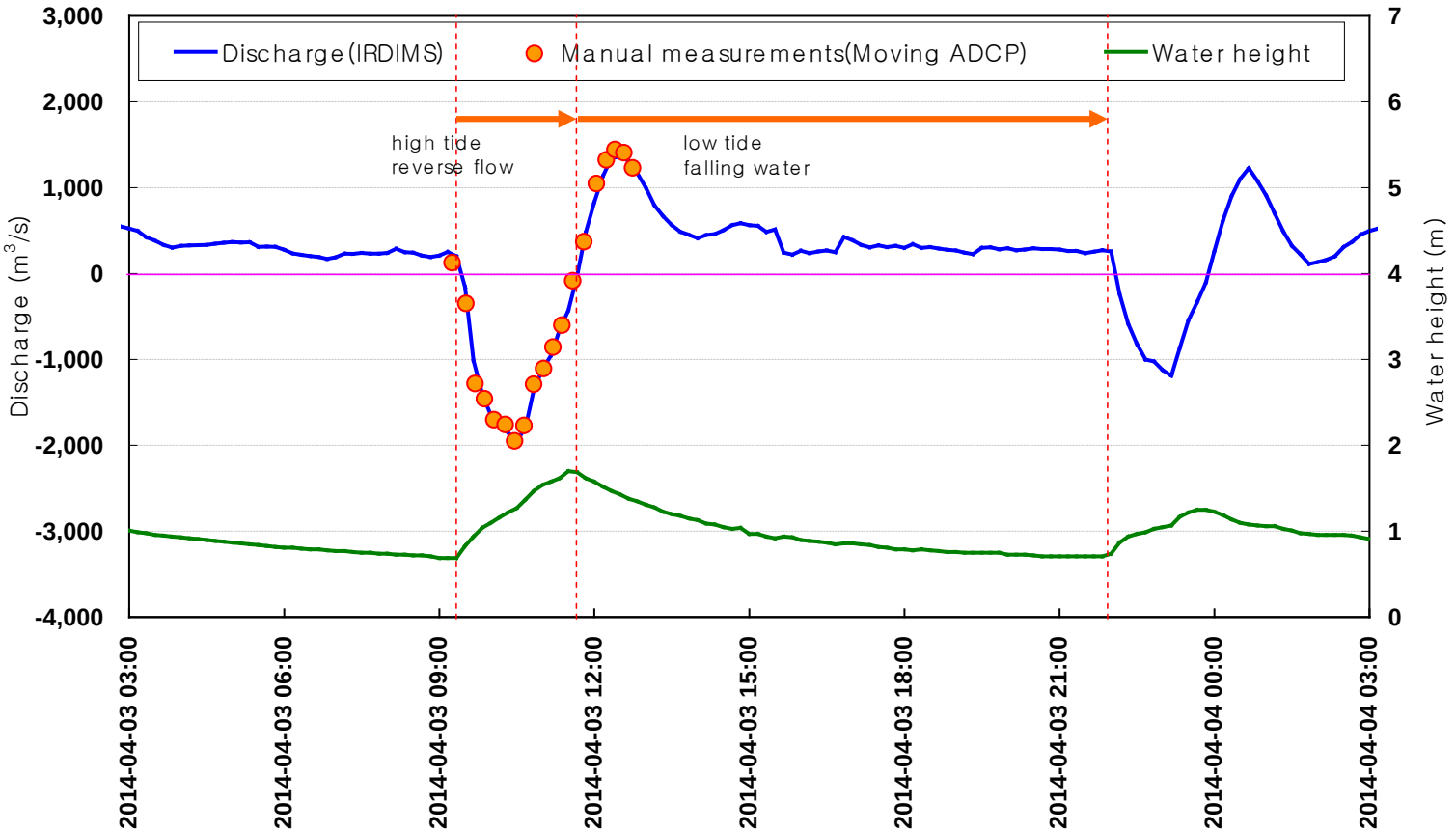
Start 2016-07-10 00:00 | Duration 5 | End 2016-07-15 00:00 | << | Refresh | >>



Example Results of IRDIMS

- **Discharge measurement in tidally affected area**

  - Beginning high tide flow, discharge at the station decreased rapidly and flow direction changed to reverse, while water height was rising. After negative peak, reverse flow returned to natural direction and discharge increased and gradually decreased until next tidal period

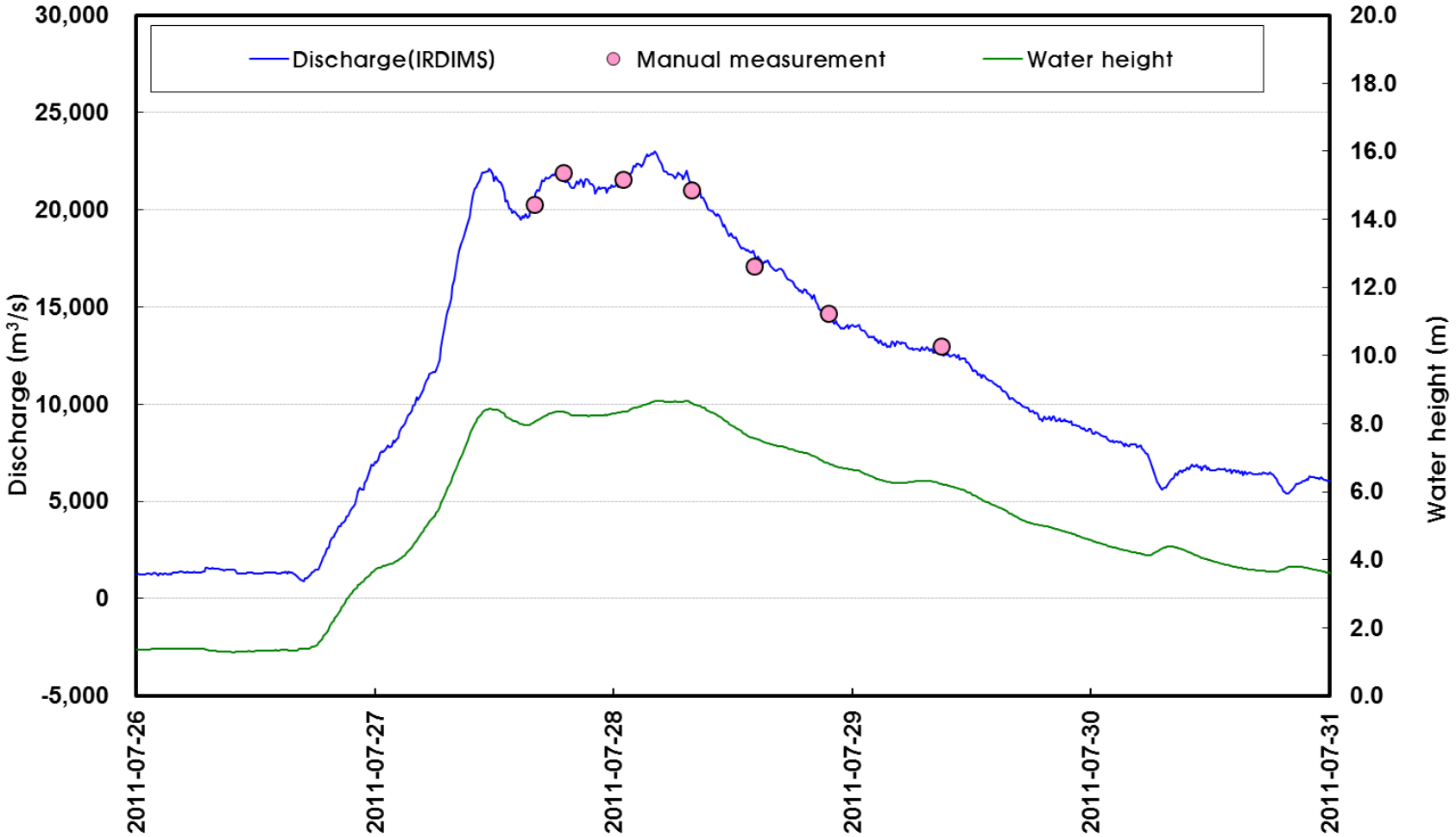


Example Results of IRDIMS

- **Discharge measurement of flood flow**

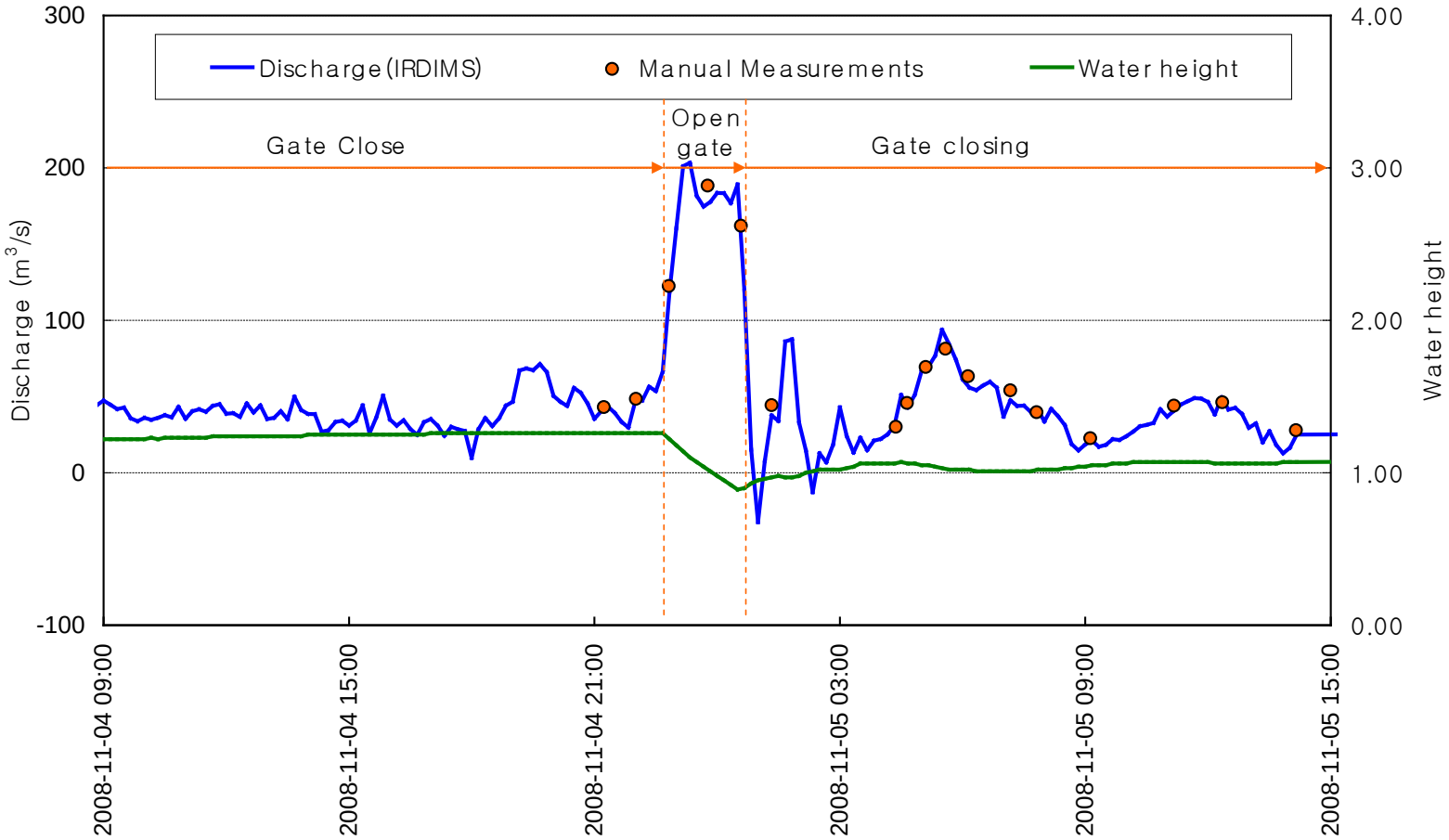
  - Maximum value : discharge 23,000m^3/s, water level 10.7m, EL., velocity 2.5m/s

    ※ maximum record since IRDIMS began to operate



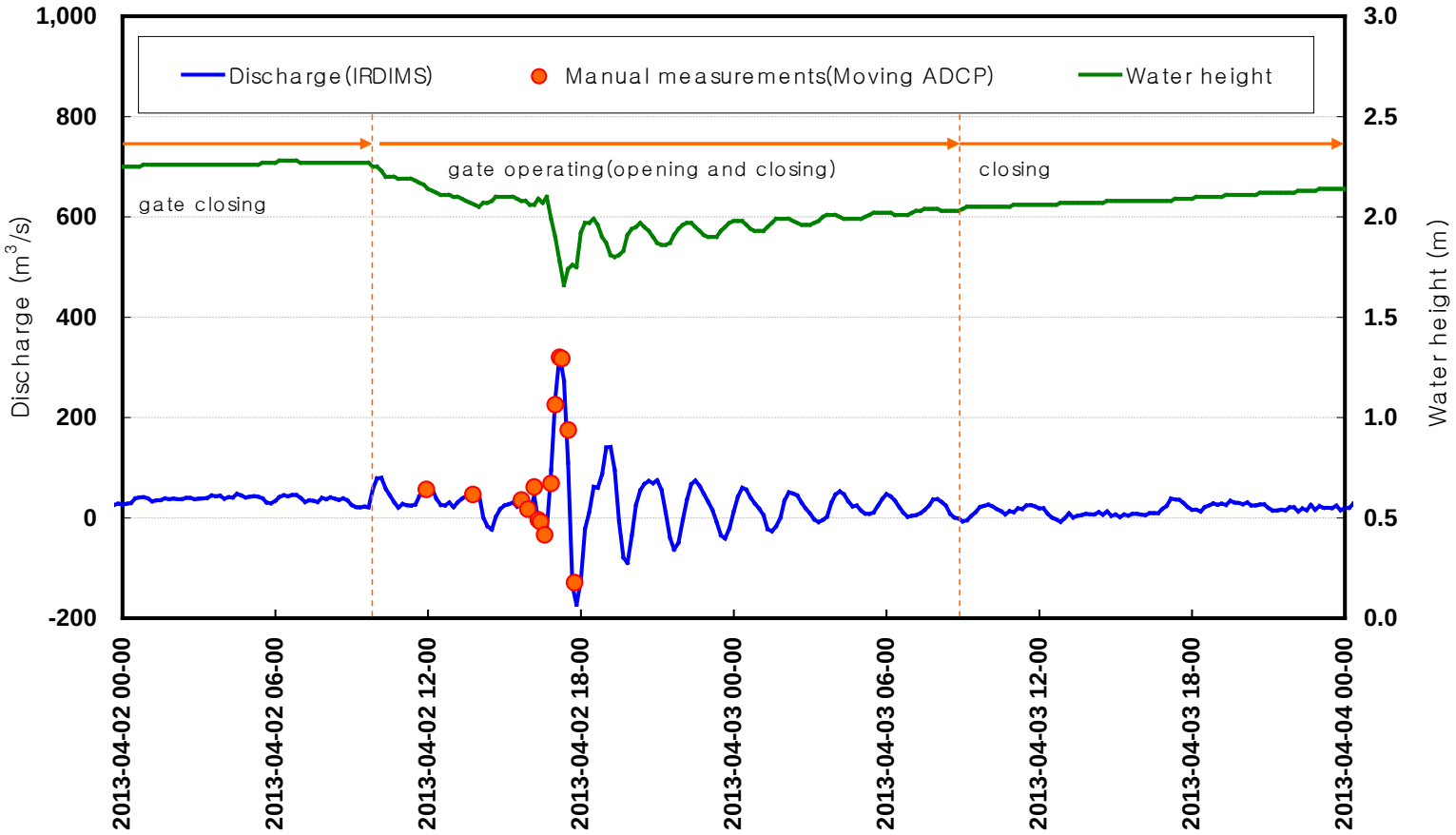
Example Results of IRDIMS

- **Discharge measurement in backwater condition by sluice in river estuary**
  - Gate operation of the sluice result in flow change of this station.



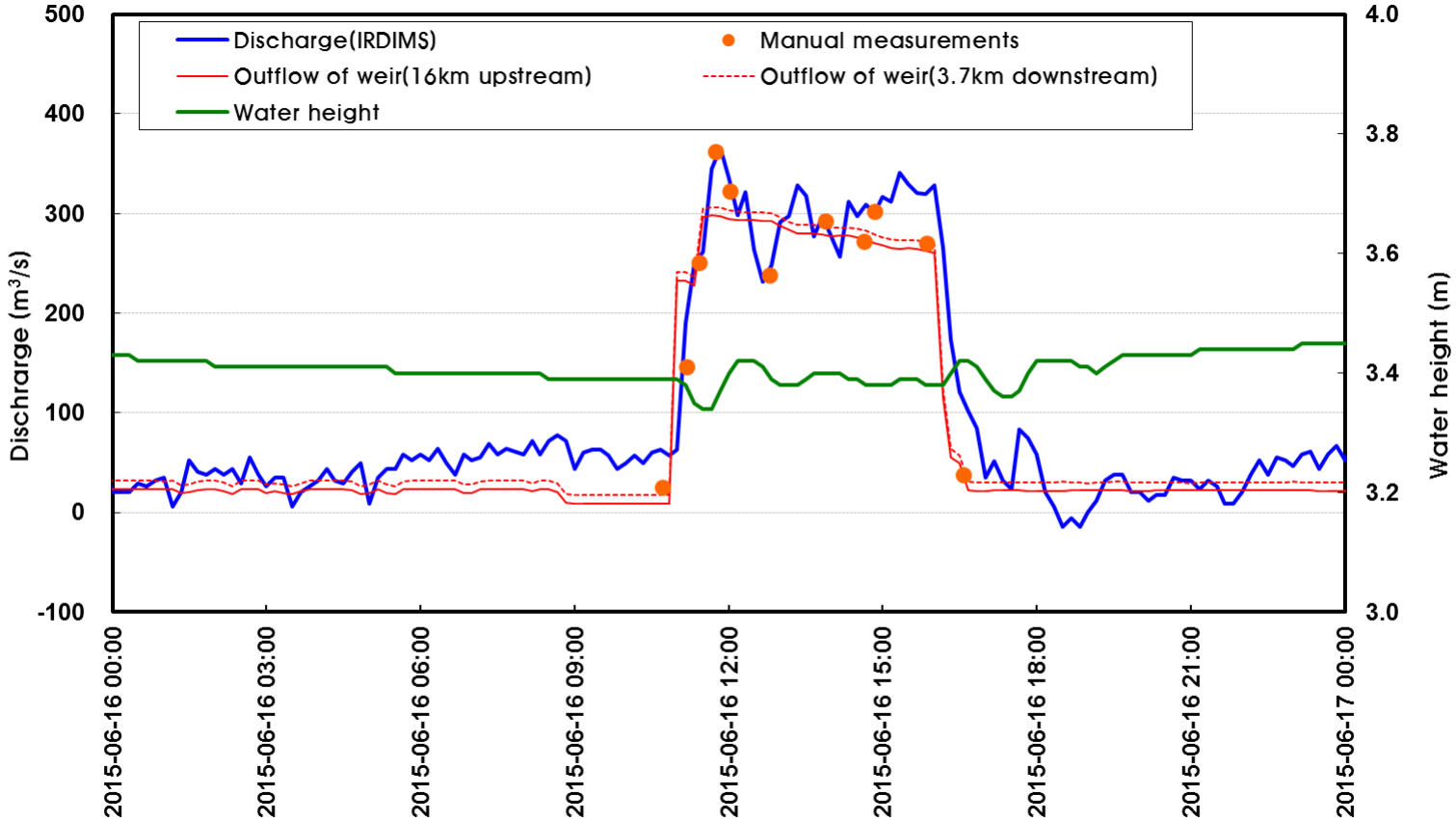
Example Results of IRDIMS

- **Discharge measurement under backwater condition caused by section-crossed structure**
  - Discharge was directly affected by outflow of the weir controlled by gate operation



Example Results of IRDIMS

- **Discharge variation between two weir**
  - Goryong st. located between 2 weirs at 15km upstream and 4km downstream

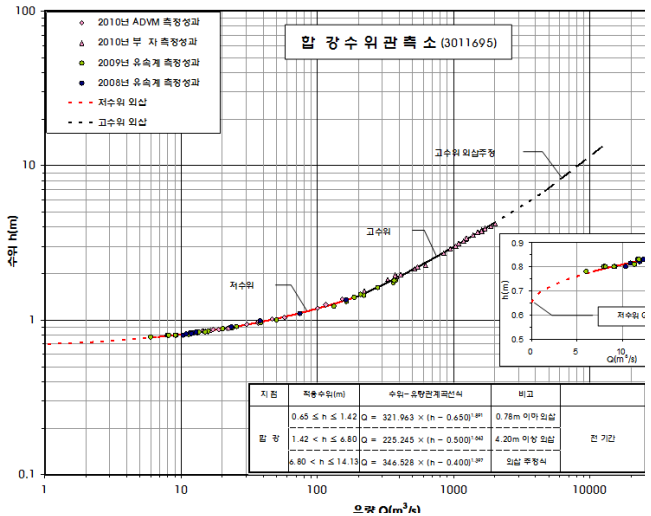


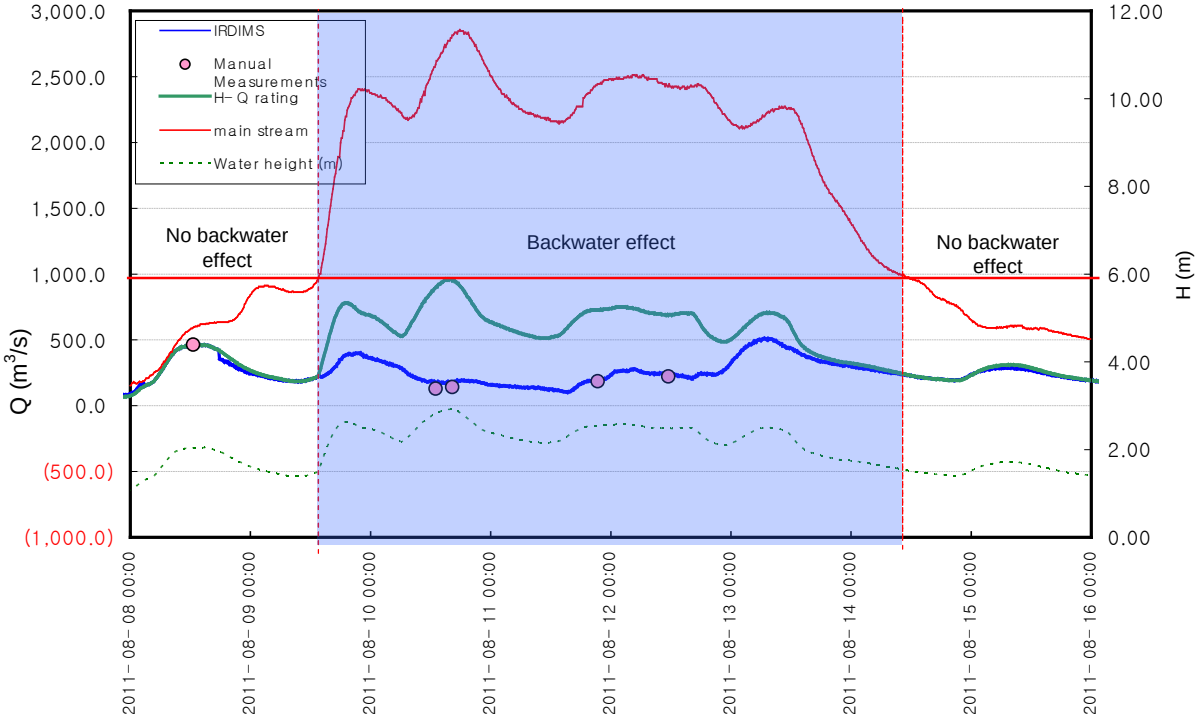
Comparison between IRDIMS and H-Q

- **Backwater at the junction caused by main stream**
  - Hapgang st. is located in 1km upstream of junction with Geum river and affected by backwater only when discharge of main stream increase significantly

Comparison between IRDIMS and H-Q

- **Backwater at the junction caused by main stream**
  - It is affected by backwater only when discharge or water height of main stream increase
  - Results of discharge by IRDIMS and H-Q had a similar trend when there was no backwater
  - However, as it started to be affected by backwater from mainstream, discharge by H-Q was showing difference and bigger than IRDIMS and manual measurements.





Comparison between IRDIMS and H-Q

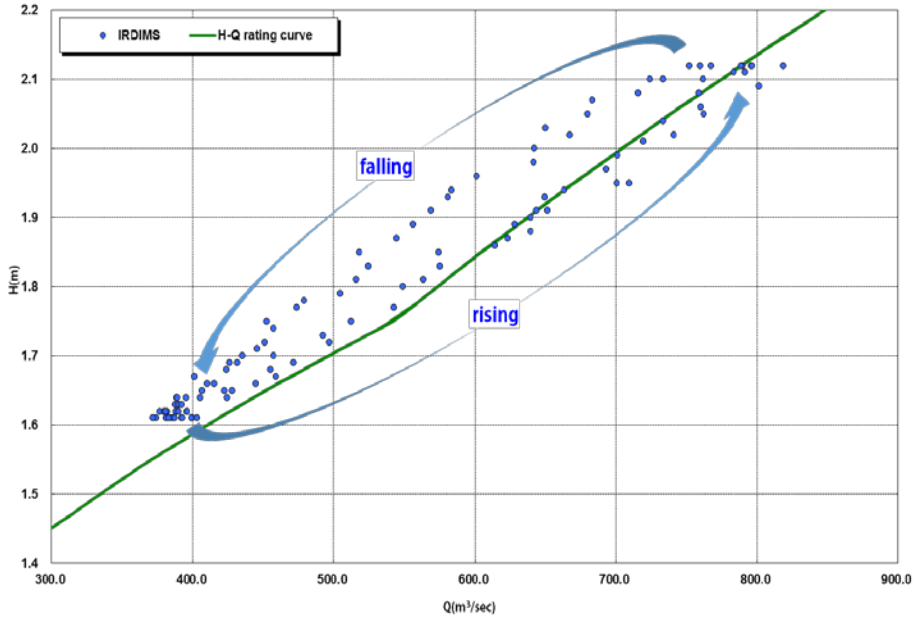
- **Measurement in Loop condition**

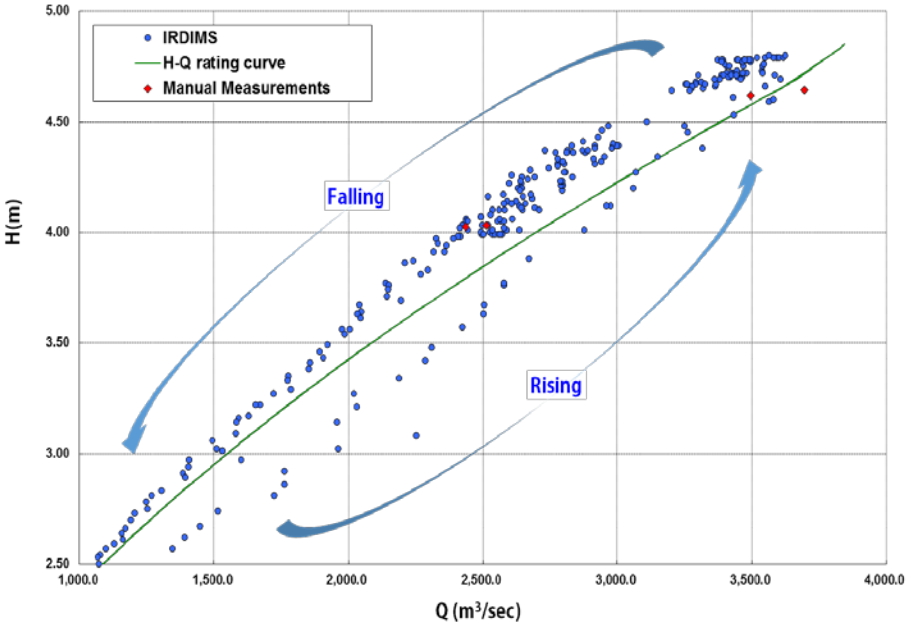
  - 2 rainfall events : 300~900m^3/s, 1,000~4,000m^3/s

  H-Q for H = 1.6~2.0m had been developed using data measured during rising flow condition

  H= 2.5~4.5m had been developed using data measured during rising and falling flow conditions

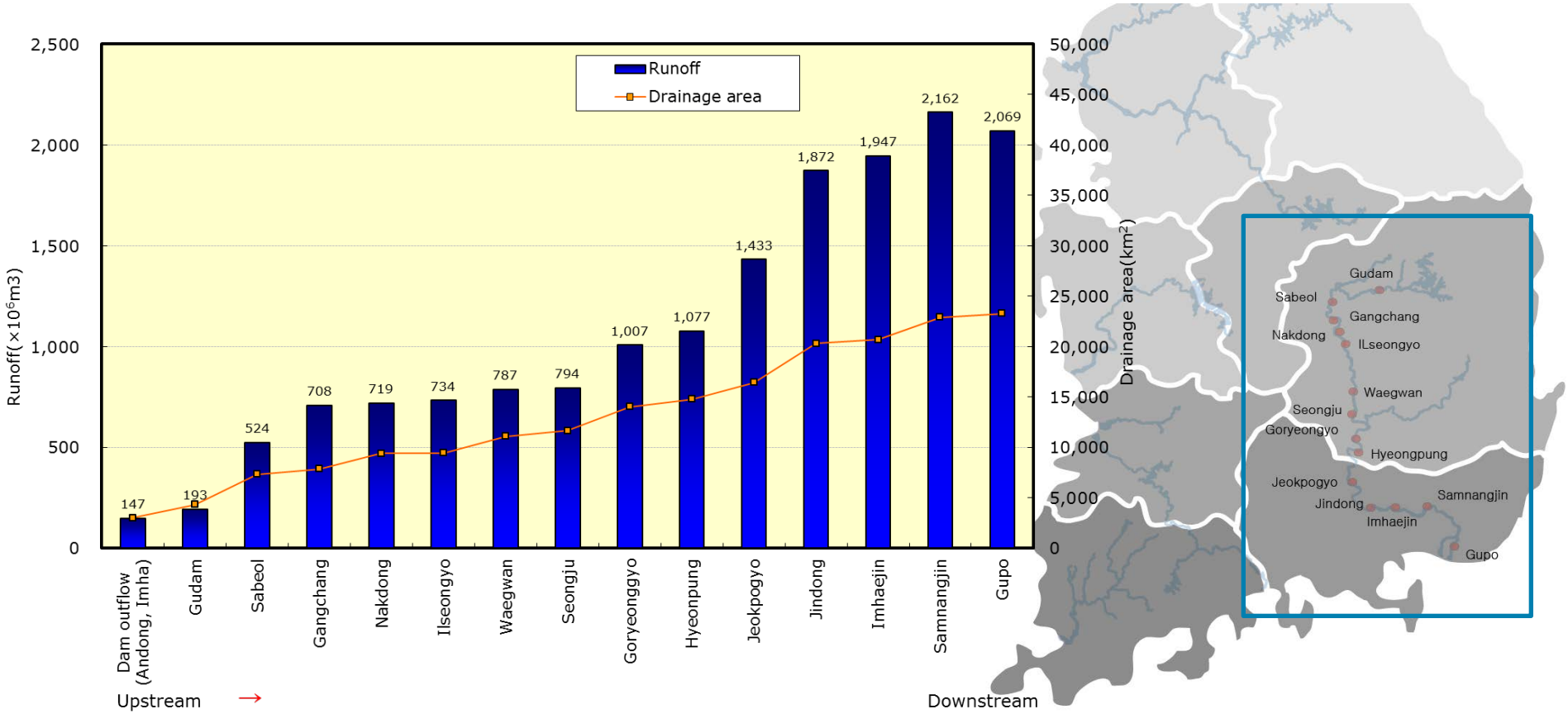
  - Difference of discharge under same H were 15~20% similarly in both events





Example Results of IRDIMS

- **Comparative analysis on runoff of IRDIMS stations**
  - Runoff at each IRDIMS station from upstream to downstream for specific period in Nakdong river
  - Runoff of each station(blue bar) gradually increased from upstream to downstream, and its trend was similar with increasing of drainage area(yellow line).



ACTIVITIES

- Hydrometric measurements with quality and accuracy

Improve sediment measuring techniques

- This Activity is to provide a technical information about sediment measurement and each methodology, and case study on sediment in various conditions

- There are two sub actions have been conducted in this action plan, these are

  (1) Collection of technical information related to sediment measurement and analysis

  (2) Case study on sediment measurement in various conditions

ACTIVITIES

- Hydrometric measurements with quality and accuracy

(1) Collection of the technical information related to sediment measurement and its analysis

(a) The status of existing sediment measurement technique

- Measurement equipment, methodology and procedure

(b) The status of new technology and its application

(c) Techniques of analysis on sediment

(2) Case study on sediment measurement in different conditions

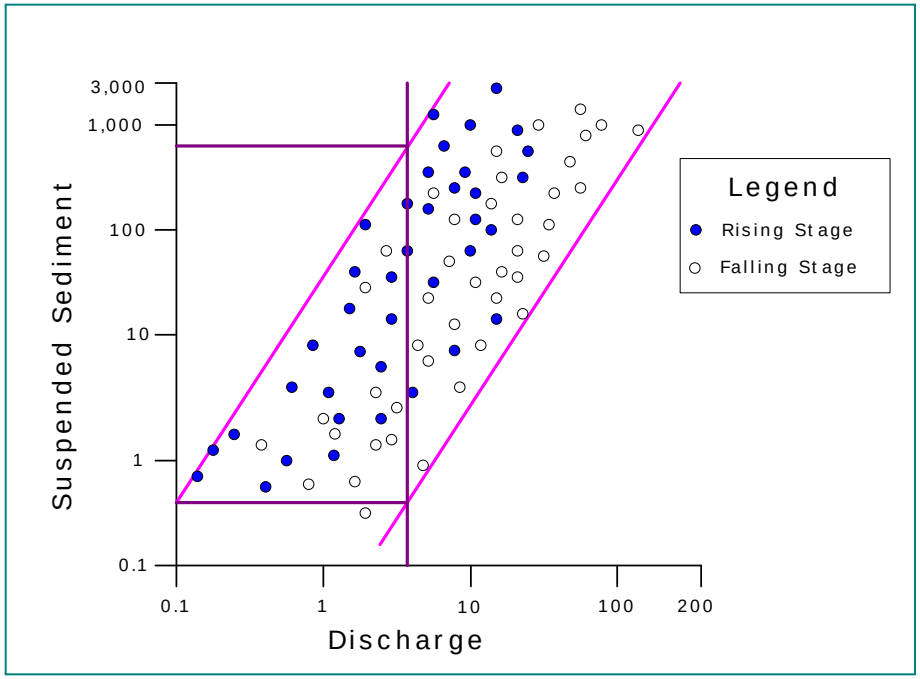
(a) Analysis on characteristics of sediment load during rising & falling water level(Loop)

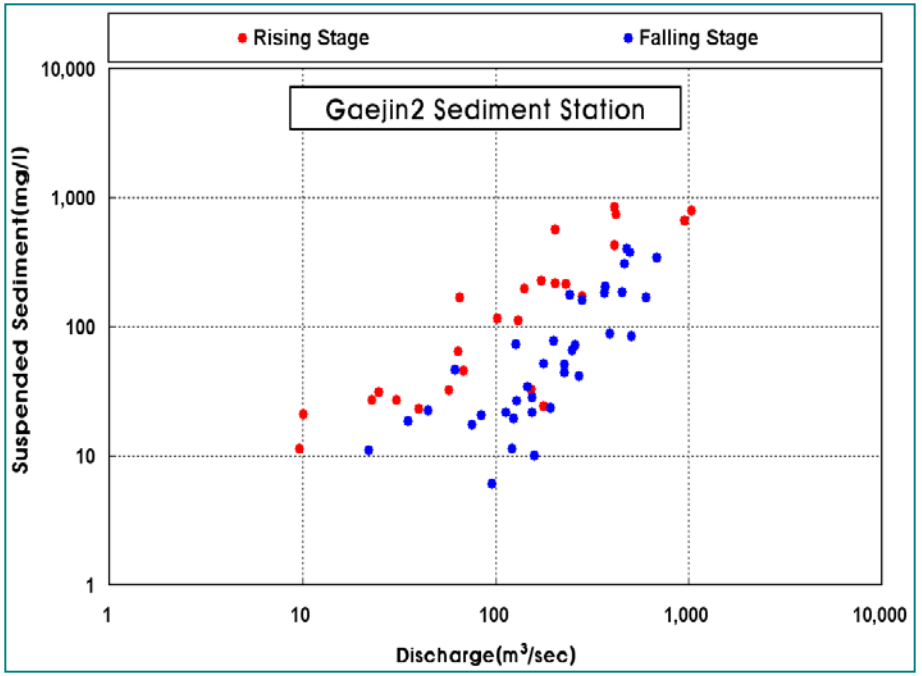
(b) Analysis on river construction effect on characteristic of sediment load, focused on 4major river project in Korea

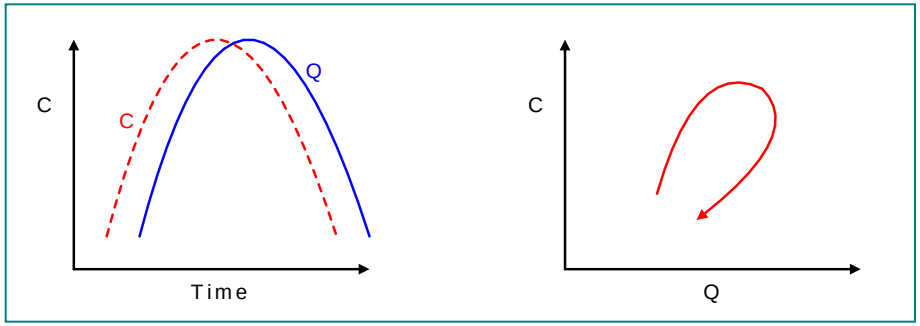
(c) A comparative analysis on sediment load by sequence of rainfall event.

Sediment measurement in different conditions

- **Loop characteristic of suspended sediment in the Gaejin2 station**
- Analysis on characteristic of C-Q rating in the rising and falling flow

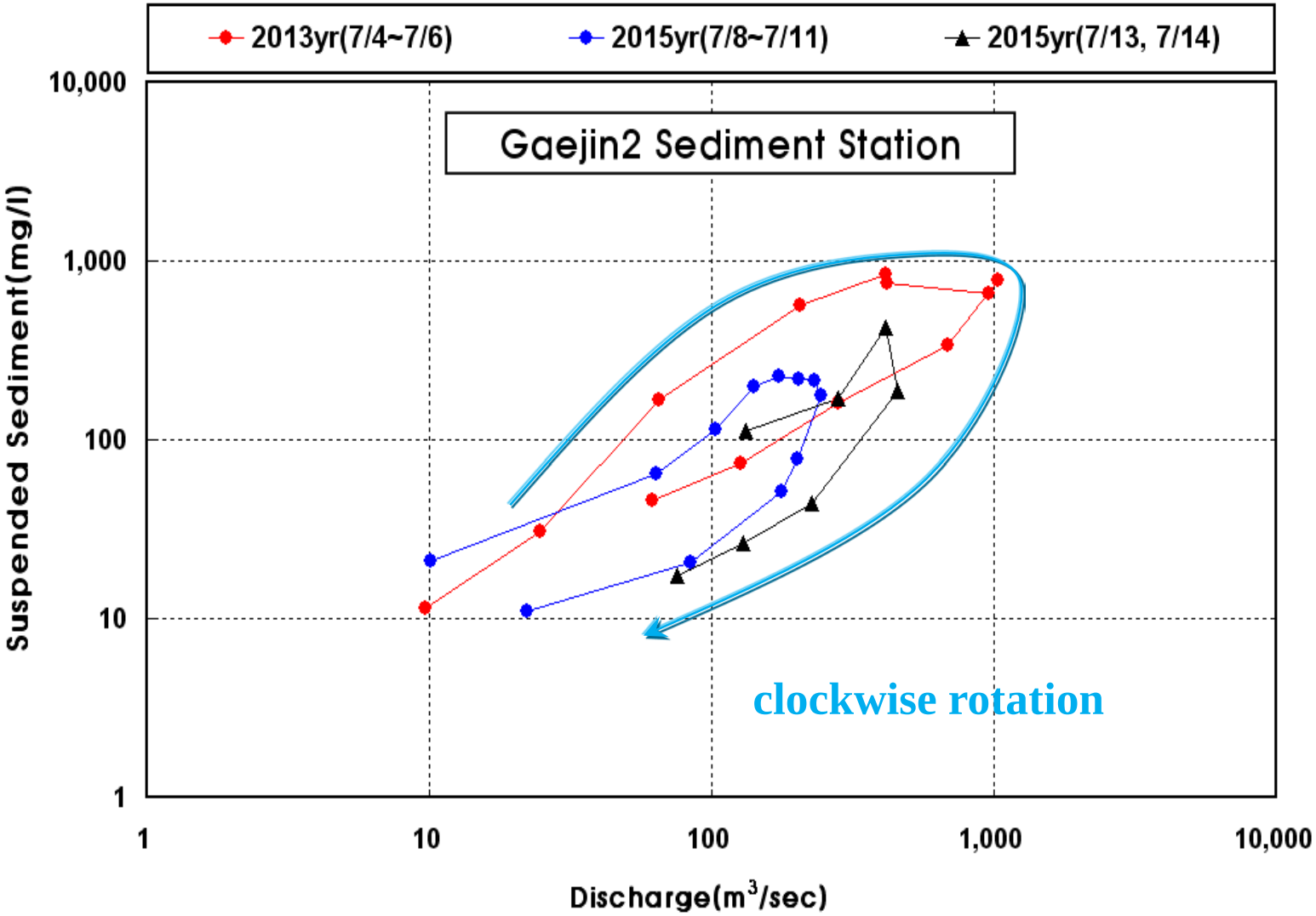






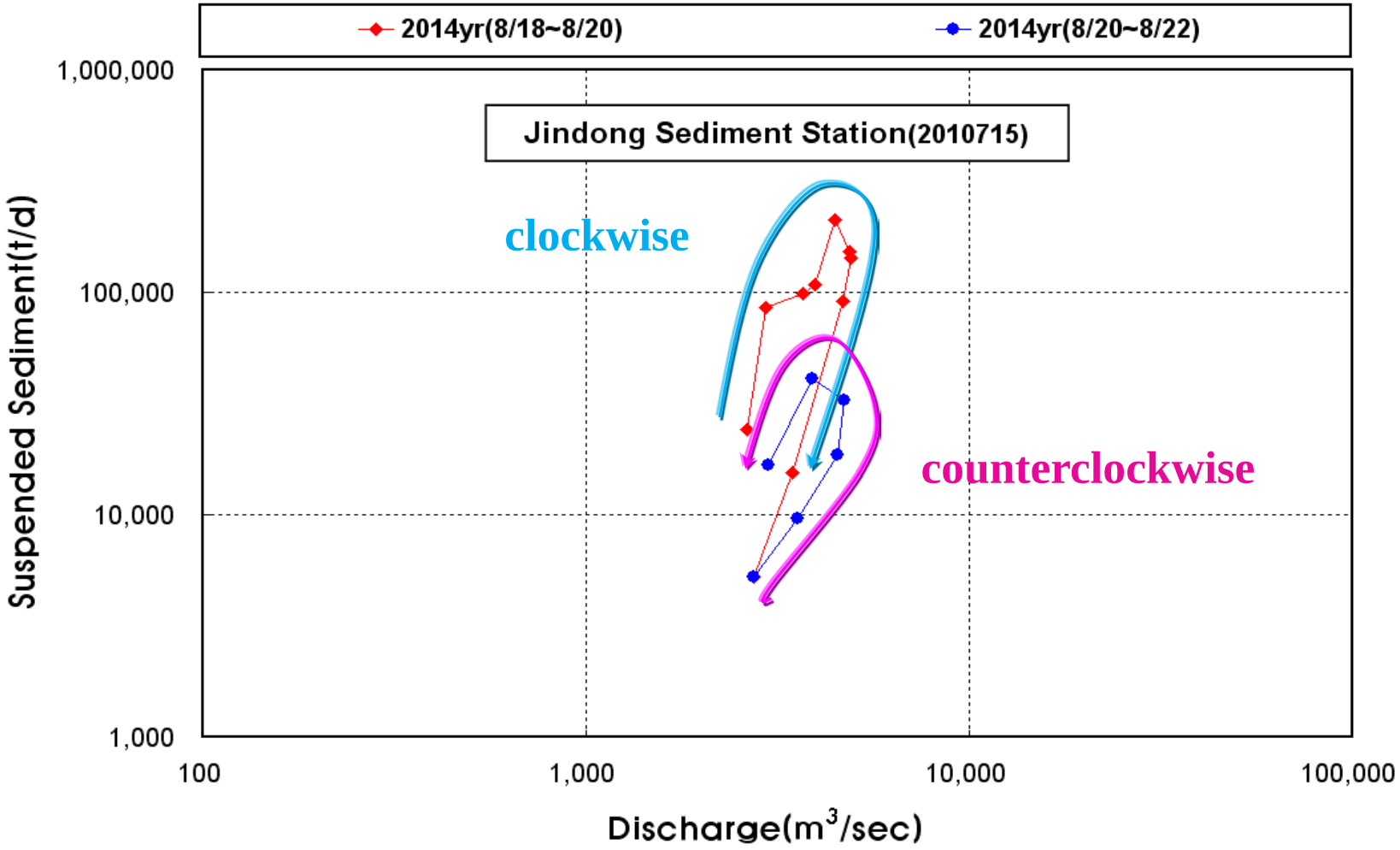
Sediment measurement in different conditions

- **Loop characteristics of suspended sediment in the Gaejin2 station**
- Gaejin2 station showed characteristics of clockwise loop



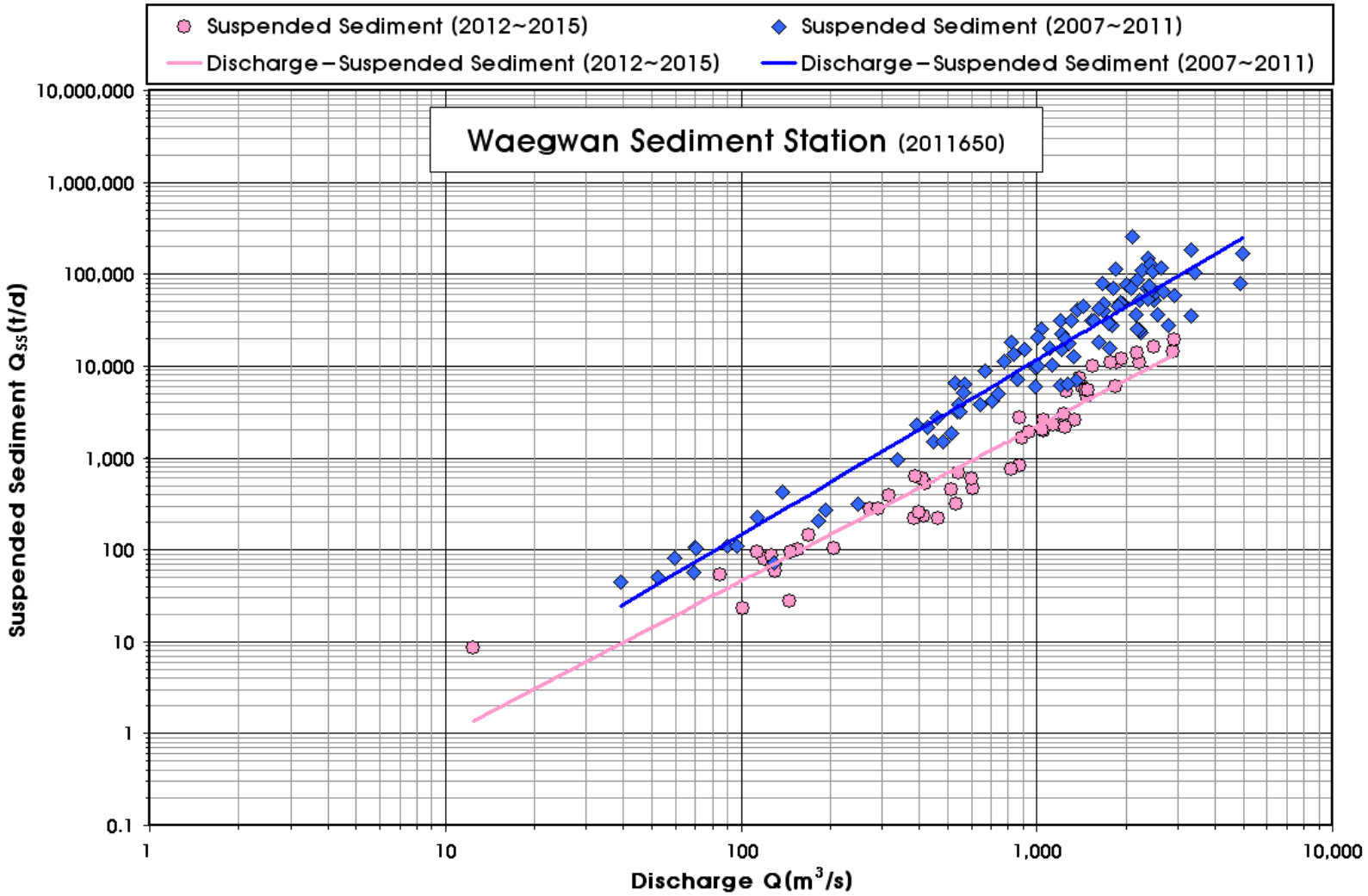
Sediment measurement in different conditions

- **Loop characteristics of suspended sediment in the Jindong station**
- Jindong station showed clockwise and counterclockwise loop together during successive 2 rainfall events



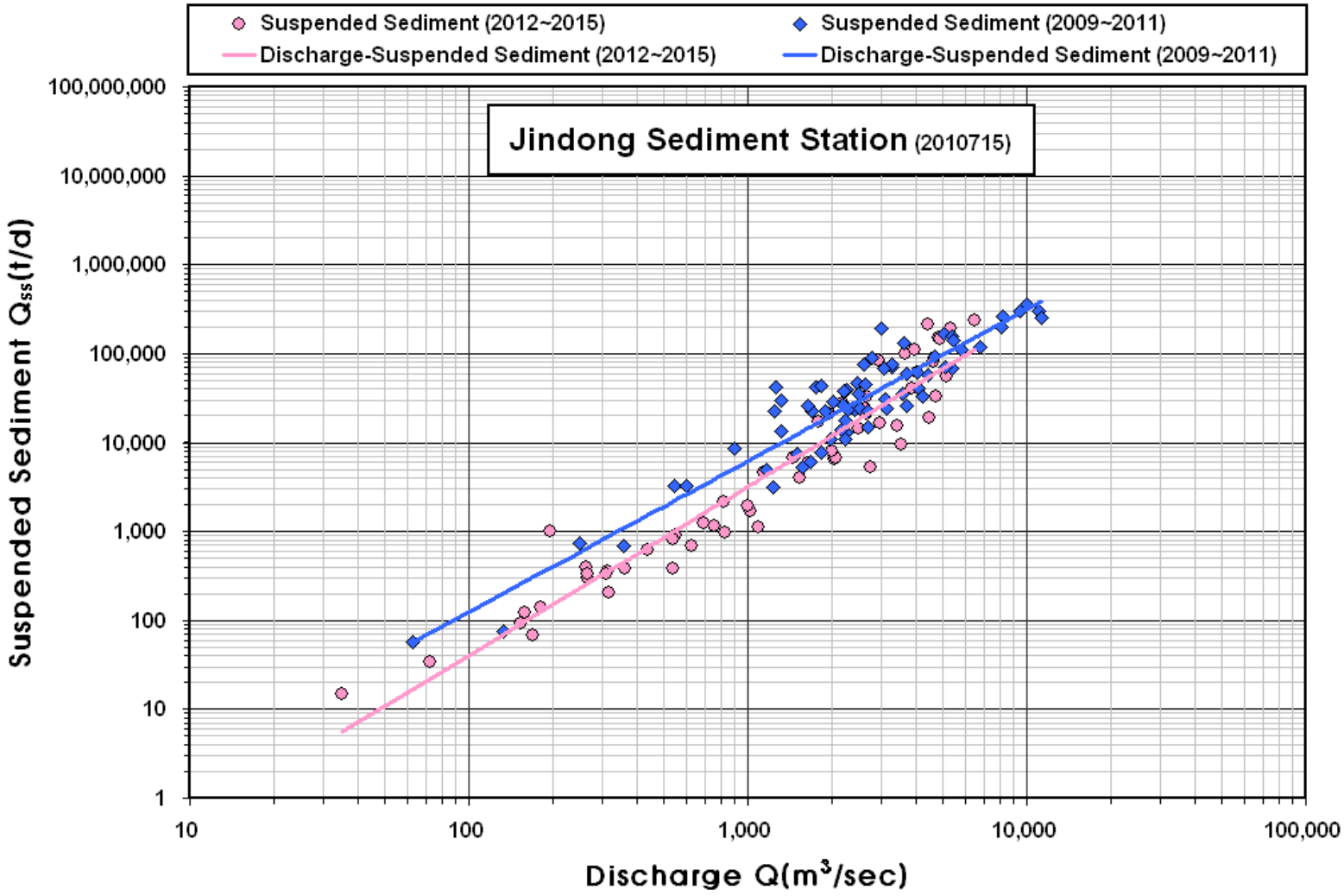
Sediment measurement in different conditions

- **Effect of large weir construction on Sediment load**
- Comparison of C-Q rating before and after construction of large weir



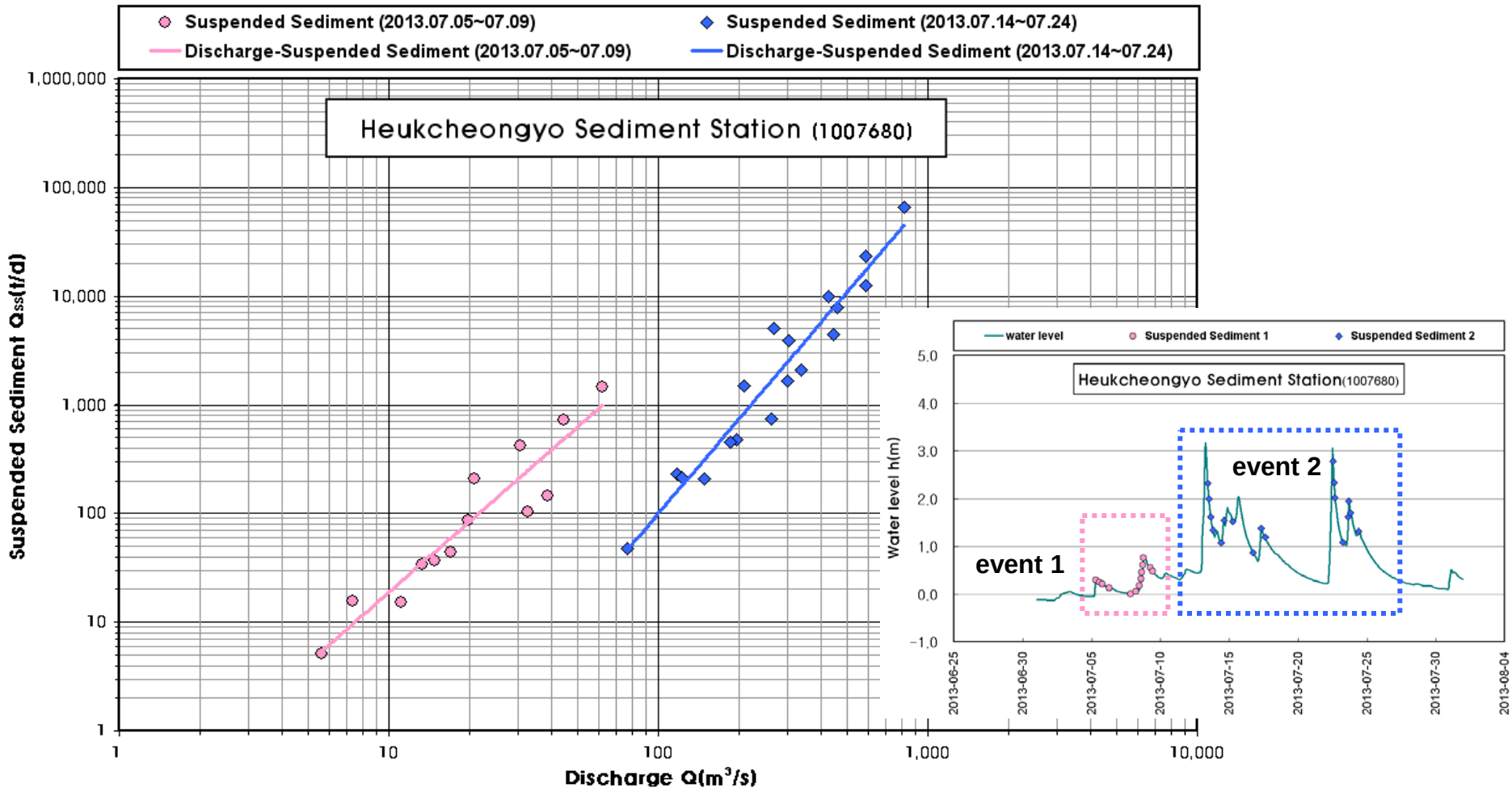
Sediment measurement in different conditions

- **Effect of large weir construction on Sediment load**
- Comparison of C-Q rating before and after construction of large weir



Sediment measurement in different conditions

- **Suspended sediment characteristics of successive rainfall events**
- A comparative analysis on suspended sediment by sequence of rainfall event



ACTIVITIES

- Hydrometric measurements with quality and accuracy
  - **Focus on the development of rating curve**

    - This Activity is to provide a report outlining procedures for developing the optimal rating curve under various conditions in Korea

    - The main purpose of this action is providing **technical information** about improved **development procedure** and introducing development tool of rating curve also providing development of **rating curve cases** in various conditions.

    - There are two sub actions being conducted in this action plan, these are

      (1) Collection of the existing technical information

      (2) Case analysis with various field conditions

ACTIVITIES

(1) Collection of the existing technical information

- This action is collection of existing technical information, which include (a) Procedure of rating curve development, (b) Development tool of rating curve

(a) **Procedure of rating curve development**

- Pre-investigation
- Discharge measurement and calculation
- Evaluation of measurement
- Quality Control (QC)
- Confirmation of data
- Evaluation of rating curve

(b) **Software tools to develop and manage of rating curve and its application**

- Data management and QC
  - HDQMS (Hydrological Data Quality Management System)
  - HDIMS (Hydrological Data Information Management System)
- Data analysis and rating curve development (DBPAD, CalPAD)

ACTIVITIES

(2) Case analysis with various field conditions

- This activity is to introduce **many cases of rating curve** development and its practical experionce in **various specific conditions** and suggest adequate methodology and evaluation of results by runoff anlysis etc.

(a) **Development of rating curve in backwater effect**

- Weir, stream junction

(b) Guideline for development of rating curve considering **vegetation**

- Method and procedure of vegetation monitoring

(c) Analysis on effect of **stream environment change** on rating curve

- Bed change, river construction

Stage-discharge rating curve (Rating)

- This continuous record of stage is translated to river discharge by applying the stage-discharge relation (also called rating)

- Stage-discharge relations are developed for streamgages by physically measuring the flow of the river with a mechanical current meter or ADCP at a wide range of stages; for each measurement of discharge there is a corresponding measurement of stage (http://water.usgs.gov/edu)

- **$Q = aX(h-b)^c$**

  (h : stage (water level) , b : Gauge Height os zero flow : GZF , c: slope)

  The stage-discharge relation depends on the shape, slope, and roughness of the channel at the streamgage and is different for every streamgage

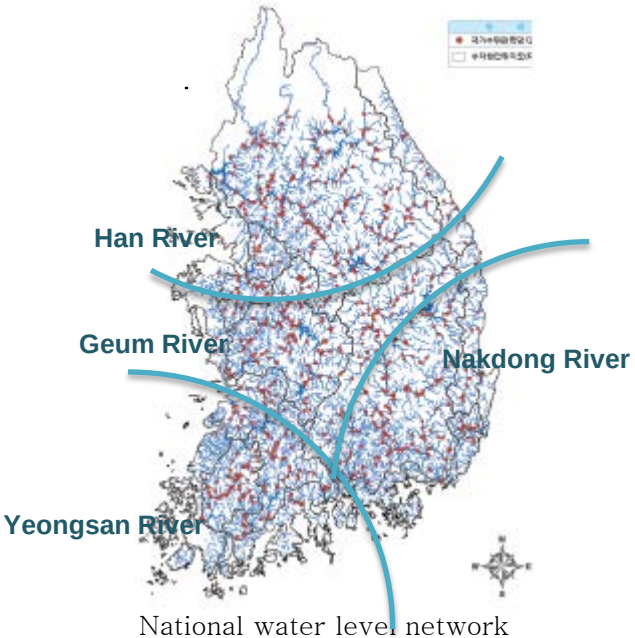
- HSC(MLIT) is conduction the **flow measurement more than 130 stations per year.** Also rating curves was developed from measuring stations per year except a few stations due to tidal or back water effect etc.

National Hydrological Survey Network in Korea

Status of NHSN in Korea

Division	Water level	Streamflow	Realtime streamflow	Sediment load	Soil Moisture	Evapotranspiration
Number of sites	645	380	97	138	25	25

* Final NHSN is planned to finish by 2020(Currently 80% completed and managed(2012))



National water level network

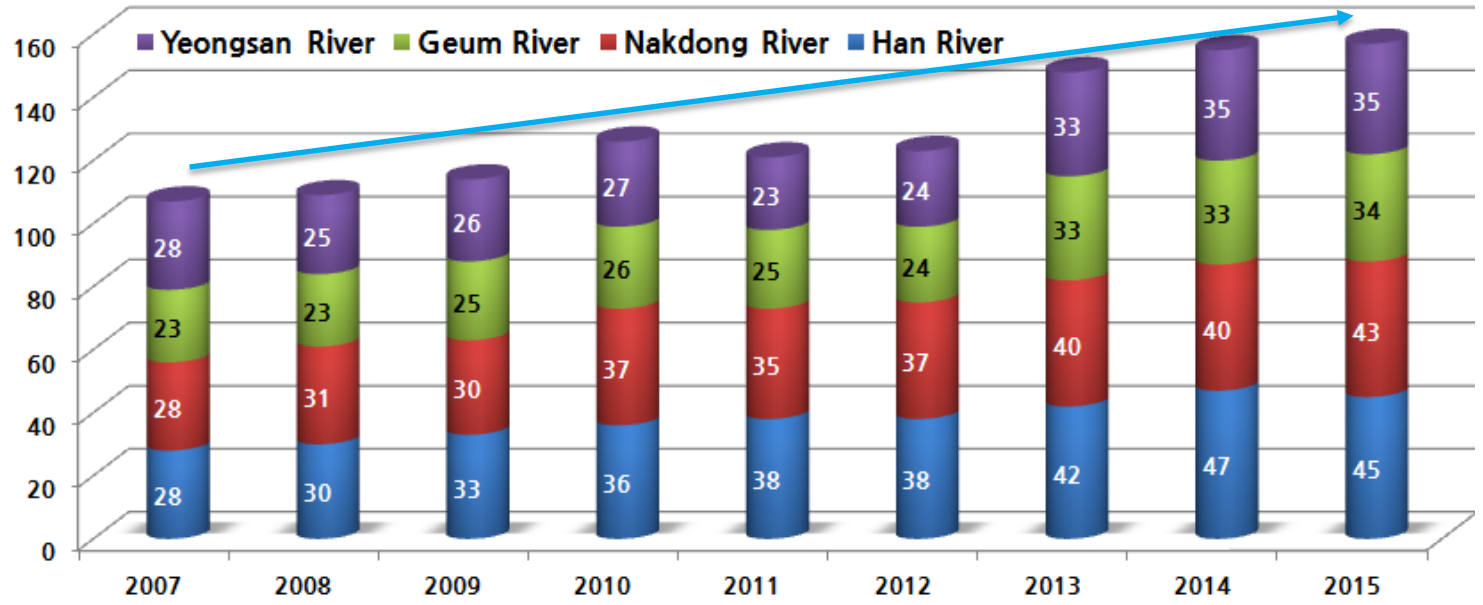
Realtime streamflow, sediment load, soil moisture, evapotranspiraion network

The status of discharge measurement (2007-2015)

Status of flow measurement the past 2007-2015 years

by the Report of Hydrological Survey

Flood Control Office	2007	2008	2009	2010	2011	2012	2013	2014	2015
Han River	28	30	33	36	38	38	42	47	45
Nakdong River	28	31	30	37	35	37	40	40	43
Geum River	23	23	25	26	25	24	33	33	34
Yeongsan River	28	25	26	27	23	24	33	35	35
Total	107	109	114	126	121	123	148	155	157



The status of discharge measurement (2011-2014)

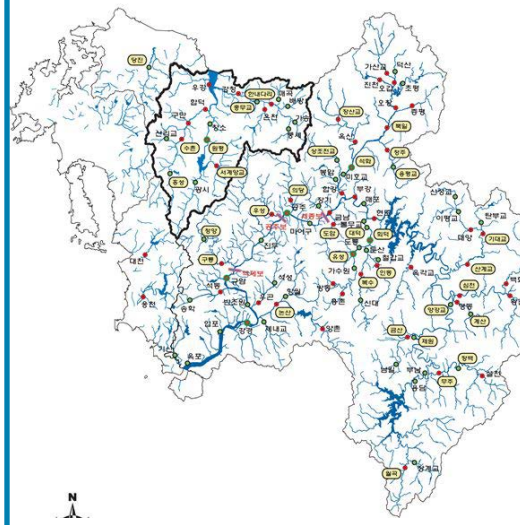
Status of discharge measurement the past 2011-2014 years

Hydrological Annual Report in Korea (by **M**inistry of **L**and, **I**nfrastructure and **T**ransport)

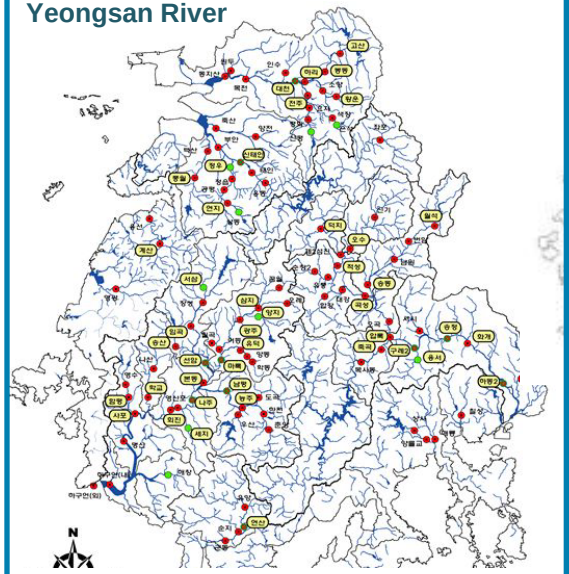
Year	Flood Control Office	Total St.	Discharge Measurement	Automatic Discharge Measurement	Development of Rating Curve
2011	Han River	47	38	9	44
	Nakdong River	44	35	9	40
	Geum River	29	25	4	29
	Yeongsan River	27	23	4	26
	Total	**147**	**121**	**26**	**139**
2012	Han River	49	39	10	38
	Nakdong River	58	41	17	35
	Geum River	31	27	4	27
	Yeongsan River	35	28	7	25
	Total	**173**	**135**	**38**	**125**
2013	Han River	52	40	12	42
	Nakdong River	60	38	22	39
	Geum River	37	30	7	33
	Yeongsan River	40	33	7	33
	Total	**189**	**141**	**48**	**147**
2014	Han River	57	47	12	47
	Nakdong River	61	40	22	40
	Geum River	38	33	7	33
	Yeongsan River	43	35	8	35
	Total	**199**	**155**	**49(6)**	**155**

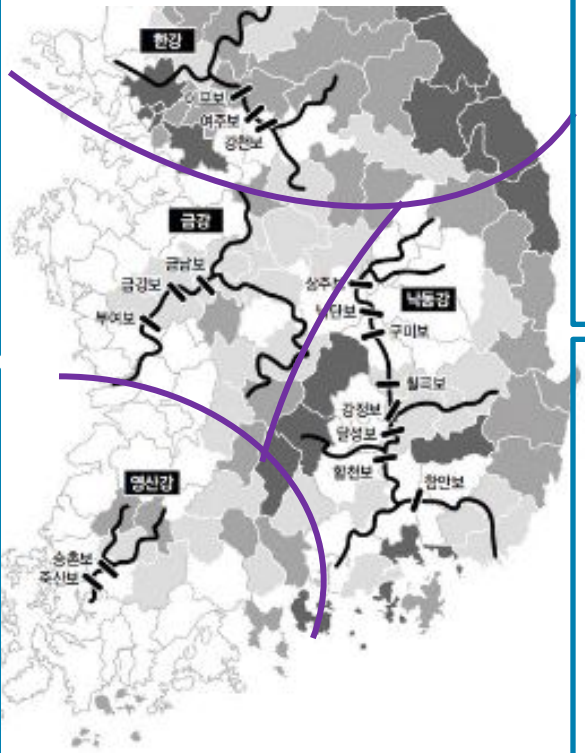
Location of discharge measurement stations

Geum River

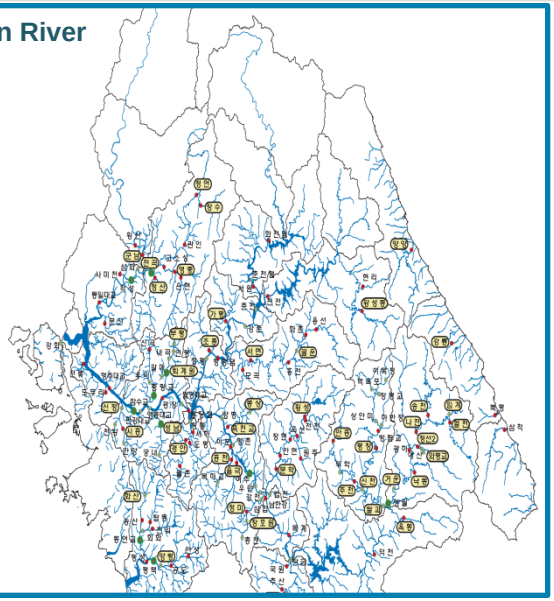


Yeongsan River

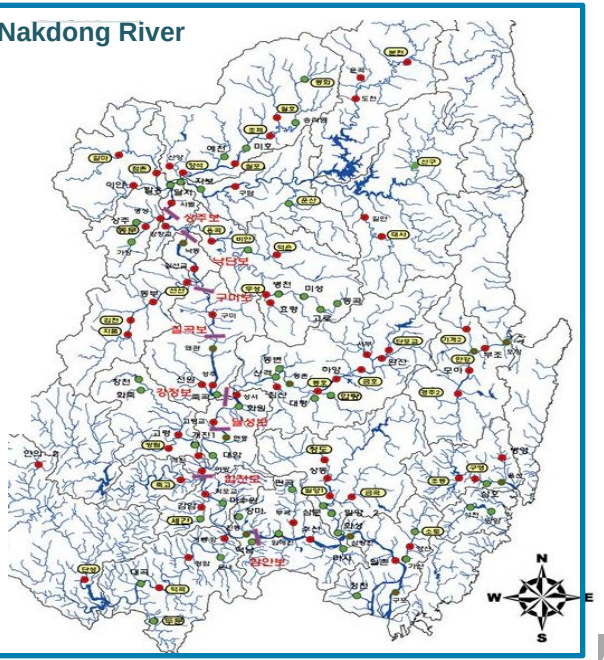




Han River



Nakdong River



The status of development of rating curve (2011-2013)

Status of Sites (Rating curves effected by controls in various field conditions)

Hydrological survey Report (by HSC_Ministry of Land, Infrastructure and Transport)

Year	Weir	Backwater of main river	Discharge of Dam	Sea wall & Tide	River Construction	Vegetation	Curved Channel	Development of Rating curve
2011	34	17	39	7	25	8	4	**139**
2012	34	21	13	1	12	17	5	**125**
2013	19	13	30	2	22	9	3	**147**
2014	29	17	35	1	23	16	9	**155**

streamflow measurement

Streamflow measurement

Step1) Water level measurement

(measuring stream stage)

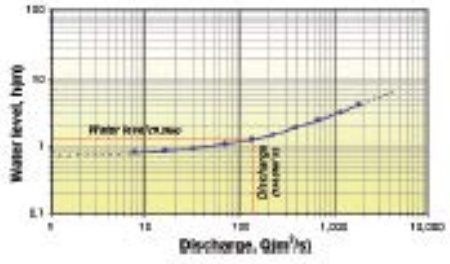
Step2) Discharge measurement (Over 130 sites per year)

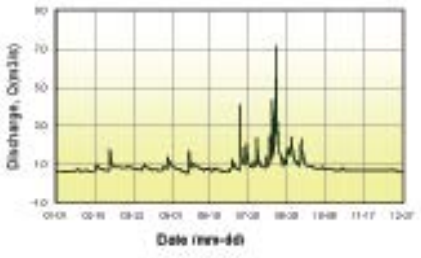
Acoustic Doppler Current Profiler (ADCP)

Current-meter discharge measurement

Measurement by floats and bridge board

Step3) Development of H-Q rating curve and Discharge hydrograph





Procedure of rating curve development

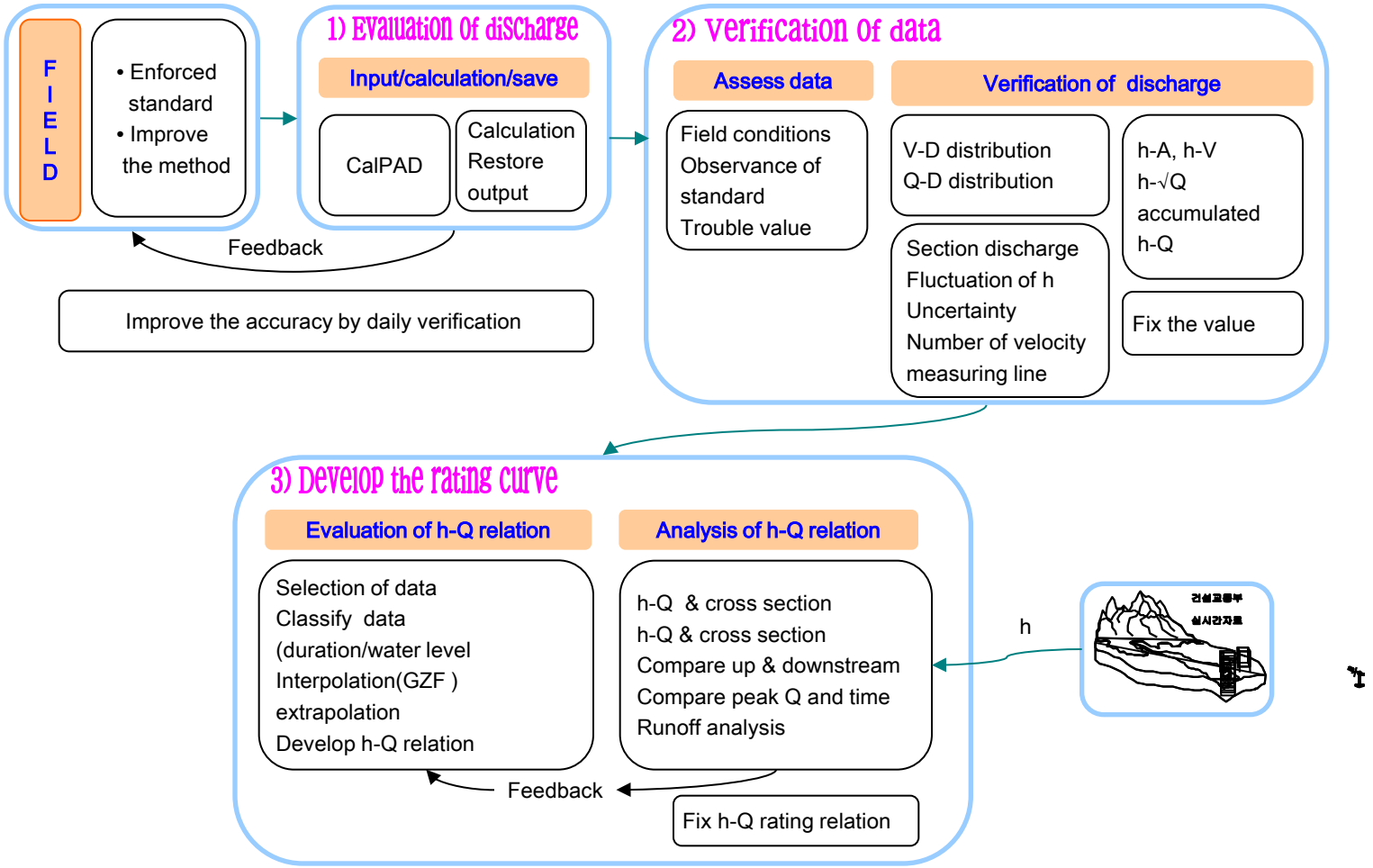
- **Procedure of rating curve development is**

  Pre-investigation – flow measurement – QC of measured data – Development of rating - Evaluation

Major Procedure	Main Contents
Pre-Investigation	- Collecting of past material, Pre-investigation for field measurement - Planning for hydrological observation considering the field conditions
Discharge Measurement and Calculation	- Standards compliance and decision of measuring method, measurement location considering the field conditions - Calculation using standard-calculation sheet
Evaluation of data	- Compliance with standards about measured data, Uncertainty evaluation - Error review of survey method and calculation
Quality Control(QC)	- Error analysis and supplementation according to results of valuation of data - Reflected on future measurement
Confirmation Of data	- Confirmation of data through the data revaluation
Evaluation of rating curve	- Development of rating curve - Accuracy evaluation of rating curve - Runoff analysis etc.

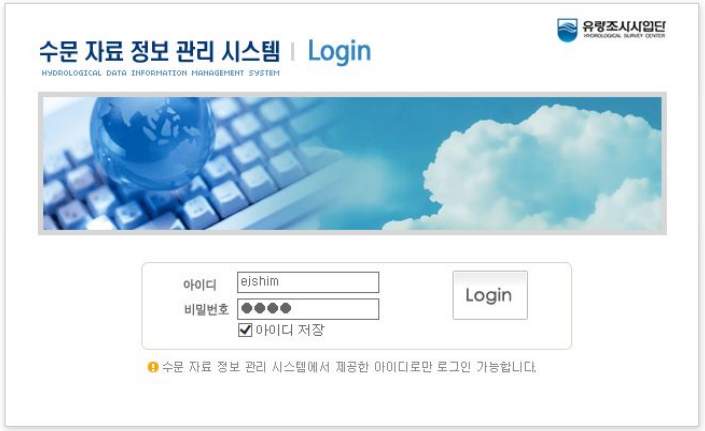
Software tool to development and manage of rating curve

- **HDQMS** (Hydrological Data Quality Management System)

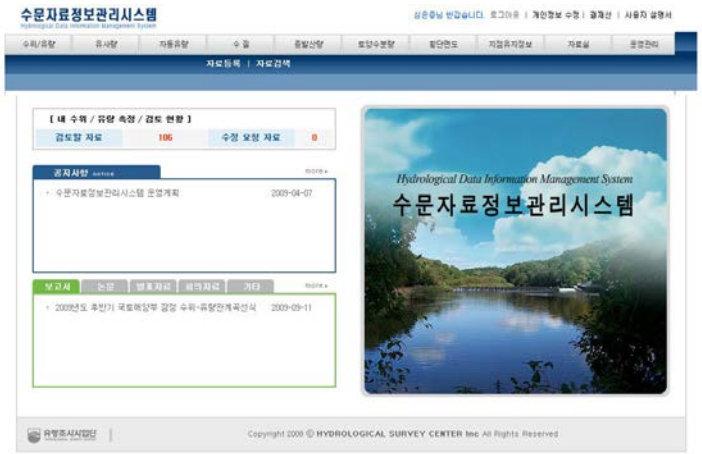


Software tool to development and manage of rating curve

- **HDIMS** (Hydrological Data Information Management System)

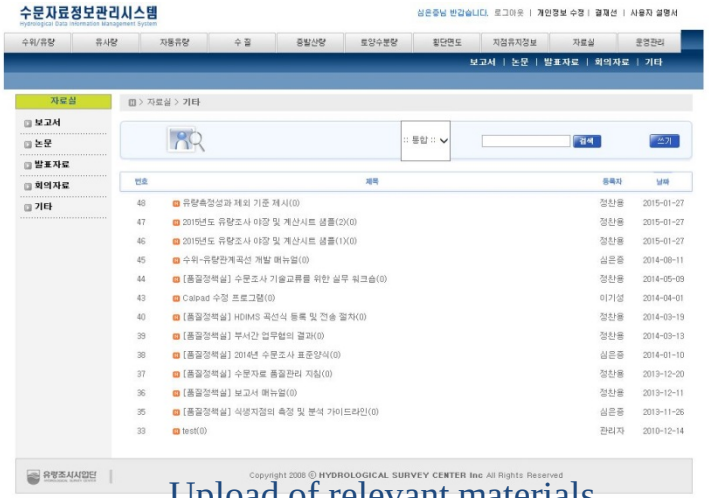


Main Screen (Log-in)



Examination of data (Electronic system)

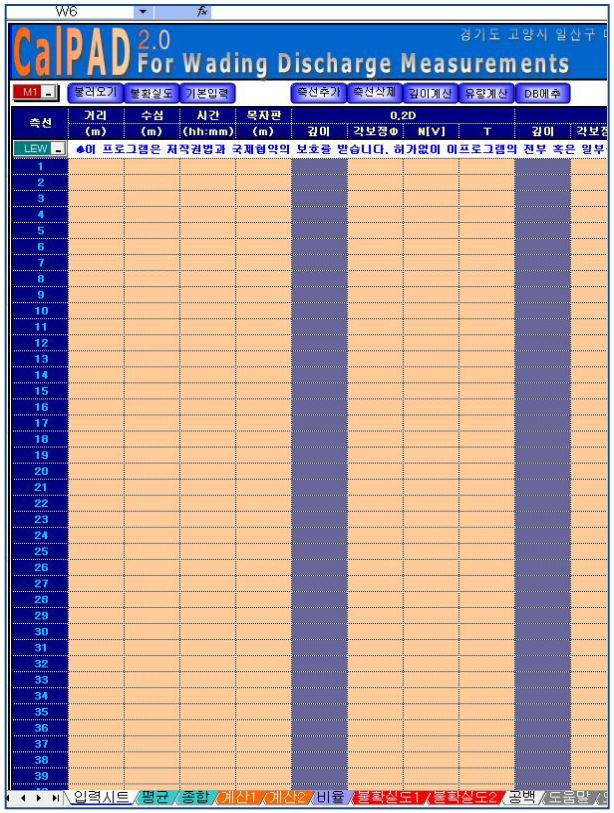
Request of data review



Upload of relevant materials

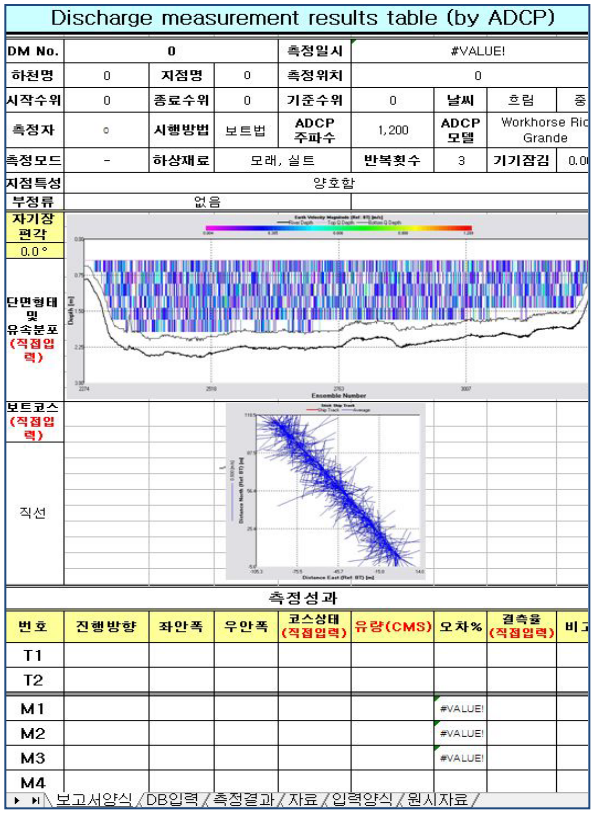
Software tool to development and manage of rating curve

- **Data analysis and rating curve development (DBPAD, CalPAD)**
- Computation sheet of discharge by measuring instrument



CalPAD
(measured by current meter)

FloatPAD
(measured by float)



ADVM sheet
(measured by ADCP)

Software tool to development and manage of rating curve

- **Data analysis and rating curve development** (DBPAD)

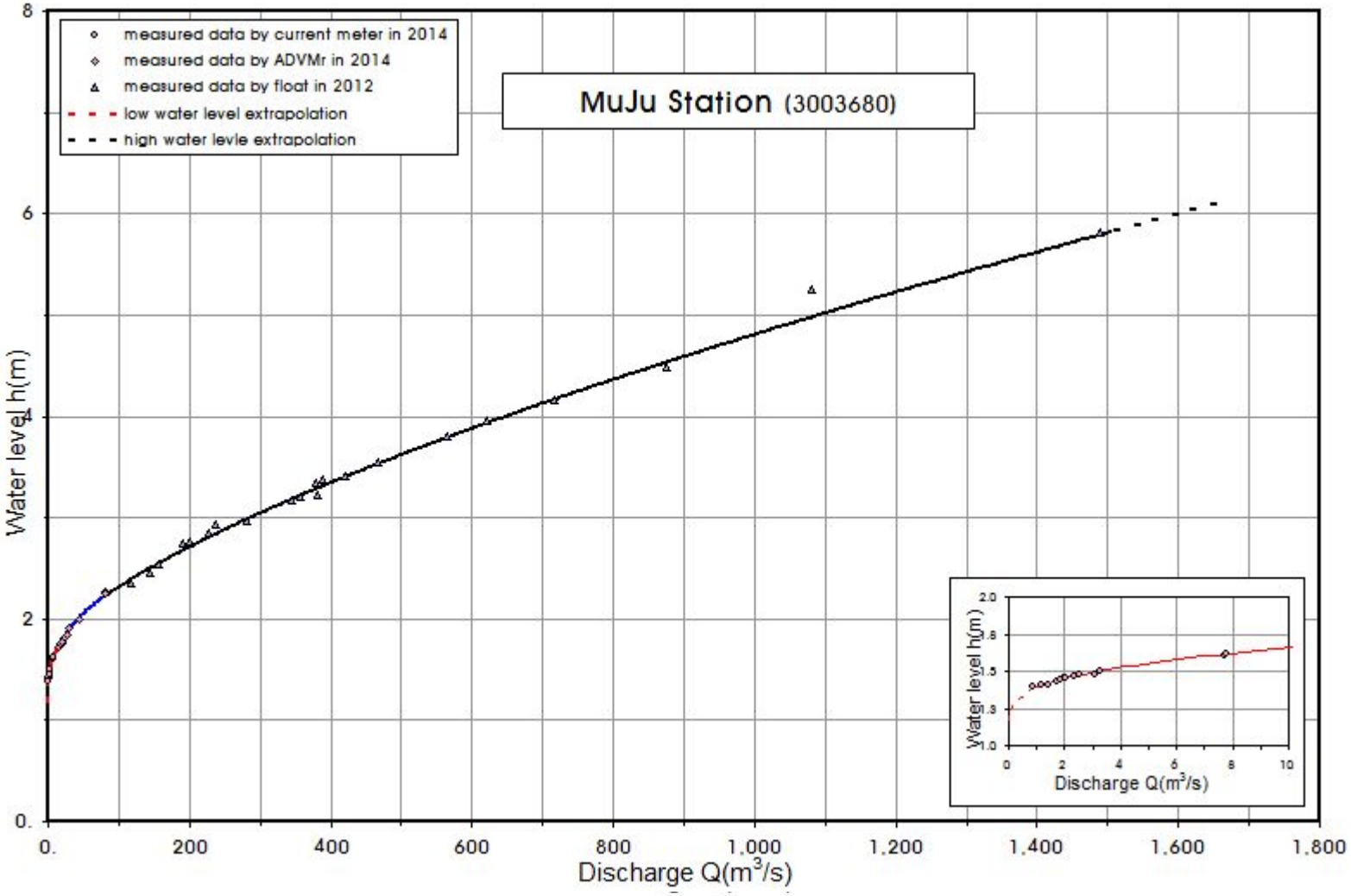
유량측정성과(지점명) HSC2011 K.S.Lee 자료추가 환산수위 (H=h+?) 최대 1,3 1,3 최저 0,13 0,13

DM No	측정 일시 (yy-mm-dd hh:mm)	수위 H (m)	수면폭 (m)	단면적 (㎡)	평균유속 (m/sec)	유량 (㎥/sec)	측정장비 (유속계종류)	유속 측선수	구간유량비(%) 최대	최소	평균	무작위 X'm (%)	계통 X''b (%)	X''d (%)	X''c (%)	X'o 무작위	X''o 계통	검 불확
3101640_14_001	2014-01-23 14:20	0,20	56,00	5,82	0,21	1,20	Flow-Tracker	38	6,38	0,87	2,63	2,00	0,50	0,50	1,00	4,08	1,22	
3101640_14_002	2014-02-13 13:26	0,21	55,50	5,67	0,21	1,21	Flow-Tracker	34	6,81	0,79	2,94	2,20	0,50	0,50	1,00	4,32	1,22	
3101640_14_003	2014-02-26 16:20	0,19	56,00	5,31	0,18	0,97	Flow-Tracker	34	6,08	0,26	2,94	2,20	0,50	0,50	1,00	4,38	1,22	
3101640_14_004	2014-03-25 14:50	0,20	55,50	5,32	0,18	0,98	Flow-Tracker	34	6,34	1,00	2,94	2,20	0,50	0,50	1,00	4,41	1,22	
3101640_14_005	2014-04-15 15:51	0,16	55,50	3,91	0,16	0,61	Flow-Tracker	34	7,77	0,83	2,94	2,20	0,50	0,50	1,00	4,63	1,22	
3101640_14_006	2014-04-25 11:40	0,18	56,00	4,39	0,19	0,82	Flowtracker	35	6,11	0,27	3,23	2,00	0,50	0,50	1,00	4,29	1,22	
3101640_14_007	2014-05-13 12:00	0,25	55,50	7,74	0,25	1,94	Flowtracker	35	5,81	0,94	3,23	2,00	0,50	0,50	1,00	4,16	1,22	
3101640_14_008	2014-05-28 16:25	0,19	55,70	5,13	0,15	0,78	Flowtracker	37	7,24	0,70	3,03	2,00	0,50	0,50	1,00	4,48	1,22	
3101640_14_009	2014-06-17 15:25	0,19	55,50	4,90	0,18	0,90	Flowtracker	34	6,90	0,82	3,33	2,20	0,50	0,50	1,00	4,39	1,22	
3101640_14_010	2014-06-24 12:03	0,22	56,50	6,81	0,22	1,53	Flowtracker	36	5,61	1,56	3,13	2,00	0,50	0,50	1,00	3,96	1,22	
3101640_14_011	2014-07-02 14:22	0,15	55,50	3,14	0,13	0,40	Flowtracker	36	7,53	0,04	3,13	2,00	0,50	0,50	1,00	4,52	1,22	
3101640_14_012	2014-07-10 14:00	0,22	55,50	6,46	0,21	1,36	Flowtracker	34	8,11	1,11	3,33	2,20	0,50	0,50	1,00	4,34	1,22	
3101640_14_013	2014-07-17 12:50	0,13	55,00	2,31	0,09	0,21	Flowtracker	43	5,93	0,00	2,56	2,00	0,50	0,50	1,00	4,23	1,22	
3101640_14_014	2014-07-23 14:42	0,54	56,00	21,06	0,78	16,49	프라이스 AA	37	4,79	0,67	3,03	2,00	0,50	0,50	1,00	3,61	1,22	
3101640_14_015	2014-07-23 15:34	0,51	56,00	20,17	0,75	15,05	프라이스 AA	37	4,81	0,65	3,03	2,00	0,50	0,50	1,00	3,61	1,22	
3101640_14_016	2014-07-23 16:30	0,49	56,00	19,66	0,69	13,64	프라이스 AA	37	5,00	0,61	3,03	2,00	0,50	0,50	1,00	3,62	1,22	
3101640_14_017	2014-07-24 13:31	0,31	56,00	10,57	0,36	3,76	Flowtracker	36	6,64	0,80	3,13	2,00	0,50	0,50	1,00	3,97	1,22	
3101640_14_018	2014-07-25 11:40	0,40	56,00	15,04	0,50	7,49	Flowtracker	35	6,34	0,55	3,23	2,00	0,50	0,50	1,00	3,87	1,22	
3101675_14_019	2014-08-03 14:34	0,27	55,50	8,99	0,31	2,78	프라이스 AA	36	5,52	0,82	3,13	2,00	0,50	0,50	1,00	3,71	1,22	
3101640_14_020	2014-08-13 15:20	0,25	55,00	8,74	0,29	2,53	Flowtracker	34	6,57	0,57	3,33	2,20	0,50	0,50	1,00	4,13	1,22	
3101640_14_021	2014-08-18 12:06	0,33	56,00	11,57	0,39	4,50	프라이스 AA	35	5,92	0,99	3,23	2,00	0,50	0,50	1,00	3,83	1,22	
3101640_14_022	2014-08-19 13:26	0,30	56,00	10,85	0,39	4,28	프라이스 AA	35	6,56	0,67	3,23	2,00	0,50	0,50	1,00	3,84	1,22	
3101640_13_023	2014-08-21 13:20	1,05	39,06	64,26	1,05	67,20	부자	14	11,23	4,93	8,33							
3101640_13_024	2014-08-21 17:58	1,11	39,21	68,12	1,05	71,82	부자	14	9,89	5,14	8,33							
3101640_13_025	2014-09-03 14:05	0,80	38,51	50,37	0,84	42,26	부자	13	13,80	4,22	9,09							
3101640_13_024	2014-09-03 14:36	0,78	38,46	49,32	0,84	41,34	부자	13	12,63	3,88	9,09							
3101640_13_027	2014-09-03 15:21	0,75	38,40	47,74	0,80	38,08	부자	13	14,75	5,54	9,09							
3101640_13_028	2014-09-03 16:00	0,72	38,33	46,75	0,70	32,89	부자	14	14,64	4,87	8,33							
3101640_13_029	2014-09-03 16:40	0,70	38,28	45,69	0,70	32,14	부자	14	14,65	4,86	8,33							
3101640_14_030	2014-09-17 11:52	0,28	55,50	9,92	0,33	3,32	Flowtracker	35	5,17	0,73	3,23	2,00	0,50	0,50	1,00	3,94	1,22	
3101640_14_031	2014-10-16 12:00	0,23	55,90	7,04	0,23	1,60	Flowtracker	38	5,49	0,05	2,94	2,00	0,50	0,50	1,00	3,91	1,22	
3101640_13_032	2014-10-21 13:51	1,13	39,25	68,90	0,92	63,19	부자	14	15,08	5,13	8,33							
3101640_13_033	2014-10-21 15:08	1,23	39,48	74,40	0,98	73,12	부자	14	15,42	5,31	8,33							
3101640_13_034	2014-10-21 15:58	1,25	39,52	75,50	1,01	76,29	부자	14	15,46	4,46	8,33							
3101640_13_035	2014-10-21 16:40	1,30	39,63	78,26	1,03	80,71	부자	14	15,18	5,00	8,33							
3101640_13_036	2014-10-21 18:30	1,25	39,51	75,22	1,08	81,16	부자	14	15,50	4,96	8,33							
3101640_14_037	2014-11-04 14:21	0,28	56,00	9,41	0,30	2,83	Flowtracker	36	5,96	0,47	3,13	2,00	0,50	0,50	1,00	3,93	1,22	

DB / H_A,V,Q / 기타 / 기타2 / 단면 / 과거실과(DB) / 과거레이팅 / 수위-유량(과거)_신대 / 수위-유량(과거)_대대 / 수위-유량_신대 / 수위-유량_대

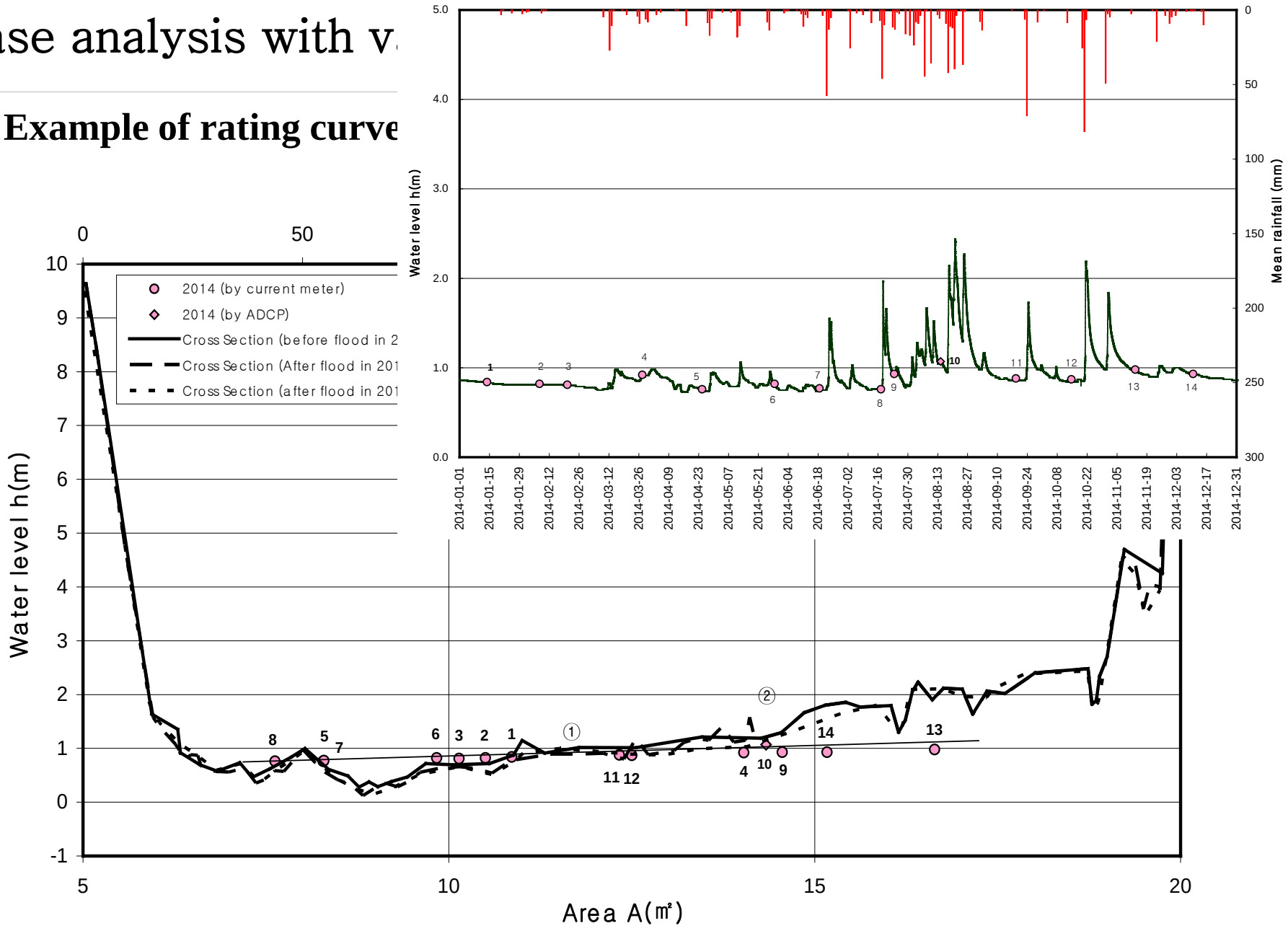
Software tool to development and manage of rating curve

- **Rating curve standard form in HSC**



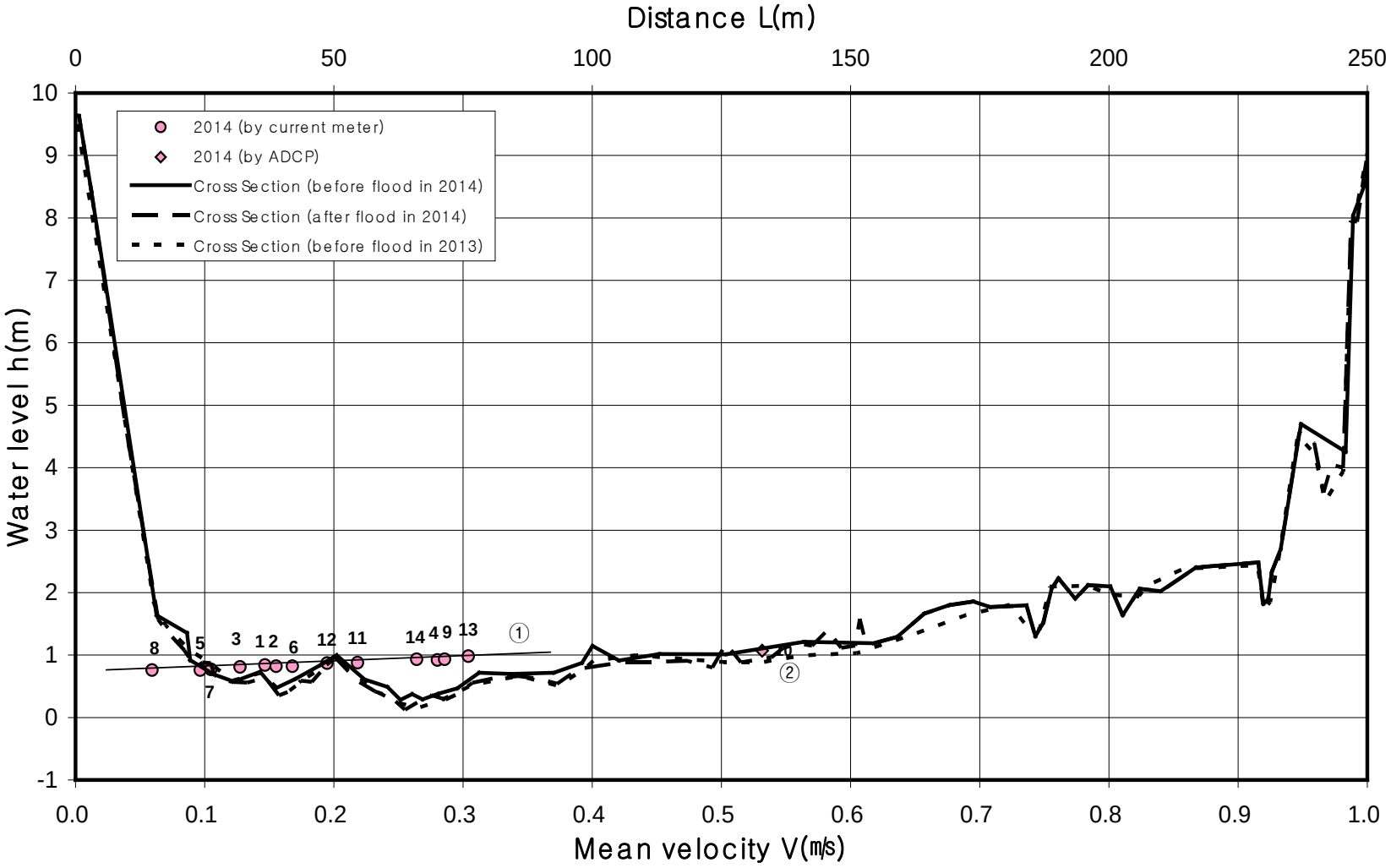
Case analysis with v

Example of rating curve



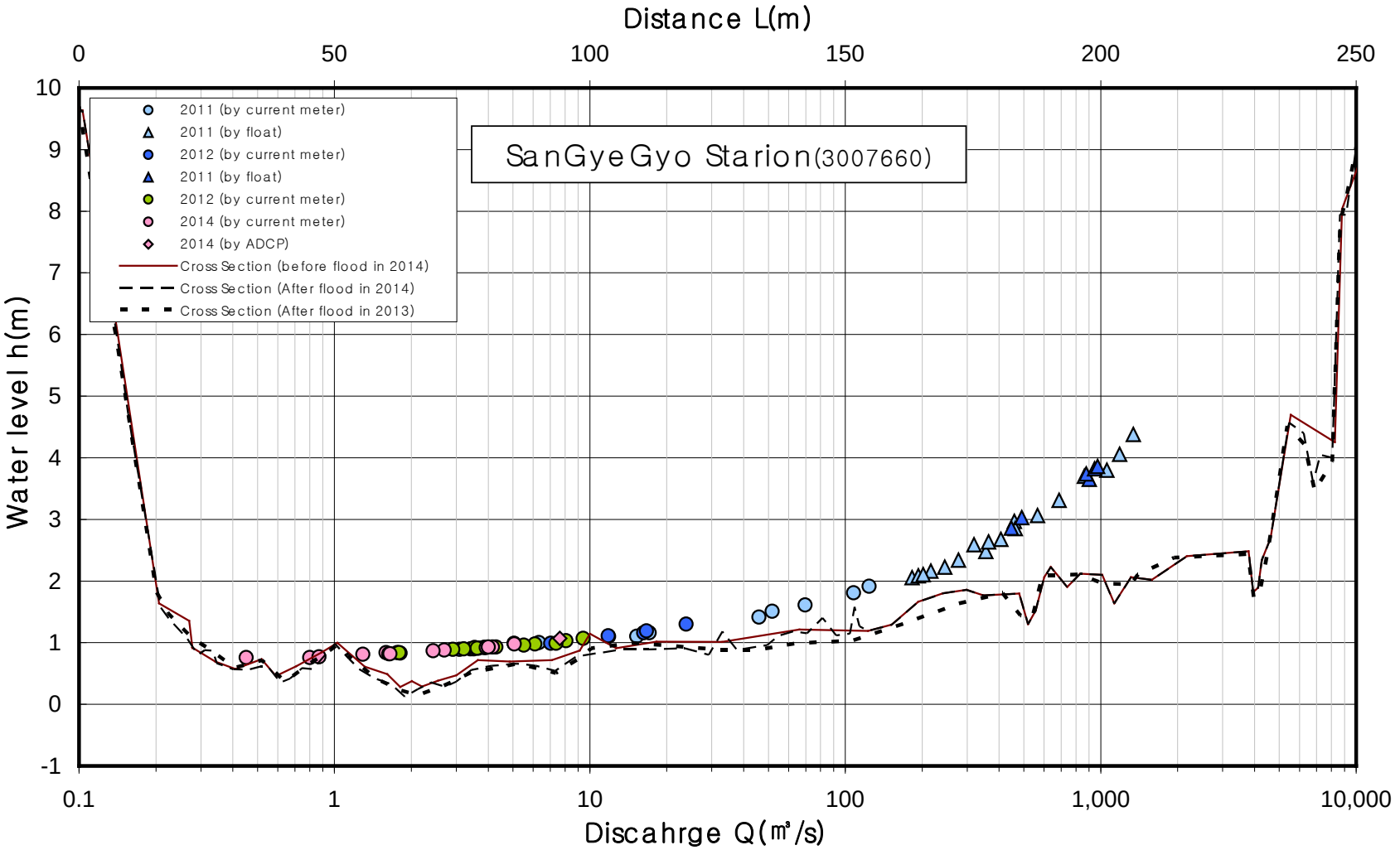
Case analysis with various field conditions

Example of rating curve development(SanGyeGyo St.)



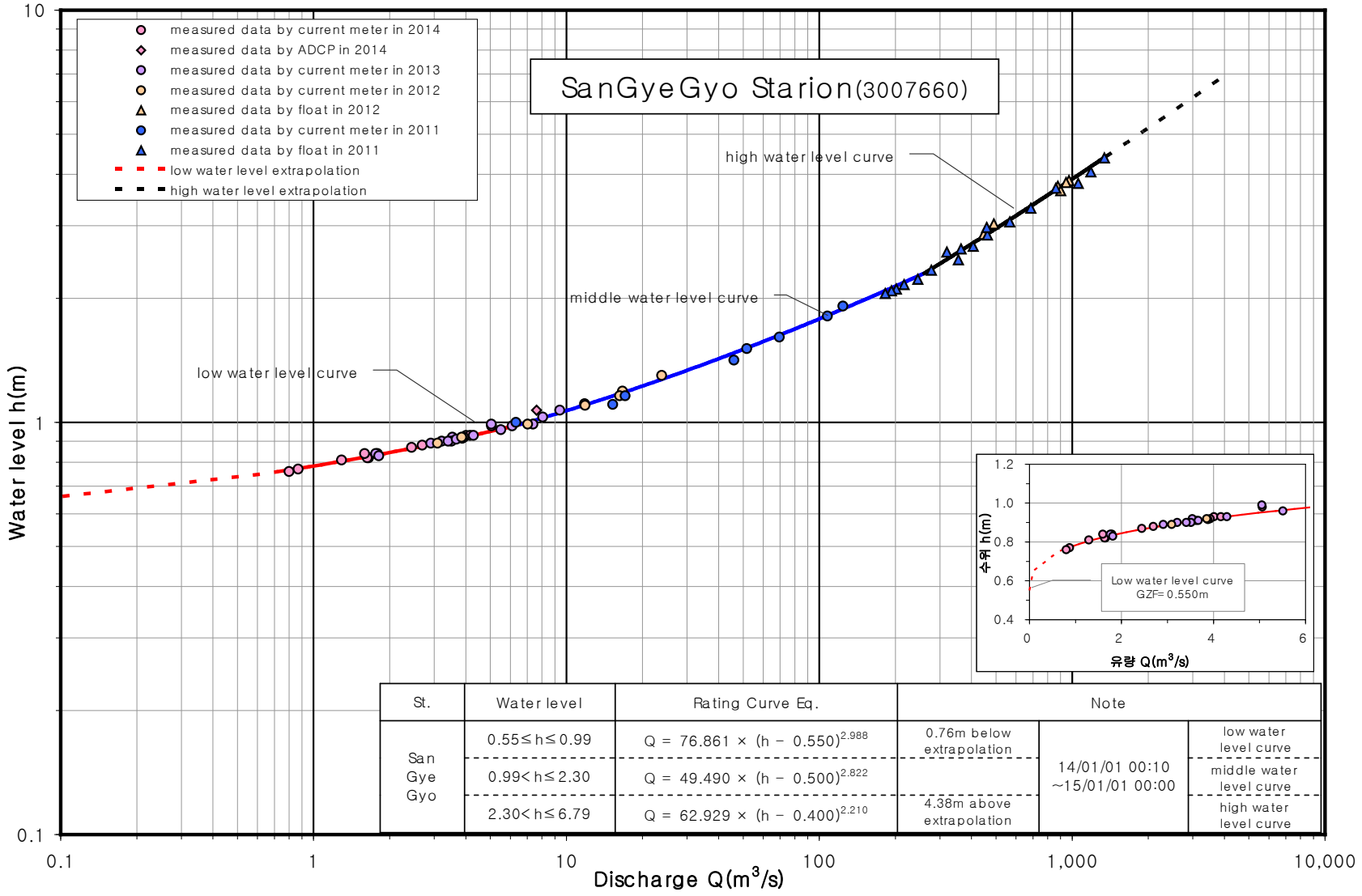
Case analysis with various field conditions

Example of rating curve development(SanGyeGyo St.)



Case analysis with various field conditions

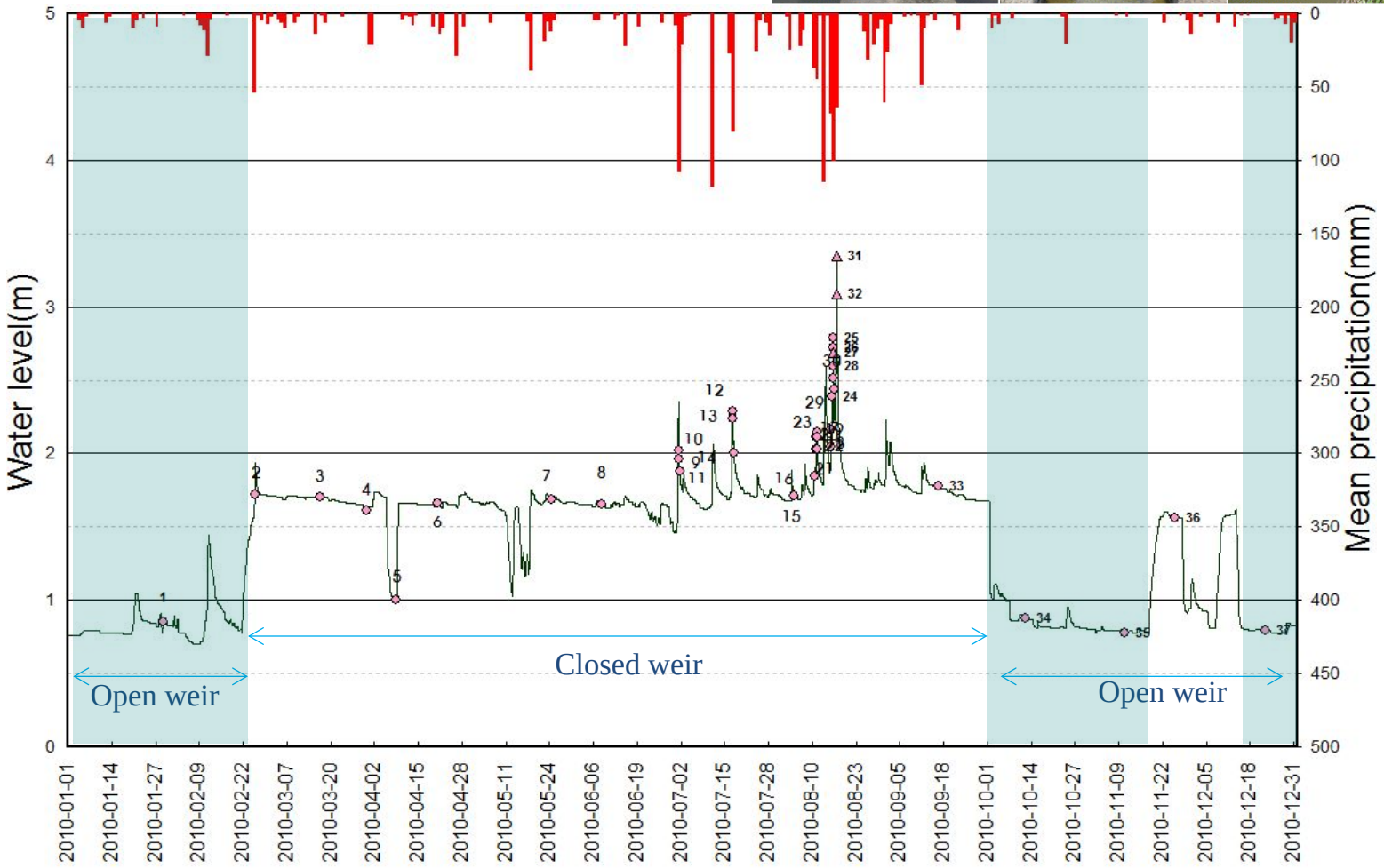
Example of rating curve development(SanGyeGyo St.)



St.	Water level	Rating Curve Eq.	Note		
San Gye Gyo	0.55≤h≤0.99	$Q = 76.861 \times (h - 0.550)^{2.988}$	0.76m below extrapolation	14/01/01 00:10 ~15/01/01 00:00	low water level curve
	0.99<h≤2.30	$Q = 49.490 \times (h - 0.500)^{2.822}$			middle water level curve
	2.30<h≤6.79	$Q = 62.929 \times (h - 0.400)^{2.210}$	4.38m above extrapolation		high water level curve

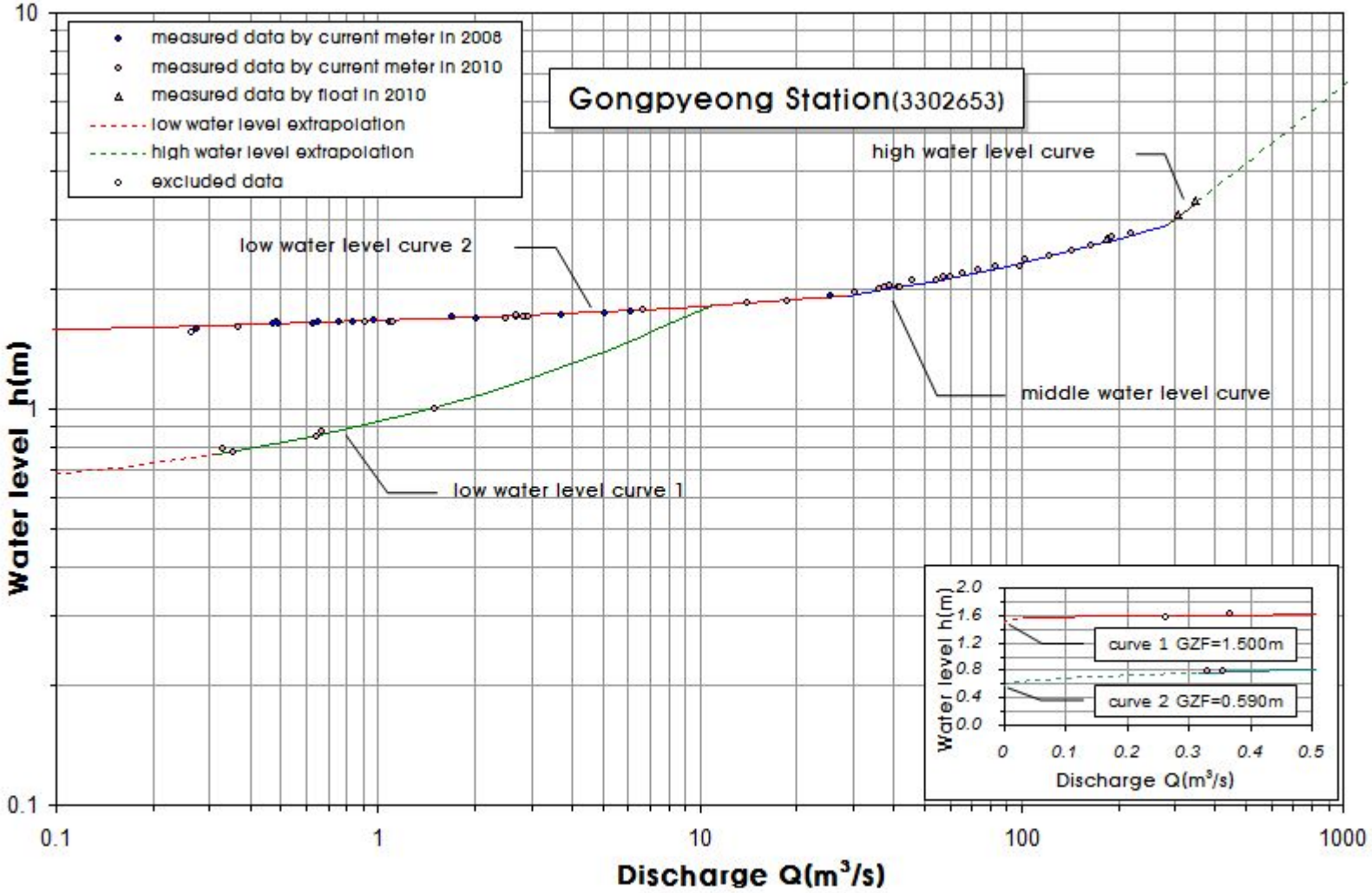
Case analysis with various field conditions

- **Development of rating curve in backwater effect (Weir, Stream juction)**
- Example of **Weir operation**
  - Field monitoring case of weir operation



Case analysis with various field conditions

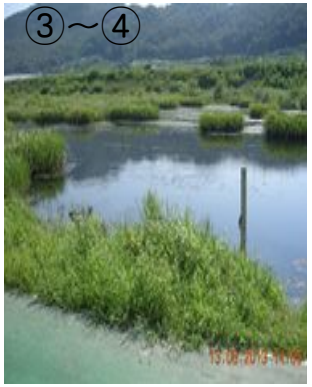
- **Development of rating curve in backwater effect (Weir, Stream juction)**
- Example of **Weir operation**



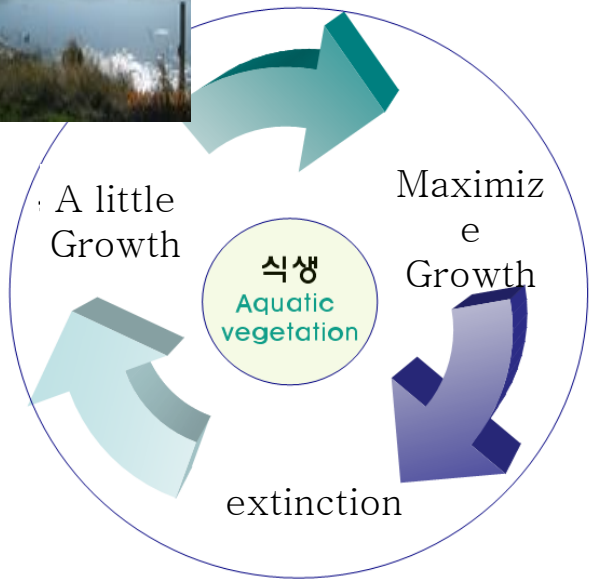
Case analysis with various field conditions

- **Development of rating curve Considering Vegetation**
- Example according to the monitoring of vegetation growth and development of rating curve by vegetation.

  - Separation of period by growth(Circulation) of vegetation



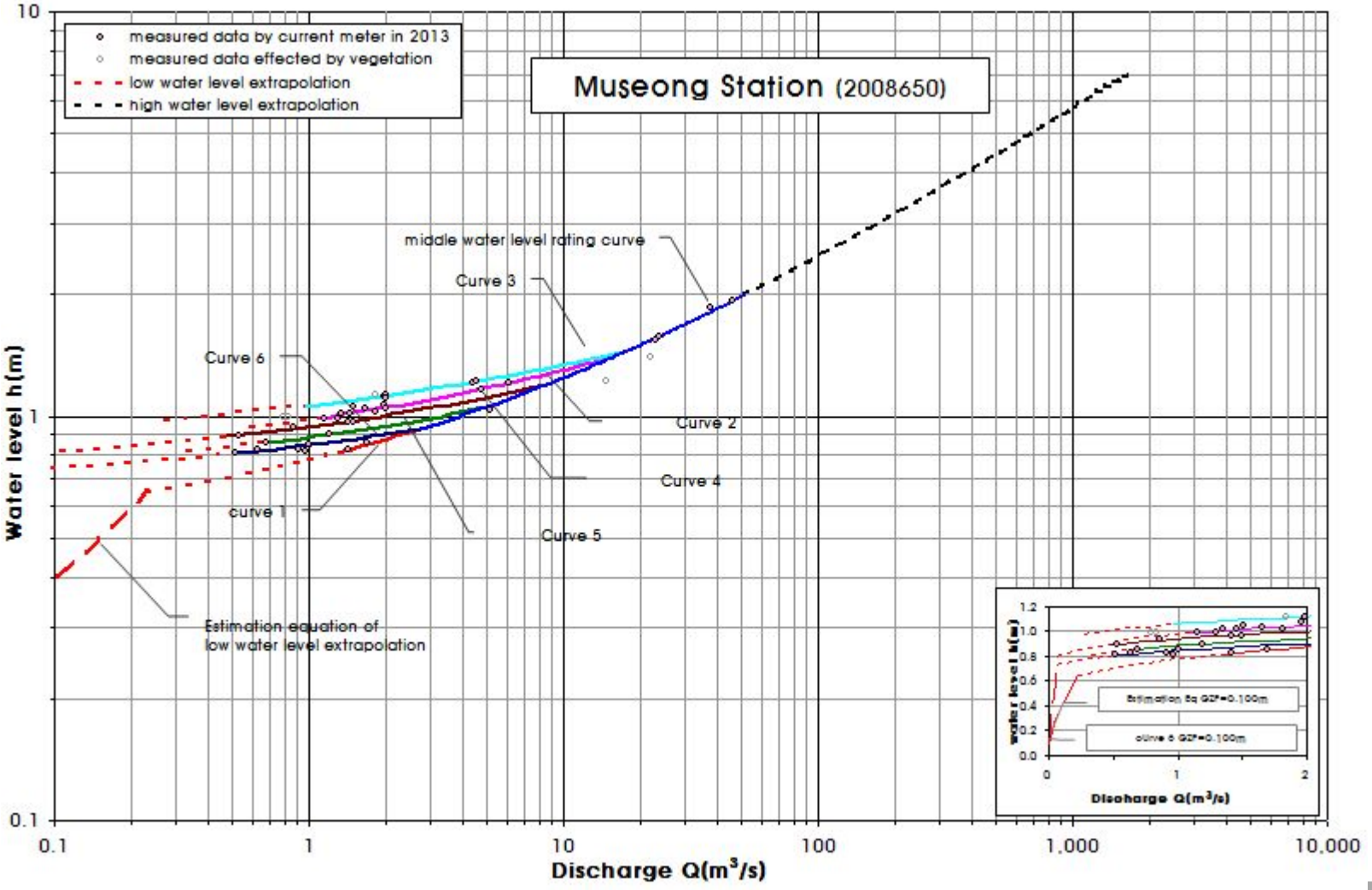
① Little effect of Vegetation
②~④ The growth period of vegetation
⑤~⑦ The extinction period of vegetation



Periodicity of vegetation

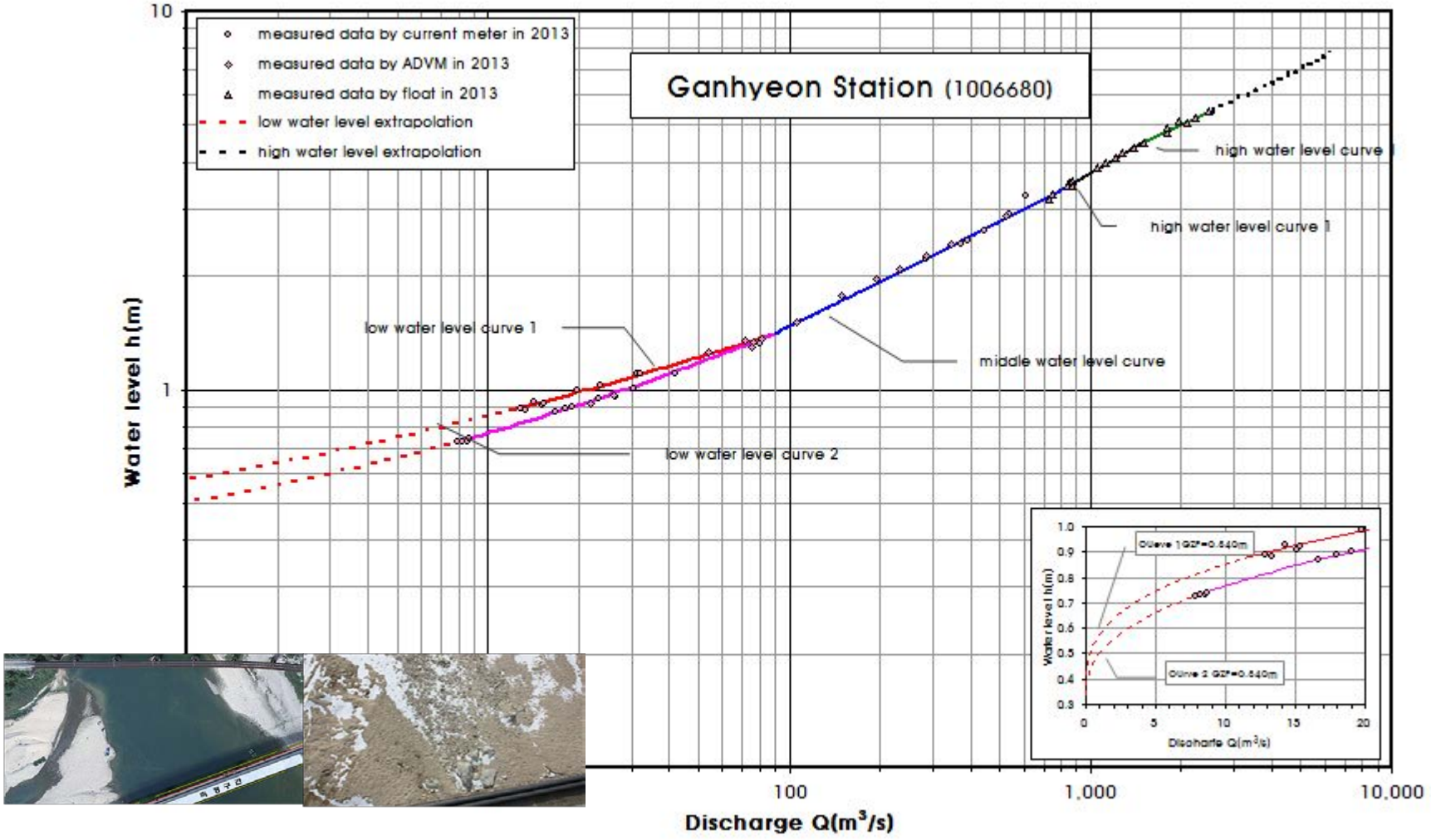
Case analysis with various field conditions

- **Development of rating curve Considering Vegetation**
- Example according to the monitoring of vegetation growth and development of rating curve by vegetation.



Case analysis with various field conditions

- **Analysis on effect of stream environment change on rating curve**
- Example of sand channel stream (Separation by before and after the flood bed change)
- ①13/01/01 00:00-13/07/20 18:40 ②13/07/20 18:50-13/12/31 23:50 (Scour of session)



Work Plan, output and future plan

Work plan_1. IRDIMS

Activities	Actions	Outputs	Resources	Milestones	Linkages	Progress
1. Hydrometric measurements with quality and accuracy (2.2.2)	- Provide guidance on the use of appropriate instruments and methods of observation in diverse conditions (Priority A) - Collection of existing technical information in IRDMIS ➢ Measurement instrumentation (ADVM) ➢ Methods of discharge calculation ➢ Construction and operation of IRDIMS - Case study on measurement by IRDMIS (52 sites) ➢ Measurement of tidal influenced discharge ➢ Measurement under backwater conditions caused by weirs, sluice gates, and river junctions ➢ Evaluation of measurement results ➢ Development of index velocity ratings - Writing Technical report about construction and management by field characteristics	• Provide Technical report and guideline to design, install and operate facilities for Integrated Real-time Discharge measurement system(IRDIMS) • Software System for developing index rating Technical report	• Republic of Korea(ROK)	• Provide Technical report and guideline with case studies - Nov 2016 • Collection of the existing technical information of IRDIMS - Dec 2015 • Collection of construction, measurement cases and management of IRDIMS (52 sites more) - Dec 2015 Writing technical report about construction and management by field characteristics - Nov 2016 → Dec 2016	• CHy • ROK	Writing technical report - *Technical information of IRDIMS* - *Installation and operation* - *Discharge calculation including development of index rating* - *Software tool for development of index rating* - *Case study on various conditions*

Work Plan

Work plan_2. Sediment

Activities	Actions	Outputs	Resources	Milestones	Linkages	Progress
	- Improve sediment measuring techniques (Priority B) - Collection of existing technical information ➢ The status of existing sediment measurement techniques ➢ The status of new technologies and their applications ➢ The status of analysis methods - Case studies on sediment measurements under various conditions (15 - 20 sites) ➢ Analysis of river construction effect on characteristics of sediment load, focused on 4 major river projects in Korea ➢ A comparative analysis on sediment load by sequence of rainfall event - Writing Technical report about sediment measurement method and analysis of field characteristics	- Technical report on sediment measurement methods	- Republic of Korea(ROK)	Provide technical report and guideline with case studies Nov 2016 → Dec 2016	• CHy • ROK	Writing technical report - *Technical information of sediment measurement* - *Case study on sediment measurement various conditions*

Work Plan

Work plan_3. Rating curve

Activities	Actions	Outputs	Resources	Milestones	Linkages	Progress
2. Hydrometric measurements with quality and accuracy (2.2.2)	• Focus on the development of rating curve - Collection of existing technical information (Priority B) ➢ On major procedures for rating curve development ➢ On tools for rating curve development - Case analysis with various field conditions ➢ On development of rating curves when backwater conditions exist (weir, junctions) - Writing technical report on rating curve development	• Report on methods to develop rating curves	• Republic of Korea (ROK)	• Provide Technical report and guideline with case studies Nov 2016 → Dec 2016 •	• CHy • ROK	Writing Technical Report - Status of flow measurement the past 3 years - Procedure of H-Q rating development - Software tools to develop & manage of H-Q rating curve - Case study on development of H-Q rating curve in various conditions and its guideline (backwater by weir, bed change, vegetation)

Thank you for your attention!