DISSERTATION

OPTIMIZATION OF SANGJU WEIR OPERATIONS

TO MITIGATE SEDIMENTATION PROBLEMS

Submitted by

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ABSTRACT

OPTIMIZATION OF SANGJU WEIR OPERATIONS

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The Four River Restoration Project (FRRP) in Korea was completed by the Korean Government in 2013. Through this project, eight weirs were constructed along the Nakdong River, which have altered the river regime from a natural environment to post-weir conditions. The construction of the consecutive weirs and excavation along the Nakdong River changed many channel characteristics such as longitudinal slope, cross-sectional area, water stage which led to changes in erosion and sediment transport patterns. It is now necessary to assess the sedimentation problem upstream of the weirs and seek a way to mitigate the problem.

Firstly, sedimentation is partly linked to the current weir operation rules. There are multiple purposes, when it comes to reservoir operations, and the various interests include: (1) flood control, (2) dredging, (3) hydropower production, (4) water supply, and (5) environment, including fish passage, recreation, tourism and downstream turbidity. Thus, introducing optimization techniques for reservoir operations is expected to mitigate sedimentation problems for complex multi-purpose weirs.

The study site of Sangju Weir has been selected for this study because it is a representative site for these types of problems and because sufficiency and availability of data.

The purpose of this research is to:

(1) estimate incoming sediment yield, define the trap efficiency and estimate the reservoir sedimentation rates of weirs and low-head dams using the Flow-Duration and Sediment

Rating Curve (FD/SRC) method, along with the Series Expansion of the Modified Einstein Point Procedure (SEMEPP) to determine the long-term sediment yield for Sangju Weir from suspended load concentration measurement;

(2) find the B/C ratio and break-even point between hydropower production revenues and sediment excavation costs using a Benefit and Cost Analysis (BCA);

(3) suggest new operation rules for Sangju Weir and propose a systematic analysis procedure to find a better operation rules for mitigating sedimentation problems using the Multi-Criterion Decision Analysis (MCDA) method.

The methodology used for this study includes the followings. First, in this study, the Integrated Reservoir Sedimentation Estimation Procedure (IRSEP) was proposed to estimate the reservoir sedimentation at weirs and low-head dams. IRSEP integrates all conventional methods related to reservoir sedimentation: (1) Flow-Duration (FD), (2) Sediment-Rating Curve (SRC), (3) Series Expansion of the Modified Einstein Point Procedure (SEMEPP), and (4) Trap efficiency (T_E), in order to estimate reservoir sedimentation rate. Steps (3) and (4) constitute the new elements of this type of analysis. Through stream flow runoff modeling and channel geometry analysis, the trap efficiencies in accordance with certain stages were defined. The trap efficiency of Sangju Weir was calculated for each sediment size fraction as a function of the variables, sediment load at daily discharges and particle size distribution of the sediment transported by the Nakdong River. The trap efficiency is also dependent on channel geometry, inflow discharge and reservoir stage determined by the operation rules at Sangju Weir. Then, the amount of reservoir sedimentation was calculated by multiplying the annual sediment load with trap efficiencies, which vary with discharge and water stage. As a result, the reservoir filling rates were examined.

Second, the B/C ratio and break-even point between hydropower production revenues and sediment excavation costs were estimated using a Benefit and Cost Analysis (BCA) method based on daily-modeling. Since the operation rules of Sangju Weir significantly affect the trap efficiency and the volume of dredging, it is essential to determine the effects of the reservoir operation rules using the Multi-Criterion Decision Analysis (MCDA) technique in order to seek improvement in the operation rules to mitigate sedimentation costs, simultaneously considering the other decision makers' interests. Finally, new operational rules for Sangju Weir and a systematic analysis procedure were proposed.

The conclusions of this research with respect to the sediment problems and reservoir operation rules are summarized as follows:

(1) the total incoming sediment load and the average trap efficiency (T_E) at the lowest (EL37.2m) and highest (EL47.0m) stages were estimated as 425,000 tons/year, 50.1 % and 78.1%, respectively; and the maximum annual amount of reservoir sedimentation at Sangju Weir was estimated as 332,000 tons/year (207,000 m^3/year) which corresponds to 0.76 %/year of the total reservoir storage of Sangju Weir. On the contrary, the minimum reservoir sedimentation rate was 0.49 %/year, which was come when the water stage was the lowest (EL37.2m). According to this result, it was proved that reservoir operation rules like management water stage considerably affects reservoir sedimentation.

(2) Since the operation rules of Sangju Weir affects significantly the trap efficiency, a Benefit and Cost Analysis (BCA) based on daily-modeling was performed in order to find the break-even point between hydropower production revenues and sediment excavation

costs. For daily sediment transport modeling, historical and predicted reservoir stream flow data (2015-2034) were generated by Tank model using seventy-six daily precipitation data. The B/C ratio obtained 20 years of daily simulation was calculated as 2.28. Also, the discharge and stage thresholds, balancing both hydropower production revenues and sediment excavation costs, are found as 600 m^3/s and EL43.6m, respectively.

(3) based on the daily Multi-Criterion Decision Analysis (MCDA) modeling, the most favorable Sangju Weir operation rules to mitigate reservoir sedimentation were found in Alternative 5 after including seasonal management of stage control according to the magnitude of the upstream inflow. Proposed operation rules are shown below:

Season	Inflow (m^3/s)	Stage (EL. m)
Non-flood season (October-May)	Any	47.0
Flood Season (June-September)	below 50	47.0
	50 ~ 600	46.0
	above 600	44.5

The systematic analysis procedure, the combination of the Integrated Reservoir Sedimentation Estimation Procedure (IRSEP) and the Multi-Criterion Decision Analysis (MCDA) method, are deemed useful to find optimum operation rules of weirs and low-head dams, which can mediate the disputes among various decision makers who have different interests related to reservoir operation. The proposed methodology could be applied to the other weirs of the Four River Restoration Project, and elsewhere.

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DEDICATION

To Ho Sun and Myong Seob

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1 CHAPTER I – INTRODUCTION AND OBJECTIVES

1.1 FOUR RIVER RESTORATION PROJECT IN KOREA

The Four River Restoration Project (FRRP) in Korea was initiated in 2009 by the Korean Government to preemptively respond to climate change. Through this project, sixteen weirs were installed on major rivers in Korea. Before the FRRP, Korean rivers suffered from severe droughts and floods due to the hydrological characteristics of Northeast Asia. The rapid industrialization, river basin development, and crop cultivation within levees resulted in significant inflows of pollutants that resulted in deterioration of the river water quality.

The Korean government undertook the project in order to improve flood control, restore the river ecosystems, and provide drought relief, with a total budget of approximately 18 billion US dollars. The project was completed in 2013, and has shown successful results of decreasing the damage by floods and droughts. The project included the construction of sixteen movable weirs (length: 184 - 953 m, height: 3.5 - 11.8 m) with associated hydropower plants. Large scale dredging operations were conducted to reduce flood stages and restore floodplains for agriculture in the major rivers of Korea – Han River, Nakdong River, Geum River and Yeongsan River. The deteriorated levees were reinforced, and approximately 450 million m^3 of material was dredged in order to increase the flood control capacity for a 200-year flood. As a result, lowered riverbeds have increased the flow capacity of the river cross section, resulting in reducing flood damage to adjacent farming land and residential areas near the rivers. In addition, an improvement in base flow discharge has been supplied from two multi-purpose dams (Yeongju and Bohyunsan) constructed in the upstream of the Nakdong River watershed. The project successfully lowered the river water level by 4.9 m during the flood season in 2012.

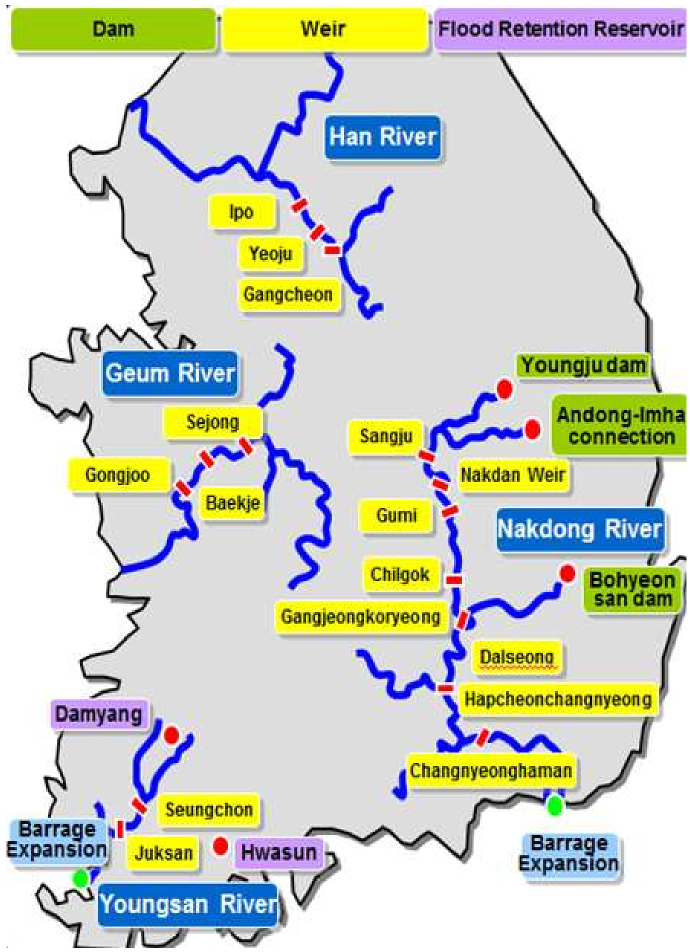


Figure 1: The location of sixteen weirs constructed by FRRP

1.2 PROBLEM STATEMENT

The construction of consecutive weirs and excavation along major rivers has changed many characteristics of the channel such as longitudinal slope, cross-sectional area, water stage, and others, which will lead to change in erosion and sediment transport patterns.

The natural processes of erosion, transport, and sedimentation of solid particles can lead to significant engineering and environmental problems. Sediment particles at a given stream cross section were eroded somewhere in the watershed and transported by flow from the place of erosion to the cross section.

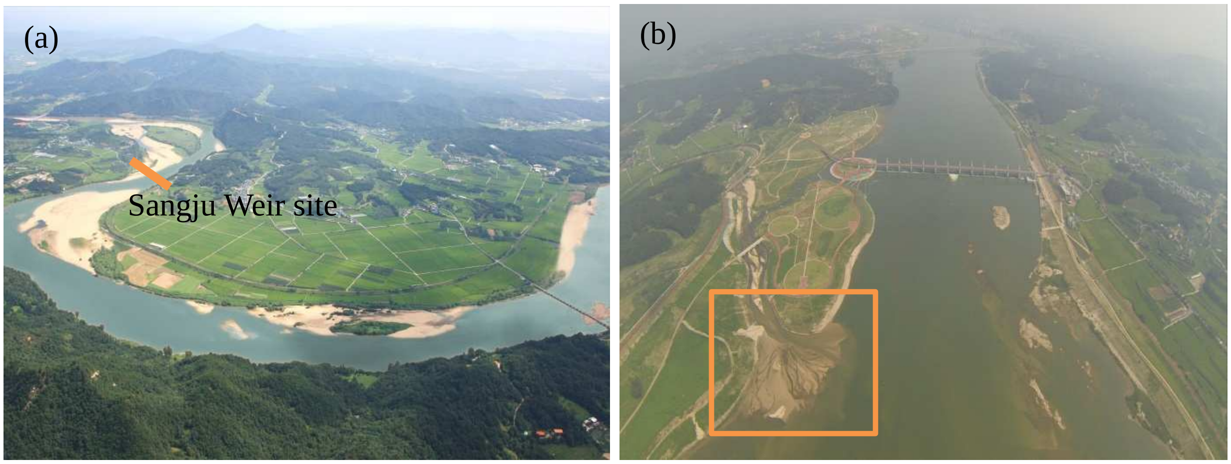


Figure 2: Example of reservoir sedimentation; (a) Sedimentation of Sangju Weir in Nakdong River; (b) the sedimentation problem at Yeoju Weir downstream in Han River

Figure 2 shows two reservoir sedimentation examples, one of which has occurred upstream of Sangju Weir in the Nakdong River. Reservoir sedimentation depends on sediment discharges and trap efficiency of the reservoir. The sediment trap efficiency increased after construction of weirs. In this condition, the operation rules of hydraulic structures significantly affect reservoir trap efficiency significantly.

Reservoir sedimentation problems can be summarized as below:

(1) after consecutive weir construction along the river, sedimentation problems have been severe at the reservoirs;

(2) ambiguous reservoir operation rules aggravate the reservoir sedimentation problem;

(3) reservoir sedimentation leads to undesirable costs required for excavation.

Since reservoir operation is influenced by various decision makers, conflicts may arise among them. It is necessary to suggest reasonable operation rules to alleviate disputes among various decision makers. The study site of Sangju Weir has been selected for this study because it is a representative site for these types of problems and because of sufficiency and availability of data. The Sangju Weir is one of the weirs constructed by FRRP. Since the Sangju Weir is the most upstream on the Nakdong River and includes two tributaries: the Naesung Stream and the Yeong Stream as well as the main Nakdong River, the Sangju Weir can be considered one of the representative sites for sedimentation problem research.

1.3 DISSERTATION OBJECTIVE

The purpose of this research is to improve the operation rules of Sangju Weir to mitigate sedimentation problems, considering sediment concentration in the catchment area, discharge of the river, water stage of the reservoir, operation of upstream dams, hydropower production of the hydraulic facilities, and sediment trap efficiency.

The main objectives of this research are to:

(1) estimate incoming sediment yield, define the trap efficiency and estimate the reservoir sedimentation rates of weirs and low-head dams using the Flow-Duration and Sediment Rating Curve (FD/SRC) method, along with the Series Expansion of the Modified Einstein Point Procedure (SEMEPP) to determine the long-term sediment yield for Sangju Weir from suspended load concentration measurement;

(2) find the B/C ratio and break-even point between hydropower production revenues and sediment excavation costs using a Benefit and Cost Analysis (BCA);

(3) suggest new operation rules for Sangju Weir and propose a systematic analysis procedure to find better operation rules for mitigating sedimentation problems using the Multi-Criterion Decision Analysis (MCDA) method.

It is important to note the differences of operation rules between dams and weirs; usually dams are planned to store water for flood control, water supply, hydropower production, and other purposes. On the other hand, weirs typically do not store water. However, erosion and sedimentation problems also occur in reservoirs that are operated by weirs.

Many researchers have studied reservoir sedimentation, the estimation of incoming sediment load, and the optimization of operation rules in view of flood control and water supply; however, the optimization of operation rules in view of sedimentation problems by predicting incoming sediment load and giving careful consideration to various decision makers has been rarely attempted.

This dissertation consists of seven chapters. An introduction is presented in Chapter 1. Chapter 2 provides the literature review for the reservoir sedimentation and optimization method. The site descriptions and characteristics of the study area are described in Chapter 3. Chapter 4 presents the sediment transport in this area including data from previous measurement and estimation of trap efficiency. In Chapter 4, the Flow-Duration and Sediment Rating Curve (FD/SRC) method and the Series Expansion of the Modified Einstein Point Procedure (SEMEPP) were used. Chapter 5 addresses a Benefit and Cost Analysis (BCA) using the historical data. Chapter 6 provides information and simulation results using multi criterion decision analysis (MCDA) optimization and proposes the new systemic analysis procedure to solve these complex problems. The conclusions are addressed in Chapter 7.

1.4 RESEARCH APPROACH AND METHODOLOGY

Three steps are required to achieve the goals in this research as follows:

Stage.1: Estimation of hydrologic and hydraulic quantities

The incoming sediment load and reservoir sedimentation were calculated using the Flow-Duration and Sediment Rating Curve (FD/SRC) method and the Series Expansion of the Modified Einstein Point Procedure (SEMEPP) and sediment trap efficiency. The stream flows are generated based on historical precipitation and meteorological data. A series of analyses were performed separately in three basins: (1) Naesung Stream including Yeongju multi-purpose dam sub-basin; (2) Yeong Stream; and (3) upper part of Nakdong River basin which includes sub-basin of Andong and Imha multi-purpose dam.

Stage.2: Define the cost threshold in view of hydropower generation and sediment excavation

A Benefit and Cost Analysis (BCA) was performed to find the thresholds for balanced hydro-power production revenue and sediment excavation cost, using historical operational data.

Stage.3: Optimization with MCDA method

The optimal Sangju Weir operation rule was proposed using the Multi-Criterion Decision Analysis (MCDA) method, which can mediate the dispute among various decision makers. And a new systematic analysis procedure was proposed

Figure 3 presents the detailed research procedure and flow including the phases of the study and their associated analyses.

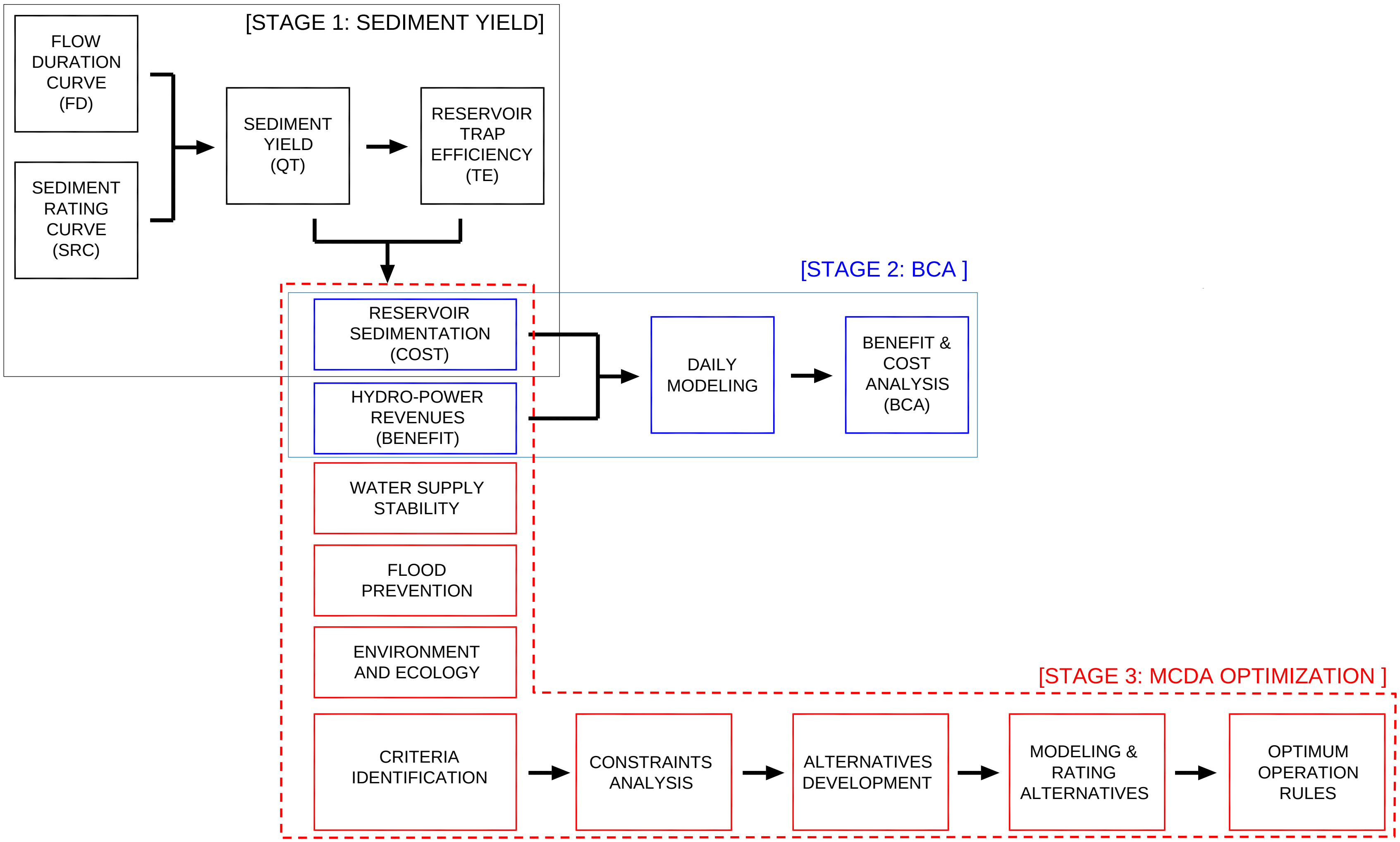


Figure 3: Study procedure

2 CHAPTER II – LITERATURE REVIEW

Although dam construction on alluvial rivers decrease peak flood flow and sediment discharge downstream (Williams & Wolman, 1984), dams disturb longitudinal continuity, and interfere with continuities of flow and sediment transport in rivers. Channel bed elevation increases and channel slope is reduced upstream of the dam. When water flows into a reservoir, the capacity of sediment transport is decreased significantly. In addition, this stimulates the development of a delta at the boundary of the backwater and decreases the storage capacity of the reservoir. Reservoirs usually trap over 90% of the total sediment load and in particular, trap efficiencies of giant reservoirs are typically over 99% (Williams & Wolman, 1984). Mahmood (1987) presented that about 1% of the total storage overall reservoirs in the world is annually lost because of reservoir sedimentation, which is corresponding to replacing approximately 300 large dams worldwide with the estimated cost of 9 billion dollars to replace existing storage capacity (Annandale, 2001).

In view of reservoir operation, although released water from a dam has energy to transport sediment discharge, there is no sediment. This flow is called ‘hungry water’ which dissipates its energy to scour the channel bed and bank (Kondolf, 1997). Several years of channel bed and bank erosion after dam construction, an equilibrium is reached as bed-material grain size becomes coarse: the bed-material cannot move anymore because of channel bed armoring (Julien, 2002). The eroded bed sediment directly downstream of a dam or weir functions as a sedimentation source downstream.

Reduction of sediment discharge in rivers downstream of dams varies due to factors such as the storage of the reservoir, facility operation, and the location of dam related to sediment sources (Brandt, 2000). After construction of weirs and dredging the river bed through the Four River Restoration Project, the natural river environments were changed. Also, sediment transport and reservoir sedimentation rates are affected by reservoir operations.

This chapter provides a literature review in terms of total sediment load, trap efficiency, and optimization techniques.

2.1 TOTAL SEDIMENT LOAD (Q_{TOT})

There are difficulties in estimating the total sediment load in sand-bed channels, because there are three different ways: (1) by type of movement, (2) by the method of measurement, and (3) by the source of sediment. The total sediment load L_T consists of the bedload and suspended load, measured load and unmeasured load, washload and bed material load, respectively (Figure 4, and Equation 1-3).

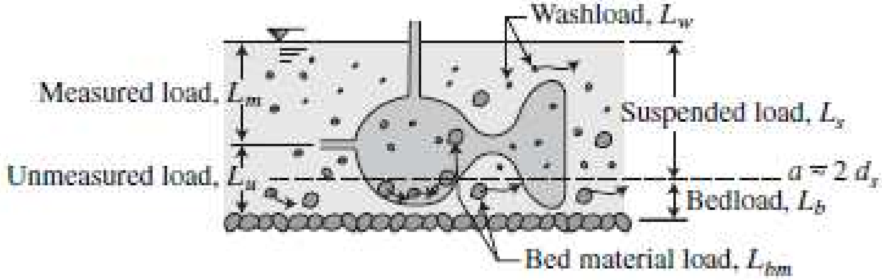


Figure 4: Sketch of ways to determine the total load (Julien, Erosion and Sedimentation, 2010)

$$L_T = L_b + L_s \quad (1)$$

$$L_T = L_m + L_u \quad (2)$$

$$L_T = L_w + L_{bm} \quad (3)$$

where, L_T = the total sediment load,

L_b = the bed load,

L_s = the suspended load,

L_m = the measured load,

L_u = the unmeasured load,

L_w = the wash load,

L_{bm} = the bed material load

2.1.1 Einstein procedure

Einstein (1950) first developed a method to determine the total sediment load in open channel which uses the bedload function from Einstein (1942) and determines the suspended sediment concentration profiles from Rouse (1937). His approach calculates the suspended load from the bed load. The integral of the product of velocity and sediment concentration profiles resulted in the total sediment load (i.e., the sum of bed load and suspended load (Eq. 1)).

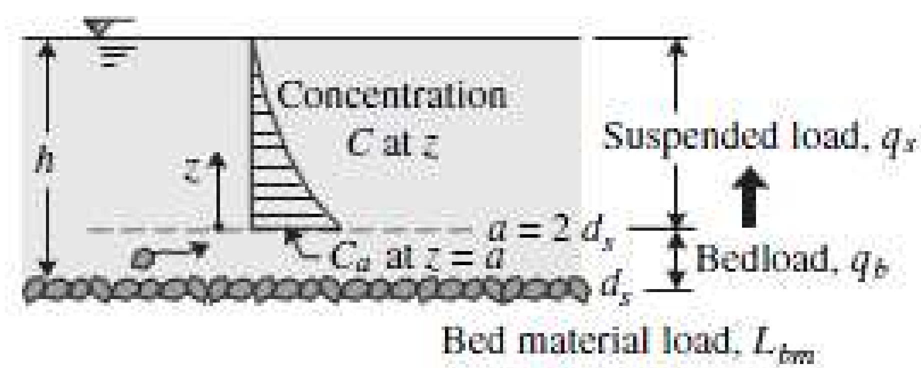


Figure 5: Sketch of the Einstein approach

$$q_t = q_b + q_s = q_b + \int_a^h C\, v\, dz \tag{4}$$

The sediment concentration profile is described by the Rouse equation (Rouse, 1937). The suspended sediment distribution described in Eq. 5 provides the concentration at a specified distance x above the bed.

$$\frac{C}{C_a} = \left(\frac{h-z}{z}\frac{a}{h-a}\right)^{R_o} \tag{5}$$

$$C = C_a \left(\frac{h-z}{z}\frac{a}{h-a}\right)^{\frac{\omega}{\beta K u_*}} \tag{6}$$

where C is the concentration at an elevation z above the bed, C_a is the reference concentration at $a = 2d_s$ above the bed and h is the total depth of flow.

The turbulent velocity profile within a river is based on the logarithmic velocity distribution (Keulegan, 1938).

$$\frac{v}{u_*} = \frac{1}{\kappa} \ln\left(\frac{z}{z_o}\right) \tag{7}$$

$$v = \frac{u_*}{\kappa} \ln\left(\frac{30z}{ks}\right)$$

where v is the velocity at a distance z above the bed, u_* is the shear velocity, κ is the von Karman constant assumed equal to 0.4, and z_o is the vertical elevation whater the velocity equals zero. By the pipe experiment on rough boundaries, the corresponding value of $z_o = ks/30$, and grain roughness height ks can be considered as d_s.

Substitution of these values of C and v in Equation (4) yields

$$q_t = q_b + \int_a^h C_a \left(\frac{h-z}{z}\frac{a}{h-a}\right)^{\frac{\omega}{\beta K u_*}} \frac{u_*}{\kappa} \ln\left(\frac{30z}{d_s}\right) dz \tag{8}$$

Rewriting Eq. 8 in dimensionless form with $z^* = z/h$, $E = 2d_s/h$ and $Ro = \frac{\omega}{\beta K u_*}$ gives:

$$q_t = q_b \left(1 + I_1 \, ln\frac{30h}{d_s} + I_2\right) \tag{9}$$

where

$$I_1 = 0.216\frac{E^{Ro-1}}{(1-E)^{Ro}} \int_E^1 \left(\frac{1-z^*}{z^*}\right)^{Ro} dz^* \tag{10}$$

$$I_2 = 0.216\frac{E^{Ro-1}}{(1-E)^{Ro}} \int_E^1 \left(\frac{1-z^*}{z^*}\right)^{Ro} \ln z^* \, dz^* \tag{11}$$

2.1.2 Modified Einstein Procedure (MEP)

Since the Einstein Procedure was developed, the method has been improved several times; including the Modified Einstein Procedure (MEP) by Colby and Hembree (1955). The MEP determines the total sediment load based on field measurements obtained from a depth-integrated suspended sediment sampler which is a major difference from the original Einstein Procedure calculating suspended load from bed load. Several remodifications have been proposed by Colby and Hubbell (1961), Lara (1966), Burkham and Dawdy (1980), Shen and Hung (1983).

However, The MEP has difficulty calculating total load when there is not enough overlap between sediment particles sizes in suspension and in the bed material. For example, the total sediment load for gravel-bed streams with sand sizes in suspension could not be accurately calculated by the MEP.

2.1.3 Series Expansion of the Modified Einstein Procedure (SEMEP)

Shah-Fairbank et al. (2011) proposed the Series Expansion of the Modified Einstein Procedure (SEMEP) which was based on depth-integrated samples, and SEMEP has been shown to work well in sand-bed river data from the Niobrara to the Mississippi River.

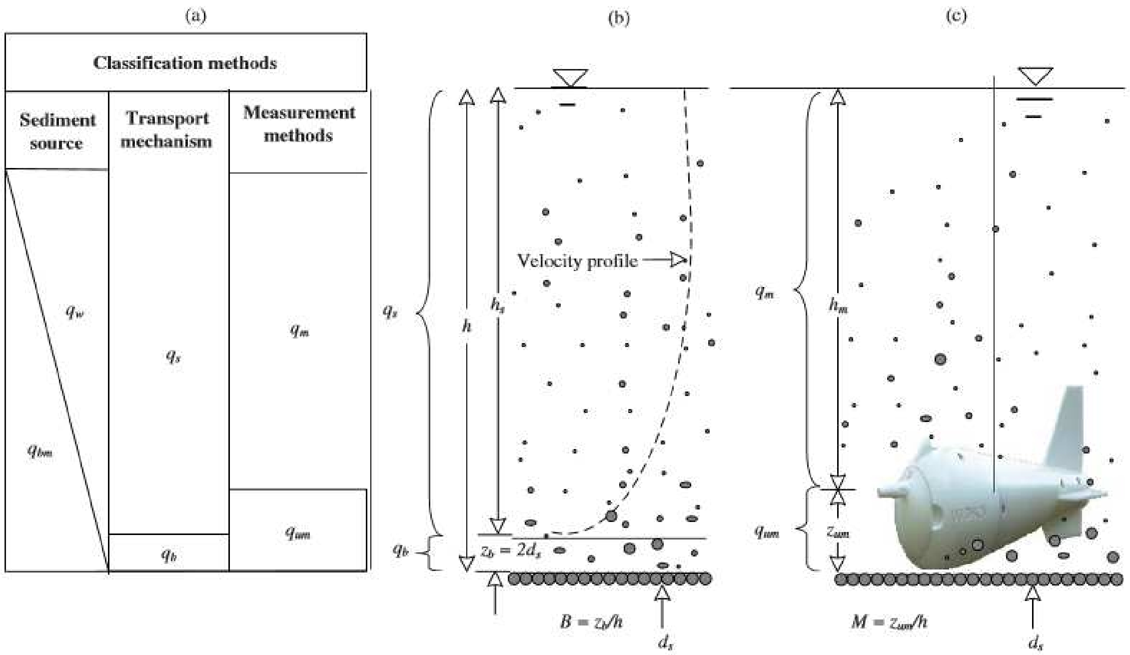


Figure 6: Definition sketch for SEMEP (Shah-Fairbank, Julien, & Baird, 2011)

As shown in Figure 6, the measured unit sediment discharge is evaluated by integrating the product of flow velocity and sediment concentration, from the nozzle height z_{um} to the free surface (i.e., $z = h$, Eq. 12))

$$q_m = \int_{z_{um}}^{h} C\ v\ dz \tag{12}$$

Eq. 13 below is obtained by inserting Eqs. 6 and 7 into Eq. 12. The only difference from the equations of the original Einstein Procedure is the change in the limits of integration:

$$q_m = 0.216\, q_b \frac{B^{Ro-1}}{(1-B)^{Ro}} \left\{ \ln\left(\frac{30h}{d_s}\right) J_{1M} + J_{2M} \right\} \tag{13}$$

$$J_{1M} = \int_M^1 \left(\frac{1-z^*}{z^*}\right)^{Ro} dz^* \tag{14}$$

$$J_{2M} = \int_M^1 \left(\frac{1-z^*}{z^*}\right)^{Ro} \ln z^*\; dz^* \tag{15}$$

where J_{1M} and J_{2M} = modified Einstein integrals evaluated in the measured zone ($M = z_{um}/h$).

In the same manner, q_s and q_t in Figure 6 can be expressed as follows:

$$q_s = \int_{z_b}^h C\, v\, dz \tag{16}$$

$$q_t = q_b + q_s = q_b + \int_z^h C\, v\, dz \tag{17}$$

$$q_s = 0.216\, q_b \frac{B^{Ro-1}}{(1-B)^{Ro}} \left\{ \ln\left(\frac{30h}{d_s}\right) J_{1S} + J_{2S} \right\} \tag{18}$$

$$q_t = q_b + 0.216\, q_b \frac{B^{Ro-1}}{(1-B)^{Ro}} \left\{ \ln\left(\frac{30h}{d_s}\right) J_{1S} + J_{2S} \right\} \tag{19}$$

$$J_{1S} = \int_B^1 \left(\frac{1-z^*}{z^*}\right)^{Ro} dz^* \tag{20}$$

$$J_{2S} = \int_B^1 \left(\frac{1-z^*}{z^*}\right)^{Ro} \ln z^*\; dz^* \tag{21}$$

where $B = 2d_s/h,\ z_b = 2d_s = 2d_{65}$ of the bed material, $\beta = 1$, and ω is based on the median grain diameter of the measured suspended samples (d_{50ss}). The value of J_{1S} and J_{2S} are detemined by the series expansion proposed by Guo and Julien (2004).

The bed load can be calculated directly on the basis of q_m because all other parameters in Eq. 13 are known, which is the novelty of the SEMEP. The following describes the SEMEP procedure for determining q_b, q_s and q_t on the basis of q_m;

a. Calculate Ro on the basis of hydraulic parameters and the median grain size in suspension
b. Determine the limits of integration (h, z_{um} and z_b in Figure 6)
c. Use the SEMEP to calculate the Einstein and the modified Einstein integrals (J_{1M} and J_{2M})
d. Calculate q_s and q_t
e. Estimate the total sediment discharge from the unit sediment discharge and the channel width.

2.1.4 Series Expansion of the Modified Einstein Point Procedure (SEMEPP)

The point measurement technique for flow velocity and sediment concentration is widely used in field measurement, because it has greater accuracy than depth-integrated measurement. Therefore, the point measurements have definite advantages in the estimation of the total load in sand bed rivers.

In order to improve the accuracy of calculation of total sediment load based on the point sampling method, Shah-Fairbank and Julien (2015) proposed the Series Expansion of the Modified Einstein Point Procedure (SEMEPP). The SEMEPP expands on the SEMEP procedure with depth-integrated sampling and also employs the series expansion to solve the Einstein integrals developed by Guo and Julien (2004). Shah-Fairbank and Julien (2015) proposed the relationship between the relative sampling depth ratio (h_m/h), shear velocity to fall velocity ratio (u_* / ω), and ratio of partial to total sediment discharge (q_p/q_t).

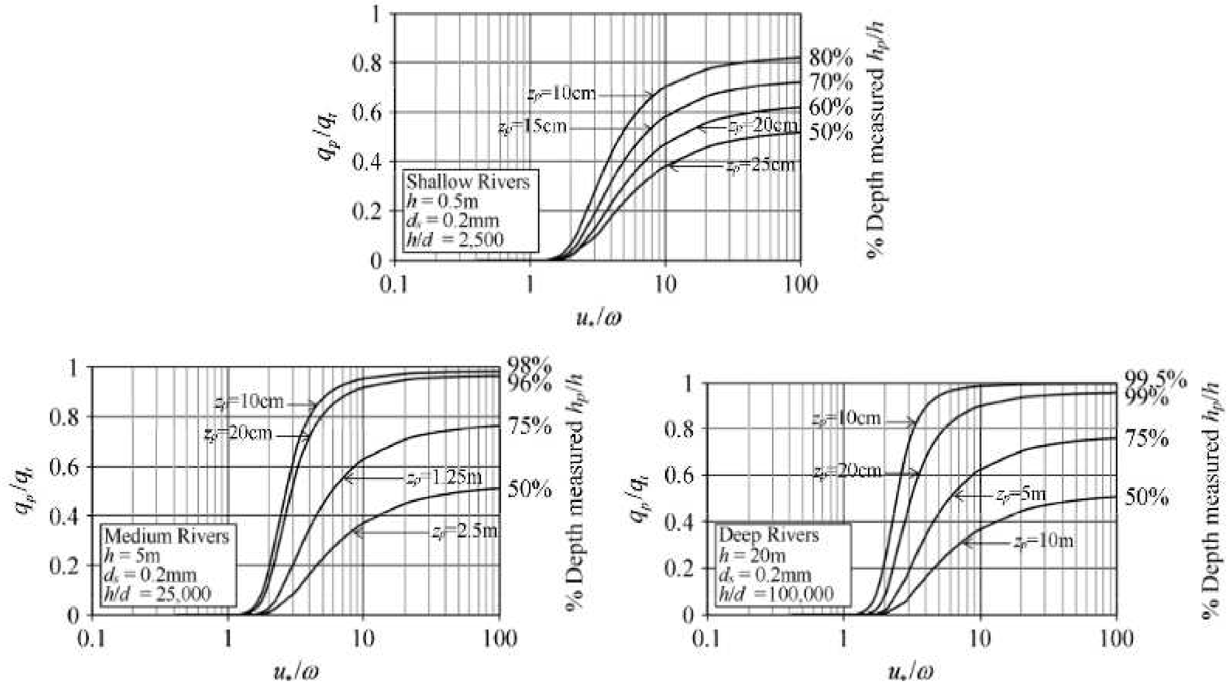


Figure 7: Point sampling efficiency for sand-bed Rivers (Shah-Fairbank & Julien, 2015)

The accuracy of the calculations depends on u_*/ω and h_p/d_s. The SEMEPP procedure is well-suited when $u_*/\omega > 5$ where at least 60% of the total sediment load is measured when 90% of the flow depth is sampled. Figure 7 shows the proposed relationship for shallow, medium, and deep Rivers.

In summary, the modes of sediment transport will determine the appropriate estimation procedures for sediment loading. Figure 8 presents the recommended sediment transport procedures as a function of Rouse number and the ratio of shear velocity to fall velocity (u_*/ω). The determination of sediment discharge from point measurement by the Series Expansion of

Modified Einstein Point Procedure (SEMEPP) is most accurate in deep rivers when $h_p/d_s >$ 10,000 and $u_*/\omega > 10$.

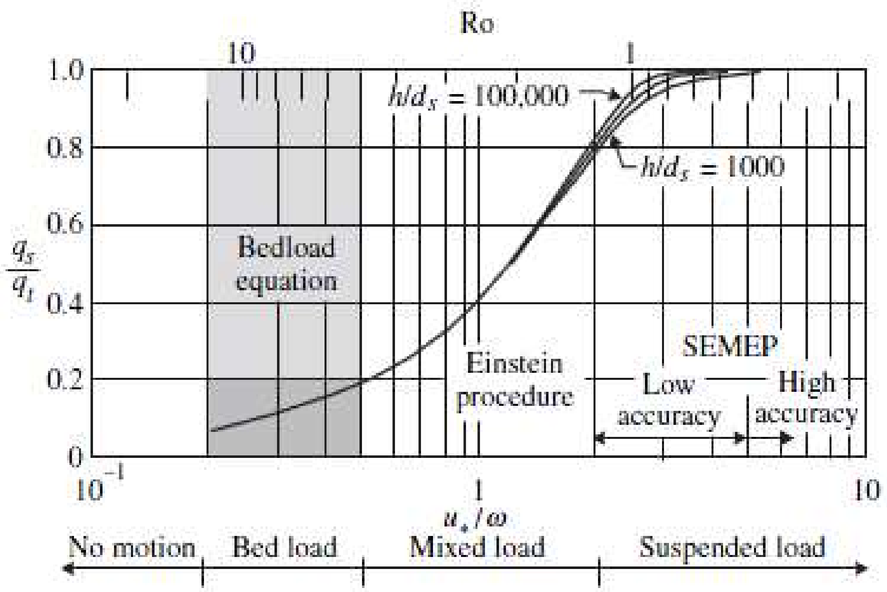


Figure 8: Modes of transport and procedure for load calculation (Julien, 2010)

2.2 RESERVOIR SEDIMENTATION

The water carries sediment particles downstream. And when the flow enters into the reservoir, sediment particles start to deposit throughout a reservoir due to decreased velocities. Figure 9 presents the typical reservoir sedimentation pattern. The longitudinal deposition consists of four main zones: Topset slope, Foreset slope, Bottom deposit (fine sediments), and Density current bed (very fine sediments) (Frenette & Julien, 1986). The coarse material forms the Delta and fine material deposits to the Bottom deposit zone. The density current carries the finer particles to Density current bed, right in front of the hydraulic structure.

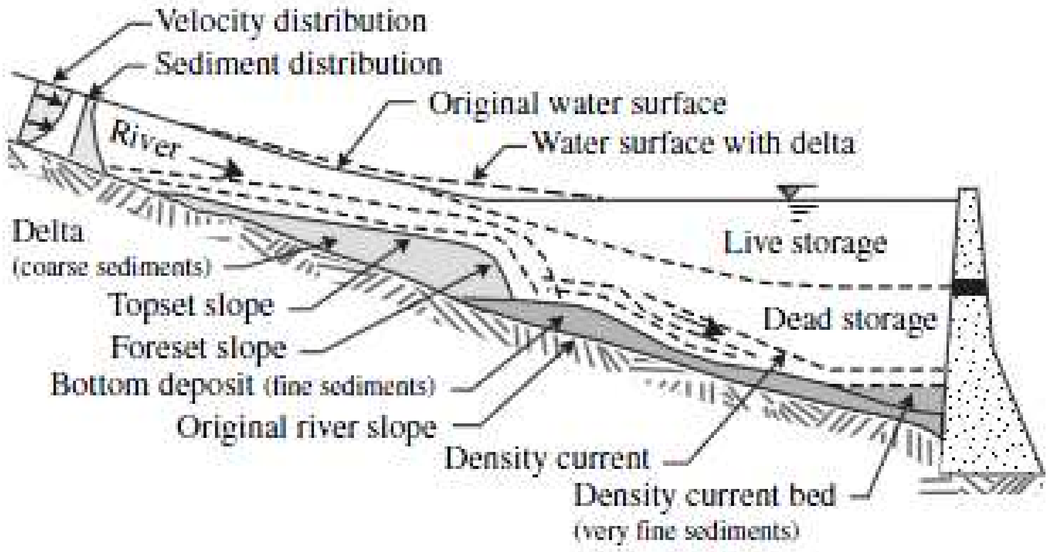


Figure 9: Typical reservoir sedimentation pattern (Julien, 2010)

The relationship between Topset bed slope and original stream slope of a reservoir delta was proposed by Borland (1971). He found that Topset slope is approximately one-half of the original bed-slope using field measurements. After that, the numerical modeling and empirical methods were used to estimate reservoir sedimentation considering geometry of the reservoirs. Miller and Borland (1963) and Borland (1975) proposed the area increment method and empirical relationship in order to determine a reservoir sedimentation pattern; they used field data from 30 reservoirs in the United States. Yücel and Graf (1973), Lopez (1978), Rice (1981), Simons et al. (1982), Graf (1984), and Frenette and Julien (1986) carried out numerical modeling to find the deposition patterns of reservoirs. Morris and Fan (Morris & Fan, 1997) presented four general types of longitudinal deposits: (1) delta; (2) tapering; (3) uniform; and (4) wedge-shape, which are shown in Figure 10.

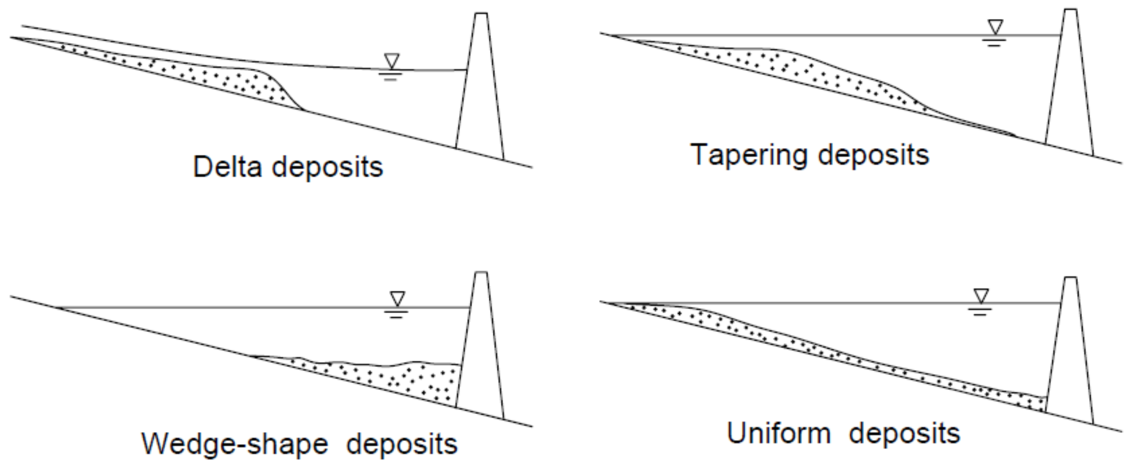


Figure 10: Basic types of longitudinal deposit (Morris & Fan, 1997)

A coarse fraction of sediment or large amount of finer sediment like silt forms the delta type reservoir sedimentation pattern. Tapering and uniform patterns commonly appear in long reservoirs with fine sediment and narrow reservoirs with frequent discharge fluctuation and a small sediment load, respectively. When the water discharge containing a large portion of fine sediment enters a small reservoir, wedge-shaped reservoir sedimentation patterns occur. If the water passes regularly through the gate of a reservoir, the apex of the delta moves to the dam and the delta type deposition changes into wedge-shaped, which is considered the equilibrium of the reservoirs over a long time period (Lai & Shen, 1996). The inflowing sediment characteristics and reservoir operation rules greatly affect the formation of deposits (Morris & Fan, 1997). However, deposition patterns in nature are susceptible to the interactions among water discharge, sediment grain size, channel geometry, and reservoir operations.

Sediment surveys for multi-purpose dams and water-supply-purpose dams in South Korea were conducted by K-water, starting with Soyanggang multi-purpose dam in 1983. Following that, reservoir sedimentation surveys were conducted for Chungju, Andong, Imha, Daecheong, Seomjingan, and other multi-purpose dams. Table 1 shows the current status of sediment surveys for multi-purpose dams in Korea (K-water, 2014). Figure 11 shows locations of the multi-purpose dams, single-purpose dams, and weirs constructed by FRRP in Korea.

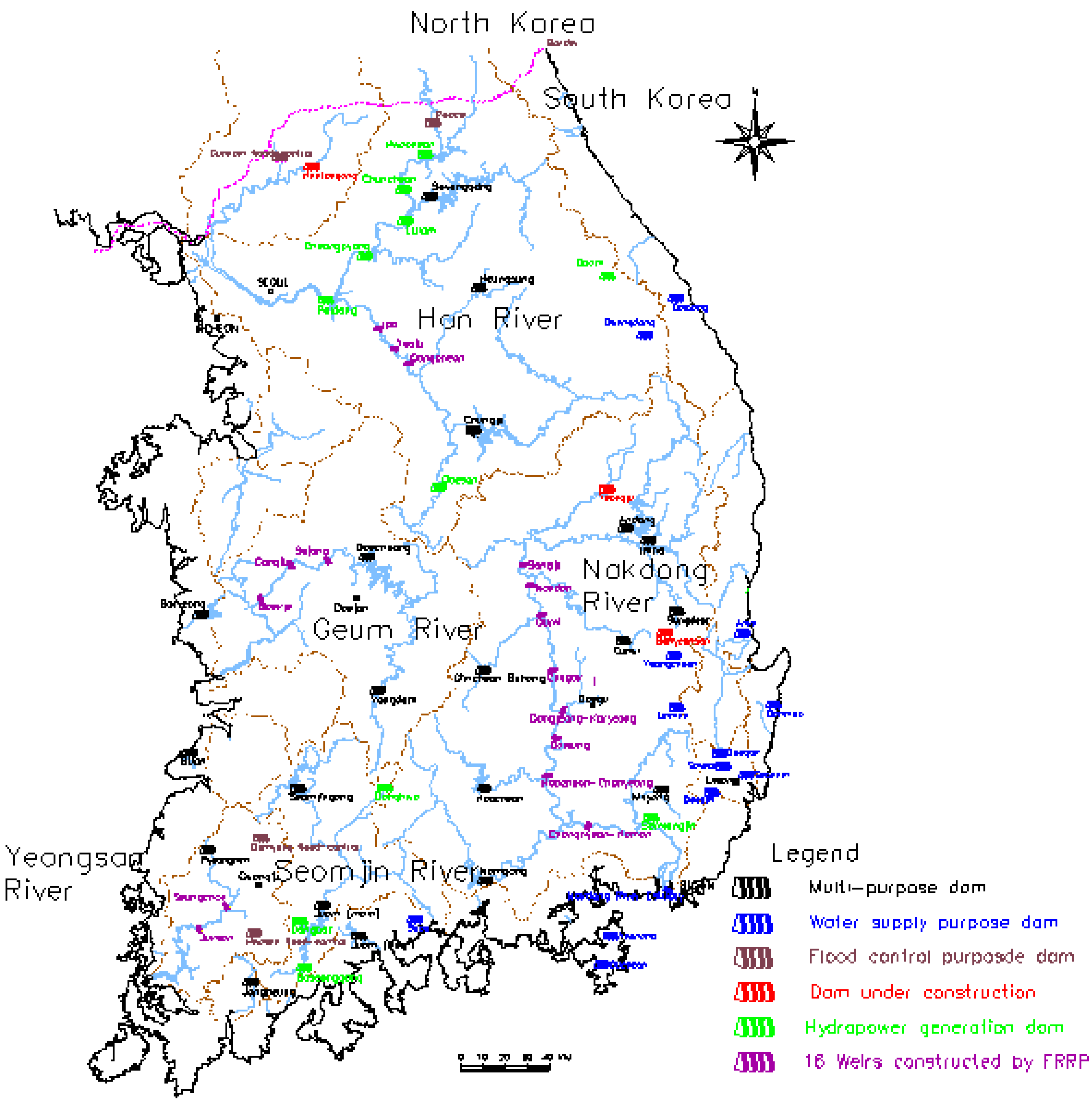


Figure 11: Major dams in Korea

Table 1: The status of sediment survey for multi-purpose dams in Korea (K-water, 2014)

Div. (Basin)	Unit	Han River			Nakdong River							Guem River		Seomjin River			Others		
Dam name		SY	CJ	HS	AD	IH	GW	K-BH	HC	NG	MY	DC	YD	SJ	JA-M	JA-R	BA	BR	JH
Watershed area (A)	km^2	2,703	6,648	209	1,584	1,361	87.5	82.0	925	2,285	95.4	4,134	930	763	1,010	134.6	59.0	163.6	193.0
Res. containing date	yy.mm.dd	72.11.10	84.11.1	99.12.28	75.12.4	91.12.3	09.12.8	12.12.12	88.7.1	98.10	00.10.4	80.6.30	00.11.9	65.7.	90.3.12	90.11.9	95.9.29	96.10.31	04.12.17
Survey year		2006	2007	2013	2008	2007	-	-	2012	2004	2013	2006	2011	1983	2003	2003	2011	2011	-
Number of years (T)		33	22	13	32	15	-	-	23	5	12	25	10	17	12	12	15	14	-
Total accumulation of sediment (X)	$10^6 m^3$	81.5	130.5	0.5	5.5	-	-	-	19.0	12.5	-	81.4	-	19.0	5.0	2.1	0.6	0.8	-
Mean annual sedimentation rate (X/T)	MCM/yr	2.47	5.93	0.04	0.17	-	-	-	0.83	2.50	-	3.26	-	1.12	0.42	0.18	0.04	0.06	-
Specific degradation (X/AT)	m^3/km^2yr	914	892	184	109	-	-	-	893	1,094	-	788	-	1,465	413	1,300	678	349	-
Annual inflow (I)	cms	71.0	174.0	6.1	32.4	22.5	1.1	0.1	21.6	69.3	3.1	86.1	26.7	17.8	21.9	14.5	1.7	4.7	5.3

Notes: SY (Soyanggang dam), CJ (Chungju dam), HS (Hoengsung dam), AD (Andong dam), IH (Imha dam), GW (Gunwi dam), K-BH (Kimcheon-Buhang dam), HC (Hapcheon dam), NG (Namgang dam), MY (Miryang dam), DC (Daecheong dam), YD (Yongdam dam), SJ (Seomjingang dam), JA-M (Juam main dam), JA-R (Juam regulation dam), BA (Buan dam), BR (Boryong dam), JH (Jangheung dam)

2.3 TRAP EFFICIENCY

Geomorphologists know that only 5-25% of eroded sediment actually reaches the ocean, with most being deposited at the bottom of hillslopes (i.e., colluvium), in floodplains and wetlands (i.e., alluvium), and in reservoirs, lakes, and estuaries (Aufdenkampe, et al., 2011).

Trap efficiency is the ratio of the deposited sediments to the total sediment inflowing from upstream basin. There are two approaches in estimation of trap efficiency: (1) empirical approach and (2) analytical approach.

2.3.1 Empirical approach

Trap efficiency has been widely used to predict the amount of sediment deposits in reservoirs. Churchill (1948) and Brune (1953) proposed empirical methods to determine the trap efficiency of reservoirs.

Churchill (1948) firstly provided a logarithmic trap efficiency relationship, in which he used reservoir data from the Tennessee Valley Authority. The sedimentation index of reservoir was defined as the percentage of incoming sediments passing through a reservoir (Figure 12). The sediment index is the ratio of the retention time to the mean velocity of water through the reservoir.

$$\text{Sedimentation Index of Reservoir} = \frac{\text{Period of Retention}}{Mean\ velocity} \qquad (22)$$

where, Period of time = reservoir capacity (V, ft^3) / inflow (Q, ft^3/s)

Mean velocity = inflow / average cross-sectional area (ft/s).

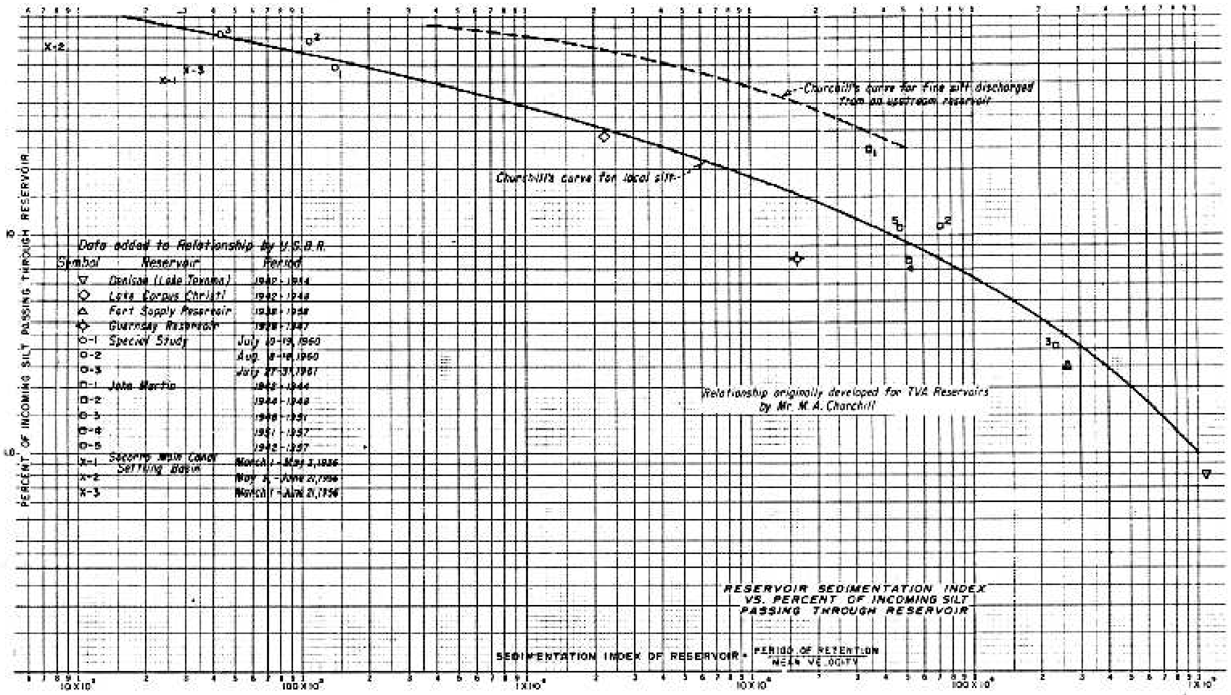


Figure 12: Trap efficiency by Churchill (Borland, 1971)

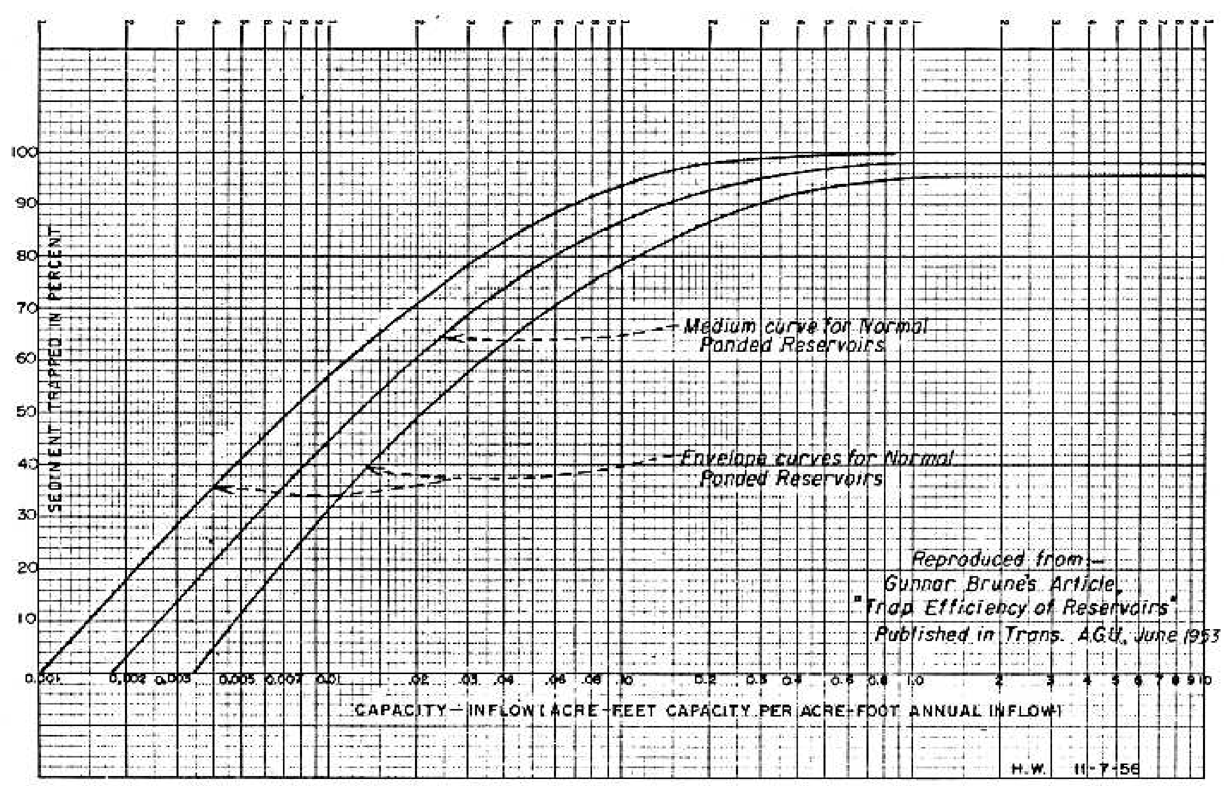


Figure 13: Brune's curve for trap efficiency (Borland, 1971)

Brune (1953) developed the empirical relationship using field records from 44 reservoirs in the U.S. He presents the relationship between the sediment trap efficiency and the capacity-inflow ratio (Figure 13). The capacity-inflow ratio is based on the mean annual water inflow (Eq. 23).

$$\text{Capacity} - \text{Inflow ratio} = \frac{\text{Reservoir Capacity (acre} - \text{feet)}}{Inflow\ (acre - feet/year)} \qquad (23)$$

Because of the lack of available data, Borland (1971) indicated that Brune's curve is not recommended for use on desilting basins, flood retarding structures, or semi-dry reservoirs; the Churchill curve is preferred for estimating the trap efficiency for desilting basins and semi-dry reservoirs.

More recently, the U.S. Bureau of Reclamation (2006) presented field measurement data co-plotted with curves from Churchill and Brune (Figure 14).

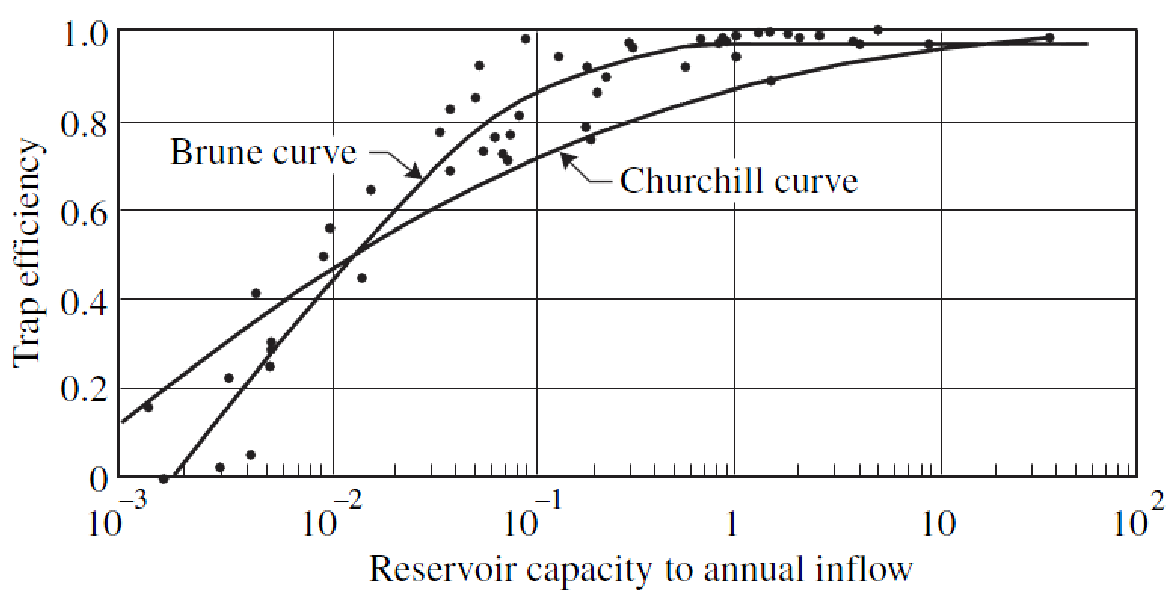


Figure 14: Trap efficiency versus reservoir capacity to annual inflow ratio (U.S. Bureau of Reclamation, 2006)

2.3.2 Analytical approach

Different approaches for estimating the trap efficiency (T_E) of a settling basin were utilized by Brown (1944). He proposed Eq. 24.

$$T_E = 100\left(1 - \frac{1}{1 + K\frac{C}{W}}\right) \tag{24}$$

where K = the numerical coefficient equal to 0.046 for the lower curve in Figure 15 and 1 for the upper curve

C = the original reservoir storage capacity (acre-feet)

W = the watershed area (acre-feet)

The design curve gives a mean value to be used for preliminary investigations. He recommended that the engineer responsible for the design must study the site and choose K between 0.046 and 1.

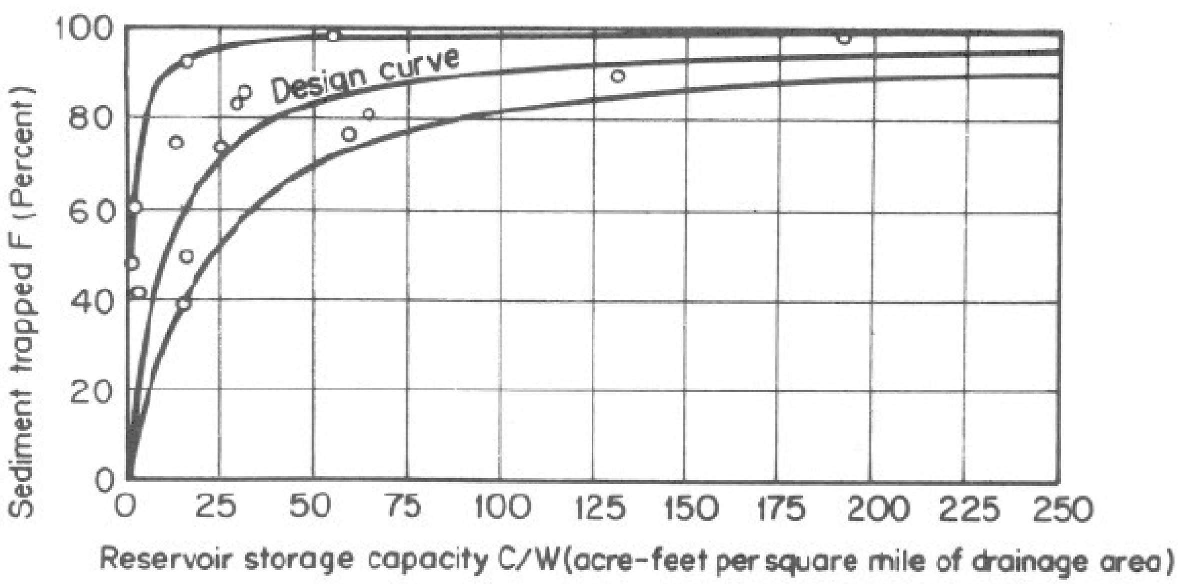


Figure 15: Trap efficiency curves due to Brown (Simons & Senturk, 1992)

Borland (1971) introduced a new computing the trap efficiency of a settling basin by applying the results obtained by Einstein (1965). He used two basic equations from Einstein's study. One is the half-life time equation:

$$T = 0.657 \frac{d}{V_s \eta} \tag{25}$$

where T = half-life time or time for concentration to be reduced on-half (sec)

d = water depth (ft)

V_s = fall velocity (ft/s)

η = the ratio of water volume above the gravel bed to the total of the flume system by Einstein (assumed equal to unity).

The second equation as follows is used in the trap efficiency computations.

$$P = 1 - \exp\left(-0.693 \frac{l}{L}\right) \tag{26}$$

where P = fraction of material deposited over total flume length (%)

l = settling basin length (mile)

L = length of channel over which one-half the particles are deposited (mile)

Through further mathematical treatment, the trap efficiency equation was developed applying the fraction of deposited material and the settling velocity of the suspended material as follows:

$$\mathrm{L} = \frac{\mathrm{VT}}{5,280} \rightarrow L = \frac{0.657\, Vd}{5{,}280\, V_s\, \eta} \tag{27}$$

$$P = 1 - \exp\left(-\frac{Vd}{1.055\, l\, V_s}\right) \tag{28}$$

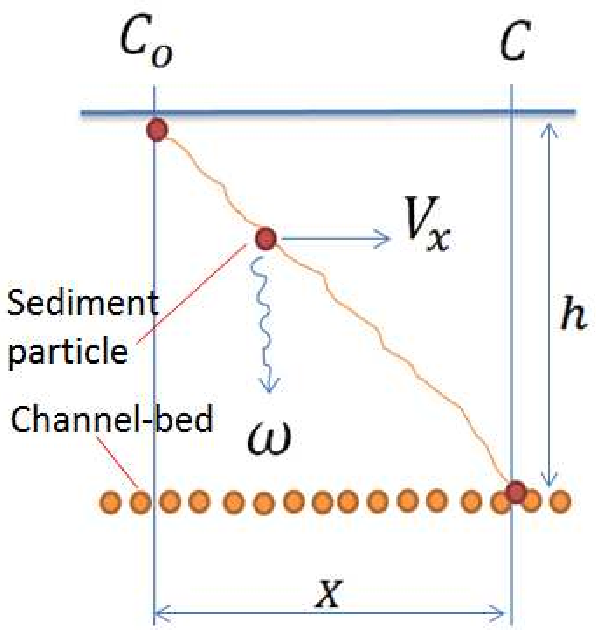
where P= trap efficiency (%)

l = settling basin length (ft)

V = cross sectional averaged velocity (ft/s)

d = water depth (ft)

V_s = fall velocity (ft/s)



Note:

C_o = Initial sediment concentration

X = settling distance

h = flow depth

V_x = flow velocity

ω = Settling velocity

Figure 16: Concept diagram for sediment conservation relationship

Julien (1998) derived a new equation from sediment conservation relationship as follows:

$$\frac{\partial C}{\partial t} + \frac{\partial q_{tx}}{\partial x} + \frac{\partial q_{ty}}{\partial y} + \frac{\partial q_{tz}}{\partial z} = 0 \quad (Unsteady) \tag{29}$$

$$\frac{\partial q_{tx}}{\partial x} + \frac{\partial q_{tz}}{\partial z} = 0 \quad (Steady, 1D) \tag{30}$$

$$\frac{\partial V_x C}{\partial x} + \frac{\partial(-\omega C)}{\partial z} = 0 \tag{31}$$

$$V_x \frac{\partial C}{\partial x} = \omega \frac{\partial C}{\partial z} \;\rightarrow\; -\omega \frac{C}{h} \; (Simple\ approximation) \tag{32}$$

$$\frac{\partial C}{C} = -\frac{\omega}{hV_x}\partial x \rightarrow \ln C = -\frac{\omega X}{hV_x} \tag{33}$$

$$C = C_o\, e^{-\frac{\omega X}{hV_x}} \tag{34}$$

According to the diagram in Figure 16, the trap efficiency can be definded as Eq. 35 and can be written as the function of reservoir surface area (A) and discharge (Q) (Eq. 36).

$$T_E = C_o - \frac{C}{C_o} = 1 - e^{-\frac{\omega X}{hV_x}} \tag{35}$$

$$T_E = 1 - e^{-\frac{\omega A}{Q}} \tag{36}$$

The distance (X) to settle the 99% of suspended sediment is calculated by substituting T_E (= 0.01) from Eq. 33 as follows:

$$\ln(0.01) = -\frac{\omega}{hV_x} \rightarrow 2.3\log_{10}(10^{-2}) = -\frac{\omega X}{hV_x} \tag{37}$$

$$X_{0.01} = 4.6\frac{V_x h}{\omega} \tag{38}$$

Frenette and Julien (1986) found that the empirical methods including Churchill's and Brune's methods underestimated trap efficiencies compared to actual measurements, during a sedimentation study of the Peligre Reservoir in Haiti. Also, Julien (1998) suggested that careful consideration is required when calculating trap efficiencies for silt and clay particles because of density currents and possible flocculation effects.

2.4 SEDIMENT YIELD

The sediment yield can be written as below:

$$Y = A_T\ S_{DR}. \quad (39)$$

where Y = sediment yield

S_{DR} = sediment delibery ratio

A_T = the gross erosion on its drainage area

The sediment yield can be estimated using the following five different methods: (1) the Flow-Duration/Sediment-Rating Curve method (FD/SRC); (2) the amount of reservoir sedimentation and trap efficiency method; (3) the basin erosion and sediment-delivery ratio method; (4) empirical and stochastic methods; and (5) deterministic sediment routing modeling (Woo, Kim, & Ji, 2015). The short-term sediment yield analysis provides information on a daily basis, while the long-term analysis gives an estimate of the expected amount of sediment yielded by a stream which is required for reservoir sedimentation control.

2.4.1 Short-term sediment load

When the stream flow and sediment concentration is steady within a day, the daily sediment load can be computed with a relatively high degree of accuracy. The total sediment load is the product of the flux-averaged total sediment concentration, the daily mean water discharge, and a unit conversion factor as following formula:

$$Q_s\ (metric\ tons/day) = 0.0864\ C_{mg/l}\ Q\ (in\ m^3/s) \quad (40)$$

The concentration and gage records can be divided into hourly increments, if the discharge and concentration vary during the certain period. The sediment-rating curve from the measurements is used in order to interpolate or extrapolate from incomplete sediment records.

2.4.2 Long-term sediment load

There are two basic approaches for the determination of the long-term average sediment load of a river: (1) the Flow-Duration curve approach; and (2) the summation approach (Julien, 2010). The flow-duration curve approach combines a flow-duration curve with a sediment-rating curve. This method is referred to as the Flow-Duration/Sediment Rating Curve (FD/SRC) method. The flow-duration curve states the percentage of time a given river discharge is exceeded. Julien (2010) explains that "the flow-duration/sediment-rating curve method is most reliable: (1) when the period of record is long; (2) when sufficient data at high flows is available; and (3) when the sediment-rating curve shows considerable scatter". Since rivers carry most of the sediment of annual total load during flood flows, field measurements have to be conducted in the flood period. However, measurements are rarely available during extreme flood events due to harsh conditions for field observation. The annual sediment load can be expressed as below:

$$\mathrm{Q_s}\ (metric\ tons/year) = 31.56\ \mathrm{C_{mg/l}}\ Q\ (in\ m^3/s) \tag{41}$$

The total annual sediment load is then given by the sum of all the intervals of the flow-duration curve. The second approach is the summation method. The summation over a long period of time of the measured and reconstituted daily sediment discharges can be accomplished using computers. Mass curves provide the cumulative sediment load as a function of time in years. Observation of the slope of the double mass curve can reveal significant changes in flow regime.

2.5 CONTROL OF SEDIMENTATION

Once storage is initiated, the reservoir's storage capacity progressively decreases. In order to maintain storage capacity, appropriate methods to control sedimentation are necessary. Reservoir sedimentation control methods have been proposed by Brown (1943), Fan (1985a; 1985b) and Brabben (1988). Morris and Fan (1997) described three strategies: (1) reduction of sediment yield; (2) sediment excavating; and (3) hydraulic regime methods such as sediment routing and flushing. The following sections discuss two of the control methods for reservoir sedimentation, in order to determine the most effective method for Sangju Weir.

2.5.1 Reduction of sediment yield

The erosion control and upstream trapping measures can delay the sediment accumulation rate of the reservoir, although these cannot totally solve the sedimentation problems (Fan & Morris, 1992). Many structural or mechanical measures are employed to reduce the flow velocity for erosion control, to increase the storage of surface water, and to dispose of runoff (Morgan, 1995). Typically, hydraulic structures like drop structures for reducing flow velocity, check dams, and sediment detention ponds are used to trap sediment at the upstream of drainage area.

Although many of measures mentioned in the previous paragraph have been installed in the study area, many of them are not effective because of maintenance issues. For example, many check dams were constructed in the watershed upstream, however, they filled with rocks and debris with several flooding events. In order to maintain sediment reduction functionality, excavation was necessary. But this has rarely occurred due to location and costs.

Figure 17: Sediment detention facility of Yeongju multi-purpose dam

Recently, a sediment detention reservoir was installed for the first time in Korea, which is located 13 kilometers upstream from the Yeongju multi-purpose dam (Figure 17). According to the detail design of the Yeongju dam, this concrete dam can trap 147,969 m^3 of sediment per year. This facility will be exposed for two months each year when the deposited sediments will be dredged by backhoes or other excavating machines (Samsung Inc., 2009).

In spite of some facilities working effectively for prevention of sedimentation, watershed management with erosion control would need to be performed widely to substantially reduce the sediment yield.

2.5.2 Sediment dredging

Channel excavation has been used widely in lakes, reservoirs, and barrages, although it is very expensive in order to protect the reservoir capacity and keep the navigation channel sound. The excavation methods are determined considering several factors such as sediment volume, location, particle size and geometry of deposits, and the water level. The dredging methods can be classified into hydraulic and mechanical. Hydraulic dredging appropriates the water to transport sediments and mechanical dredging involves digging and lifting sediments to the surface. Hydraulic dredging is efficient to handle widely distributed size materials from fine to coarse sand. The most popular type is hydraulic suction dredging with a cutterhead and hydraulic pump.

For example, Korea Water Resources Corporation (K-water) has used hydraulic suction dredging with a cutterhead and a large pump over a period of 20 years, excavating 665,000 m^3 of sediment per year at the Nakdong River Estuary Barrage. Due to completion of FRRP, dredging has ceased for the present. Table 2 presents the dredging record of Nakdong River Estuary Barrage.

Siphon dredging is one of the popular hydraulic methods which does not need pumps and discharge lines. This is because the head differences between the water surfaces in the reservoir and the lowest possible discharge point on the dam enable deposited sediment to transport downstream of reservoirs.

Many small siphon dredges are used in Chinese reservoirs (Morris & Fan, 1997). Due to head differences and the water level, however, this method has some limitations. For precise dredging, a cable-suspended dredge pump is used with a submerged video monitor. A submerged hydraulic or pneumatic pump creates a suction vortex without a cutterhead.

Table 2: Nakdong River Estuary Barrage excavation amount and costs (1990-2013) (K-water, 2014)

Year	Period	Excavation amount		Expenses	Taking out amount
		Upstream	Downstream	(mil.Won)	(thousand m^3)
1990	3.24 - 12.24	727	-	2,873	-
1991	3.30 - 12.24	627	-	2,299	-
1992	4.30 -12.22	949	-	2,269	-
1993	5.07 - 12.22	763	-	1,954	333
1994	4.14 - 12.19	938	-	2,014	1,790
1995	3.23 - 96.1.6	2,489	-	5,251	1,593
1996	4.03 - 12.31	879	-	3,703	63
1997	4.01 - 12.31	-	1,288	3,766	33
1998	4.01 - 12.15	-	330	1,980	156
1999	5.01 - 12.07	547	-	2,063	69
2000	4.07 - 12.08	726	-	2,635	139
2001	3.12 - 11.06	480	-	2,047	790
2002	4.22 - 12.07	442	-	1,782	14
2003	6.05 - 12.19	295	-	1,861	215
2004	4.16 - 12.11	347	-	1,685	427
2005	3.14 - 12.11	344	-	1,571	484
2006	6.26 - 12.27	334	-	1,675	204
2007	3.30 - 12.07	429	-	2,035	157
2008	3.17 - 12.16	229	-	1,338	198
2009	8.03 - 12.30	215	-	1,352	25
2010	5.27 - 12.22	271	-	1,442	37
2011	-	-	-	-	122
2012	-	-	-	-	-
2013	-	-	-	-	-
Total		12,020	1,618	47,557	6,849

Note: Unit cost = 47,557,000,000 KRW / 6,849,000 m^3 = 6,944 KRW/m^3 = 6.31 USD/m^3 (1 USD = 1,100KRW)

Figure 18: (a) Photos of excavation and (b) dredging method and equipment used in FRRP (K-water, 2012)

The Korean government dredged many tons of sediment during the FRRP; construction companies used various kinds of excavation equipment: (1) land dredging and (2) underwater dredging (Figure 18). Mechanical dredging removes the sediment with a closed or unclosed bucket. Compared to hydraulic dredging, mechanical dredging carries the sediment with low water content, and excavated amounts are relatively small. It may be suitable for gravel or large material in a reservoir.

2.6 OPTIMIZATION OF OPERATIONS

The Multi-Criterion Decision Analysis (MCDA) method has been used in many cases in various fields such as water quantity and quality, groundwater and the environment, sewerage, and others. Cohon and Marks (1975) and Cohon et al. (1979) tried to introduce multi-objective programming techniques. Goicoechea et al. (1976) investigated the introduction of a mechanical and chemical plants treatment method to increase the watershed runoff of San Pedro River in Arizona. This research analyzed five objectives: runoff increase, sediment reduction, wildlife balance, recreation, and commercial profit.

Tauxe et al. (1979) used multipurpose dynamic programming in the Shasta reservoir operation in California, in which three objectives were (1) to maximize the cumulative dump energy generated above the level of firm energy, (2) to minimize the cumulative evaporation, and (3) to maximize the firm energy.

Table 3: Multi-objectives and criteria used by Gershon et al. (1982)

Objective	Specifications	Criteria*
1. Water supply	Aquifer level	net change in ft/yr
	Water quality, urban	*a*, *b*, *c*, *d*, *e*
	Water quality, agriculture	*a*, *b*, *c*, *d*, *e*
2. Flood protection	Expected flood losses	expected dollars
	Expected frequency	expected number of floods (annual probability)
3. Environmental	Preservation of designated areas	*a*, *b*, *c*, *d*, *e*
	Effect on wildlife and vegetation	*a*, *b*, *c*, *d*, *e*
4. Utilization of resources	Implementation	present dollars
	Operation and maintenance	present dollars
	Indirect costs	*a*, *b*, *c*, *d*, *e*
	Natural resources	*a*, *b*, *c*, *d*, *e*
5. recreation	Preservation of existing facilities	*a*, *b*, *c*, *d*, *e*
	Creation of new opportunities	*a*, *b*, *c*, *d*, *e*

*Here, *a*, *b*, *c*, *d*, *e* is an ordinal scale, with *a* being the best and *e* being worst.

A typical example of environmental elements shared in a river basin planning was provided by Gershon et al. (1982). Balancing many interests in the Santa Cruz River Basin, Gershon et al. (1982) generated the set of objectives shown in Table 3. This example illustrates the need to span qualitative and quantitative objectives in seeking a desirable solution.

Large scale reservoir systems typically serve many important purposes, including water supply, hydropower production, flood control, and low flow augmentation for water quality enhancement. Numerous mathematical simulation and optimization models have been developed for reservoir systems analysis, but most of these techniques fail to consider multiple objectives simultaneously since they may be incommensurate and conflicting in nature (Ko, Fontane, & Labadie, 1992). The U.S. Army Corps of Engineers published "Trade-off analysis for environmental projects: An annotated bibliography" (Feather, Harrington, & Capan, 1995). Flug et al. (2000) applied this research to the optimization of Glen Canyon dam.

It is well known that reservoirs can cause numerous effects on downstream river channels. They may affect riverbed elevation, channel width and depth, bed-particle sizes and armoring, vegetation expansion, and other morphological changes in a river.

Although some research studies were performed with respect to water quantity and water quality (Ko, Fontane, & Labadie, 1992), there were few papers including the erosion and sedimentation problem. In addition, most of the research studies were performed for dams, not for weirs. Since the operation rules are apparently different between dams and weirs, the present research is needed for solving the sedimentation problem in weirs.

Since completion of the Sangju Weir in 2012, the Weir's operation rules (K-water, 2012) have been ambiguous with respect to the sedimentation problem. This ambiguity can lead to tremendous cost to excavate the deposition in the reservoir accumulating over several years. It is necessary to determine the operation rules for minimizing management cost in order to ensure long term economic viability of this hydraulic structure.

2.7 PREVIOUS STUDIES PERFORMED IN THE PROJECT LOCATION

Kim and Julien (2006) evaluated the spatial distribution of soil loss rates for the Imha multi-purpose dam watershed and predicted the mean annual soil losses caused by a major typhoon. The RUSLE model and GIS techniques were combined to analyze the mean annual erosion losses and the soil losses. Figure 19 shows the Nakdong River basin which includes the previous study area. Ji et al. (2011) defined sediment flushing curves as a function of river stage and discharge and performed analysis of long-term simulations using a quasi-steady numerical model. According to their study, about 54% of the mean annual dredging volume could be eliminated by sediment flushing at Nakdong River Estuary Barrage. An and Julien (2014) studied the propagation of the turbid density currents of the Imha Reservoir using the FLOW-3D computational dynamics code.

The Korean government investigated the Naesung Stream watershed (Saman Corp. & Isan Corp., 2012), the Yeong Stream watershed (Saman Corp., 1991), and the Nakdong River basin (Isan Corp. & Dongho Corp., 2009), to establish master plans of river improvement. They conducted river surveys, longitudinal and cross sectional surveys, and bed-material samplings.

Also, in planning for the Yeongju multi-purpose dam, K-water conducted similar investigations including sediment transport modeling; however, the investigation was confined to the Yeongju multi-purpose dam watershed (Samsung Inc., 2009). MLTM of Korea published “The sediment management plan establishment research for river channel stabilization” in 2013 (K-water, 2013). In this study, they built a watershed runoff model and predicted streambed aggradation and degradation by sediment transport modeling with view both to the long-term and short-term, for the entire Nakdong River basin. They used a SWAT model (2005) to estimate the sediment load of main tributaries, and predicted Nakdong River bed elevation changes.

Ji et al. (2014) studied sediment transport and yield for Naesung Stream watershed. They assessed erosion risks within the Nakdong River basin in South Korea. They used a three-tiered approach: (1) a screening based on topography and land use; (2) a lumped parameter analysis using RUSLE; and (3) a detailed analysis using TREX. Through this research they identified the northeast area of Songriwon as a highly erosive area, in the Nakdong River basin.

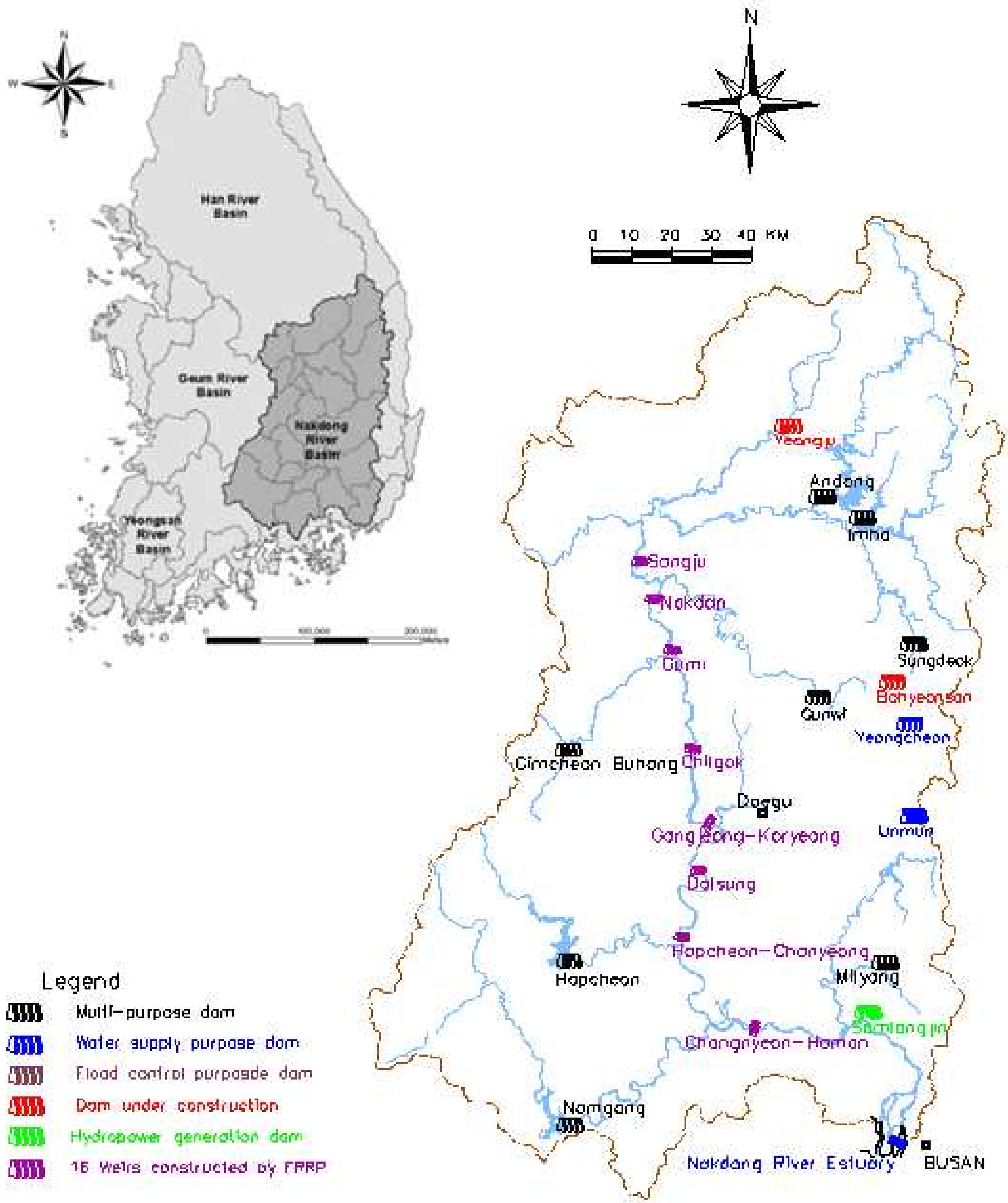


Figure 19: Nakdong River basin and dam and weir locations

2.8 SUMMARY

According to the research in previous sections, reservoir sedimentation is affected by various factors: sediment production in drainage area, the rate of transportation, the river regime, flood frequencies, reservoir geometry and operation rules, density currents, and possible land use changes over the life expectancy of the reservoir (Julien, 2010). Of all above factors, only trap efficiency in reservoirs can be controlled by reservoir operators, and furthermore there are many competing operational criteria for reservoirs. Many research studies have been conducted about reservoir sedimentation. However, almost all of these were performed on dams that have a relatively large height. Operation rules between dams and weirs are apparently different: dams usually are allowed to store water for flood control, water supply, hydropower production, and other purposes. On the other hand, weirs do not store water because the main purpose of a weir is elevating water stage at a certain stream cross-section. Thus, the mechanism of sedimentation in weirs would be different from dams. Some studies have tried to optimize water quantity and quality objectives; however, rarely have they tried to optimize operations related to sedimentation issues. Therefore, this research is unique because it provides a solution for complex optimization problems related to reservoir operation rules in view of sedimentation issues in South Korea.

3 CHAPTER III – SITE DESCRIPTION

3.1 STUDY AREA

The study area is the Sangju Weir catchment, located in the upper Nakdong River watershed, in the Gyeongsangbuk-do of Eastern Korea. This basin includes the Naesung Stream watershed, the Yeong Stream watershed, and some of the Nakdong River basin. Four multi-purpose dams; Andong (completed in 1977), Imha (completed in 1993), Sungdeok (completed in 2014), and Yeongju (completed in 2016) and the Sangju Weir (constructed through FRRP in 2012) are located in the study area. Figure 20 and Figure 21 show watersheds and a schematic diagram of the study area, respectively. The watershed area and gaging stations are presented in Table 4. Table 5 shows detailed information about multi-purpose dams located in this area.

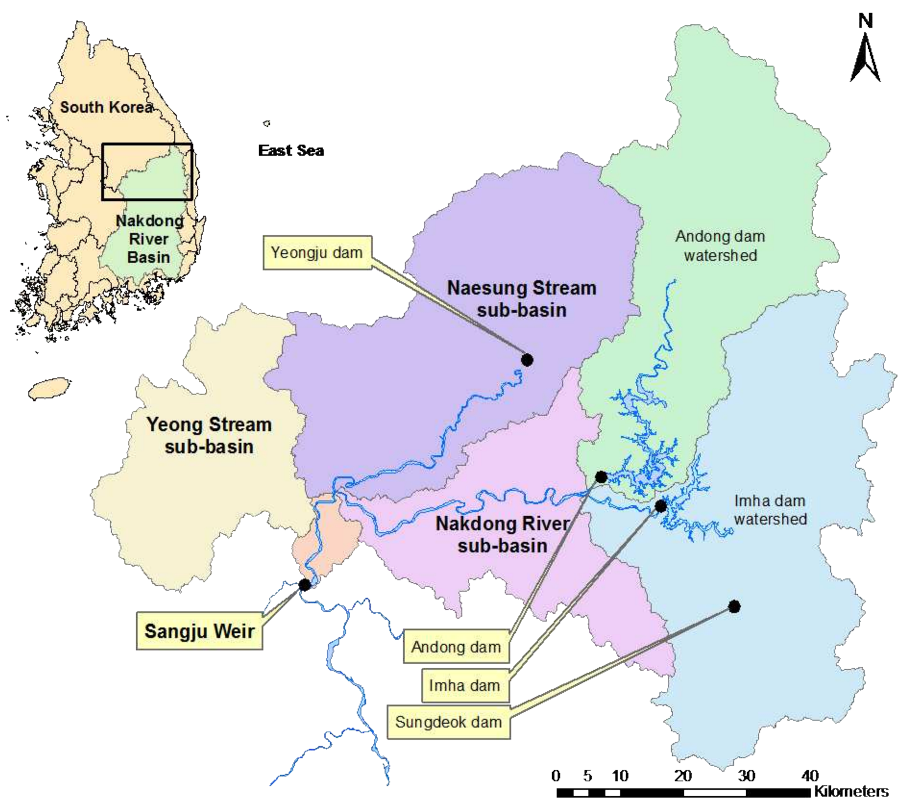


Figure 20: Study area

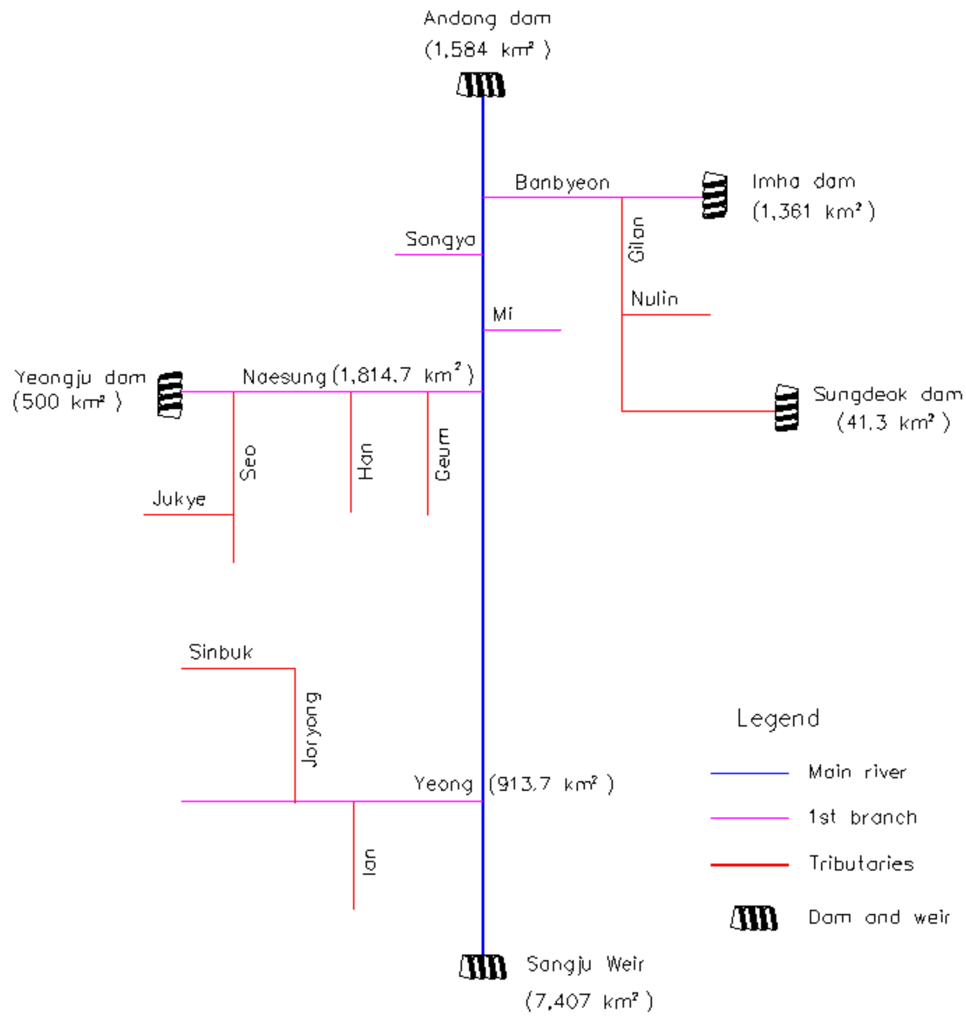


Figure 21: Schematic diagram of river system in study area

Table 4: Basic information for study area

Basin	Area (km^2)	Ratio (%)	Gaging station
Andong multi-purpose dam	1,584	21.4	
Imha multi-purpose dam	1,361	18.4	
Sungdeok multi-purpose dam	41	0.6	
Yeongju multi-purpose dam	500	6.8	
(1) Naesung stream	1,315	17.7	Hyangseok
(2) Yeong stream	914	12.3	Jeomchon
(3) Nakdong River	1,692	22.8	Waegwan
Sangju Weir	7,407	100.0	

All of these facilities have hydro power generators. The hydropower capacities of Sangju Weir and Yeongju multi-purpose dam are 3,000 kW and 5,000 kW, respectively. The maximum height to generate electricity is 7 m for Sangju Weir and 35.6m for Yeongju dam.

The schematic diagram of river systems in the study area is presented in Figure 21. The main facility, Sangju Weir, has a catchment area of 7,407 km^2. This area will be divided into three parts for this research: (1) Naesung Stream area including Yeongju multi-purpose dam; (2) Yeong Stream area; and (3) Nakdong River area upstream of Sangju Weir including three multi-purpose dams, Andong, Imha, and Sungdeok.

3.2 NAKDONG RIVER BASIN

The Nakdong River is located in the southeastern region of the Korean peninsula with a total drainage area of about 23,384 square kilometers, 25.9 % of South Korea, and a total river length of 510.36 km. The shape of the basin is nearly a rectangle; the western part of the watershed summit is almost parallel to the west coast of the Korean peninsula, and the eastern boundary of the watershed coincides with the East Sea shore. The Nakdong River flows almost through the center of the basin. The path of the flow changes its direction four times due to the Sobaek Range and finally flows into the South Sea through the Nakdong River Estuary Barrage in Busan, the second largest city in South Korea (Saman Corp. & Isan Corp., 2012).

This basin has 785 rivers, 11 national class, and 774 local class, and 7,304 km of total stream length. The population of the basin is 6.2 million people; Daegu accounts for 40.6% of the total population, Gyeongbuk 29%, Gyeongnam 18.4 %, and Busan 11.2%. The forest area accounts for the majority of the basin at 67.4%, agricultural area 23.5%, urban area 4.13 % and others 5%.

The annual rainfall is 1,255 mm which is about 20 mm less than the average of South Korea, 1,274 mm.

3.3 NAESUNG STREAM BASIN

The Naesung Stream watershed is located within the upper region of the Nakdong River Basin and drains an area of approximately 1,815 km^2. The Naesung Stream joins the main river upstream of the Sangju Weir, which is the upper-most of the new weirs constructed on the Nakdong River. Surface topography of the Naesung Stream watershed ranges from 54 m to 1,420 m above mean sea level. In this region, the Yeongju multi-purpose dam has been under construction since 2009 (it will be completed in 2015), which is located on Naesung Stream 55.6 km upstream from the confluence with Nakdong River.

The Naesung Stream was ranked the highest producer of sediment load in Nakdong River basin (K-water, 2013). Due to this, a sediment detention reservoir was introduced at the Yeongju multi-purpose dam for the first time in Korea (Samsung Inc., 2009). There are two gaging stations, Weolpo and Hyangseok, measuring water stage and discharge.

3.4 YEONG STREAM BASIN

The Yeong Stream watershed is adjacent to the Naesung stream watershed. The Yeong Stream is the first tributary of the Nakdong River and the catchment area is 914 km^2. This watershed was investigated officially in 1991, which was the latest survey (Saman Corp., 1991). There is one water stage and sediment gaging station, Jeomchon station, in the watershed.

Table 5: Detailed data of multi-purpose dams in study area (K-water, 2014)

Multi-purpose dam	Unit	Andong	Imha	Sungdeok	Yeongju
《Dam》					
Basin		Nakdong	Nakdong-Banbyeon	Nakdong-Banbyeon-Gilan	Nakdong-Naesung
River		Nakdong	Banbyeon	Bohyeon	Naesung
Type		E.C.R.D	E.C.R.D	C.G.D	C.G.D/C.F.R.D
Height	M	83	73	58.5	55.5
Length	M	612	515	274	400
Top Elevation	EL.m	166	168	368.5	168
Top elevation of core	EL.m	165.4	167.5	-	-
Volume of dam	10^3 ㎥	4,015	3,423	227	1,181
《Catchment》					
Catchment area	㎢	1,584	1,361	41.3	500
Cover ratio	%	6.7	5.8	0.2	2.1
Averaged annual inflow	CMS	27	17.3	0.77	10.04
	10^6 ㎥	940	762	24.3	316.6
Averaged annual rainfall	㎜	950	1,055.10	1,043.30	1,137
Annual water supply	10^6 ㎥	926	591.6	20.6	203.3
- Municipal and industrial		450	363.6	15.4	10.7
- Irrigation		300	13	3.1	6
- Base flow		176	215	2.1	186.6
《Reservoir》					
Surface area (flood water level)	㎢	51.5	26.4	1.53	10.4
Design flood water level	EL.m	161.7	164.7	364.9	164
Full reservoir level	EL.m	160	163	364	163
Limited water level during flood season	EL.m	-	161.7	362	156.7
Elevation of overflow section	EL.m	151	151.4	360	153
Low water level	EL.m	130	137	333	135
Lowest water level for water supply	EL.m	121	124	321	135
Target year for water supply	Year	1984	2001	2021	-
Construction period	YY.MM	1971-1977	1984-1993	2002-2014	2009-2015

Table 5 continues

Multi-purpose dam	Unit	Andong	Imha	Sungdeok	Yeongju
Total storage	10^6 ㎥	1,248	595	27.9	181.1
Effective storage	10^6 ㎥	1,000	424	24.8	160.4
Flood control storage	10^6 ㎥	110	80	4.2	75
Low-level storage	10^6 ㎥	248	124	2.2	-
- Emergency storage	10^6 ㎥	130	84	1.6	-
- Dead storage	10^6 ㎥	118	40	0.6	8.8
Total stream length (origin - mouth)	㎞	512	463	529	108.2
Stream length (origin - dam)	㎞	172	98.1	7.5	52.6
Length of reservoir	㎞	43.5		-	21.28
《Hydropower》					
Capacity	10^4kW	9.15 (Main:9, Reg.:0.15)	5.106 (Main:5, Reg.:0.1)	0.02	0.5
Annual hydropower production	GWh	90.167 (Main:89, Reg.:10.167)	83.547 (Main:78.7, Reg.:4.847)	1.65	5.78
Effective head	M	57	48.4	39.7	
Maximum design water discharge	CMS	161	119	0.707	
Generator type		DERIAZ	FRANCIS	FRANCIS	
《Regulation dam》					
Top elevation	EL.m	101.5	107	-	-
Length	M	218	320	-	-
Flood water level	EL.m	98.8	106.2	-	-
Fool reservoir level	EL.m	98	103.1	-	-
Low water level	EL.m	95	101.3	-	-
Elevation of overflow section	EL.m	91.5	97 *96.0	-	-
Total storage	10^6 ㎥	5	3.4	-	-
Effective storage	10^6 ㎥	3	1.7	-	-
Maximum design water discharge	CMS×Ea.	-	9.6×2	-	-
Distance from main dam	㎞	3	4.7	-	-

3.5 EXPECTED GEOMORPHOLOGIC CHANGES

Wohl (2014) emphasizes the interaction between humans and rivers in her book, “Rivers in the Landscape”. Human impacts can be indirect or direct. Flow regulation is considered as the most important factor for geomorphologic change.

“Direct human impacts result from activities within the river network that directly alter channel form or process. Flow regulation, and specifically the construction of dams, has received the most scientific and public scrutiny, in part because individual dams can be extremely large and can alter physical, chemical, and biological characteristics of entire watersheds (Wohl, 2014).”

3.5.1 Scour and channel degradation

Through FRRP, eight weirs were constructed consecutively along the Nakdong River in 2012 and two dams and one connection tunnel are under construction. The new hydraulic structures block upstream sediment and regulate the stream flow, which potentially causes change in channel geometry (Figure 22).

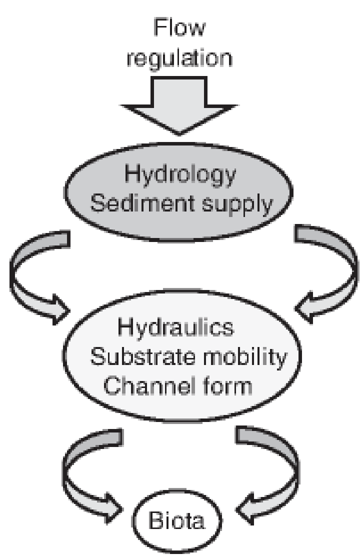


Figure 22: Schematic illustration of the changes in a river as a result of flow regulation (Wohl, 2014)

Although released flow from dam has energy to transport sediment discharge, there is no sediment. This flow is called ‘hungry water’ which dissipates its energy to scour the channel bed and bank (Kondolf, 1997). Figure 23 presents the concept of channel degradation and armoring of the channel. Figure 24 illustrates the example of the aggradation and degradation of the reservoir.

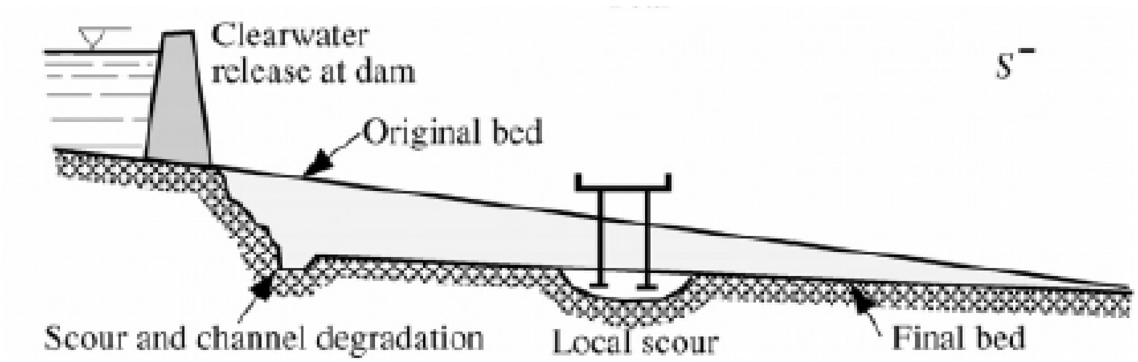


Figure 23: Concept of aggradation and degradation due to dam construction (Julien, 2002)

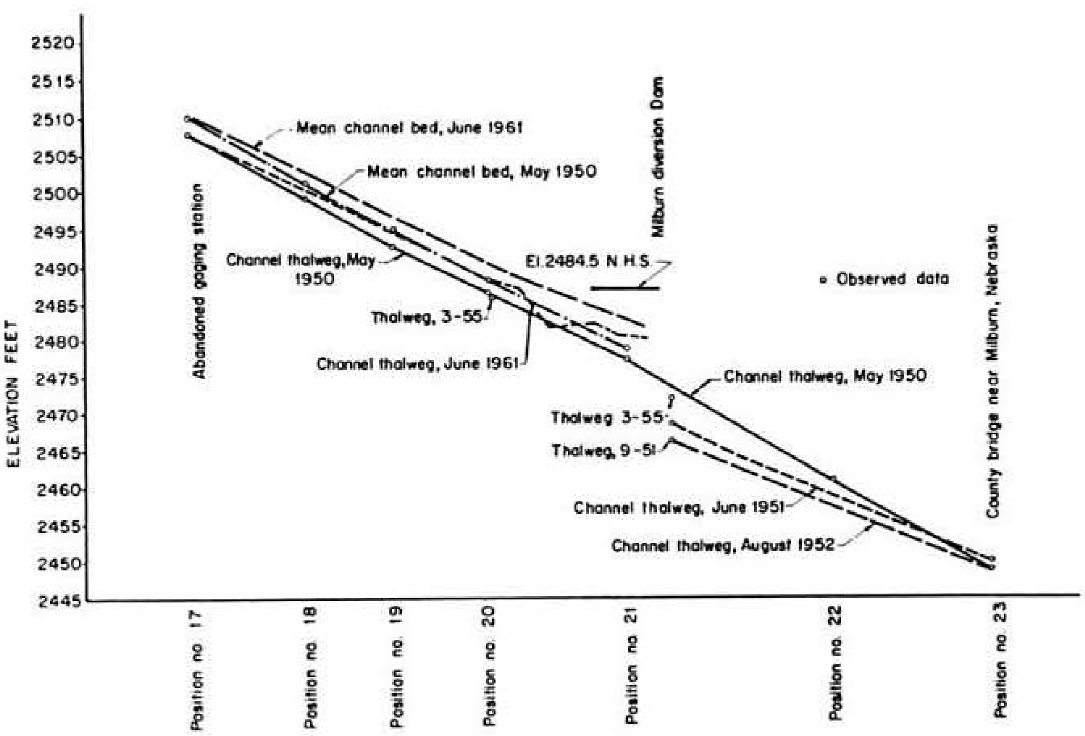


Figure 24: Aggradation and degradation at the Milburn dam site, Nebraska

"The influence of a dam constructed on a sediment-laden stream is two-fold. Aggradation of the bed of the streams occurs upstream of the reservoir and degradation of the stream bed occurs downstream of the dam." (Simons & Senturk, 1992) In this study area, hydraulic structures like the Yeongju multi-purpose dam and Sangju Weir are expected to cause the above problems. Such structures can affect geomorphic changes from right below the structure to the mouth of the river.

3.5.2 Gravel and sand mining in Naesung Stream

In spite of this theoretical background, the Yeongju city has allowed some businesses to excavate sand and gravel on Naesung Stream and its tributaries which are located downstream of the Yeongju multi-purpose dam (Figure 25 and Figure 26). This excavation can lead to increased scour and channel degradation.

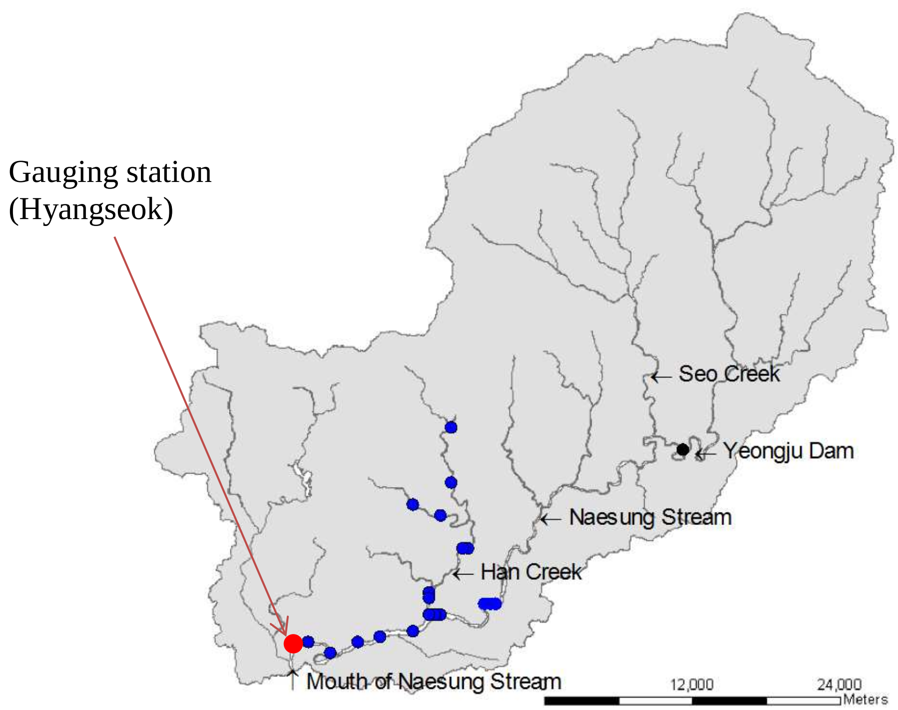


Figure 25: Location of gravel and sand mining in lower part of Naesung Stream

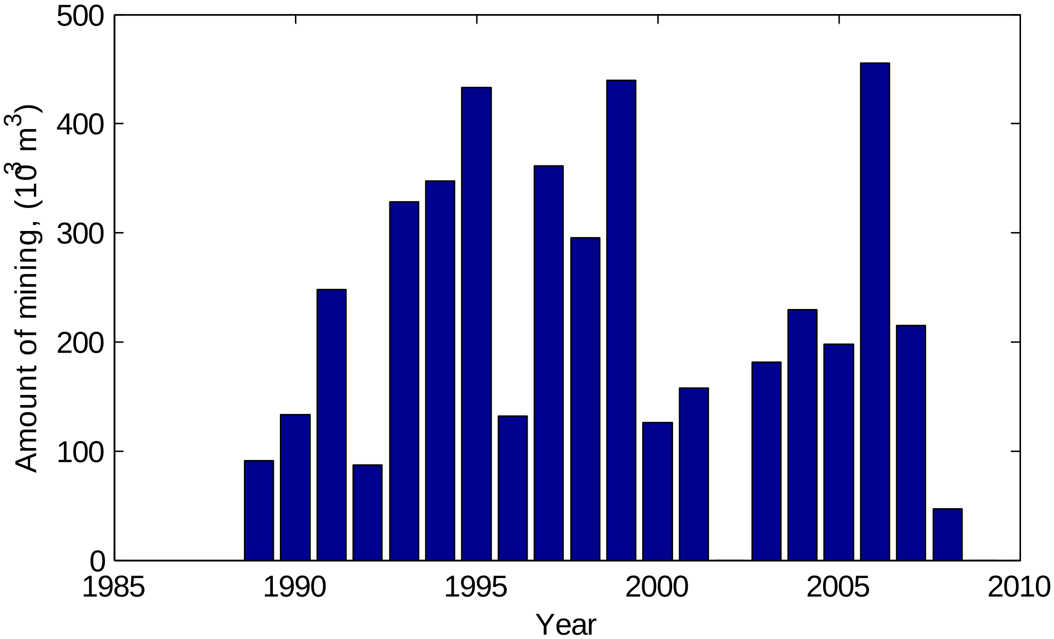


Figure 26: Amount of gravel and sand mining (1989-2009) (Saman Corp. & Isan Corp., 2013; Bonghwa-gun, Yeongju-si, & Yecheon-gun, 2013)

3.5.3 Tributary scour

The water stage of the downstream reservoir also affects the sediment transport rate of the main stream, the Nakdong River, and tributaries such as the Yeong Stream. If reservoir stage is kept lower relative to the normal condition, the friction slope of the tributary is increased, which leads to a headcut problems. However, if the reservoir stage is kept high, the opposite situation will occur.

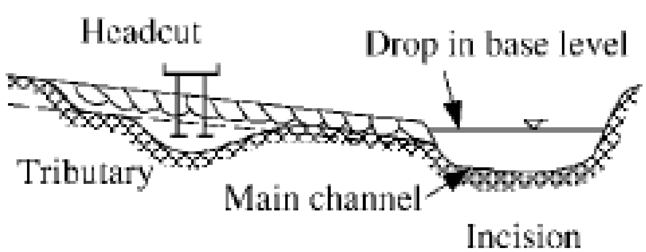


Figure 27: Concept of headcut in tributary due to changing water level in main stream

The sediment transport rate depends on various factors such as bed material, channel slope, daily discharge, upstream erodibility, and others.

Figure 28: An example photo of headcut (Wohl, 2014)

3.6 GAUGING STATION

There are twenty stations at which suspended load and bed-material sampling was performed in Korea, some of which are not sampled regularly.

In study area, there are two sediment gauging stations; (1) Hyangseok and (2) Joemchon. The Hyangseok and Joemchon stations represent the Naesung Stream and the Yeong Stream, respectively. There is no station for the main stem of the Nakdong River upstream of Sangju Weir. Instead, measured data of Waegwan Station located in the middle of the Nakdong River was used for Nakdong River watershed.

3.6.1 Hyangseok

Hyangseok gauging station is located in Hyangseok-ri Yonggung-myeon, Yecheon city, near Hoeryong-bridge, which is 270 meters long with eight piers (Figure 29). Hyangseok station provides sediment discharge and yield estimates as well as flow discharge measurement (MLTM, 2012). This station represents the total discharge of the Naesung Stream because it is almost at the outlet of the basin. The data measured in 2010 and 2011 were used for developing a sediment rating curve for this research.

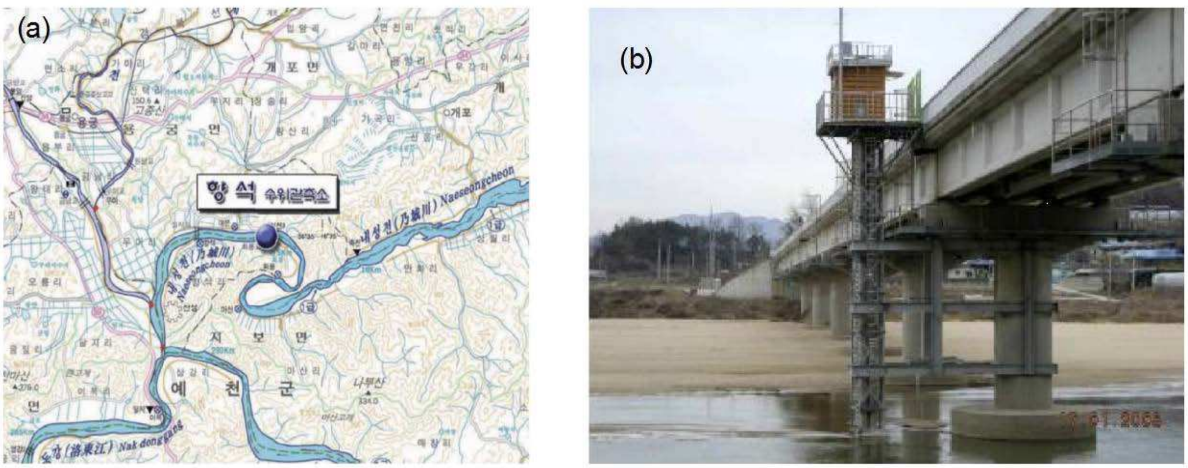


Figure 29: (a) Location of Hyangseok station and (b) picture of Hyangseok gauging station on Naesung Stream (MLTM, 2011)

3.6.2 Joemchon station

Joemchon gauging station is located in Gimyong-ri Youngsun-myeon, Munkyeong-si, near Yeongsun-bridge. Joemchon station provides suspended load, bed-material distribution as well as flow discharges for 2010 and 2013. This station represents the total discharge of the Yeong Stream because this station is almost at the outlet of the basin. The data measured in 2010 and 2011 were used for developing a sediment rating curve for this research.

Figure 30: (a) Location of Joemchon station, and (b) picture of Joemchon station (MLTM, 2011)

3.6.3 Waegwan station

Waegwan gauging station is located in Waegwan-ri Waegwan-oep, Chilgok city, near the second Waegwan-bridge. The Waegwan station has one of the longest gauge histories in Korea for variables such as suspended load, bed-material distribution, and flow discharges since 2003. This station represents the discharge and sediment concentration of the Nakdong River reach because there is no upstream gaging station representing the main Nakdong River reach.

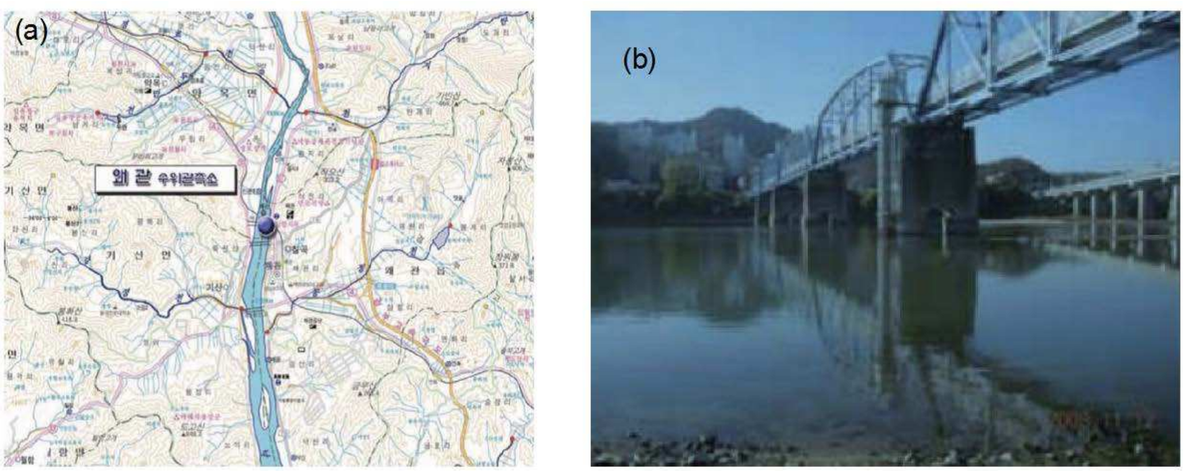


Figure 31: (a) Location of Waegwan station, and (b) picture of Waegwan station (MLTM, 2011)

4 CHAPTER IV – SEDIMENT TRANSPORT

4.1 STREAM FLOW

Discharge is one of the most important components for sediment transport analysis. For long term sediment load analysis in this study, the Flow-Duration and Sediment Rating Curve (FD/SRC) method was used, which requires daily discharge for every watershed as well as a discharge and sediment concentration relationship (Q-C relationship). Also, daily discharge is essential for calculation of trap efficiency for the daily sediment load analysis.

Approaches to obtain daily discharge in this study area are: (1) field measurement, (2) runoff modeling, and (3) proportional method. There are three reliable daily discharge data sites; (1) Andong multi-purpose dam (1977-2014), (2) Imha multi-purpose dam (1992-2014), and (3) Sangju weir (2012-2014) operational data.

In order to get daily discharges, the TANK (Sugawara, Watanabe, Ozaki, & Katsuyama, 1984) rainfall runoff model was used in this study because of its wide use in rainfall-runoff modeling in Korea. For example, the Korean government established 'Water Vision 2020' (the comprehensive water resources plan) in order to resolve water-related problems expected to happen in the future. This plan is considered as the most comprehensive plan for water resources field in Korea.

4.1.1 Precipitation and evaporation

The model requires not only hydrologic data like precipitation and evaporation but also watershed characteristics including watershed area, surface cover classification, and others.

Above all, rainfall data is the most important and dominant component for runoff simulation. Figure 33 shows the rainfall stations and thiessen polygons which were used for runoff simulation.

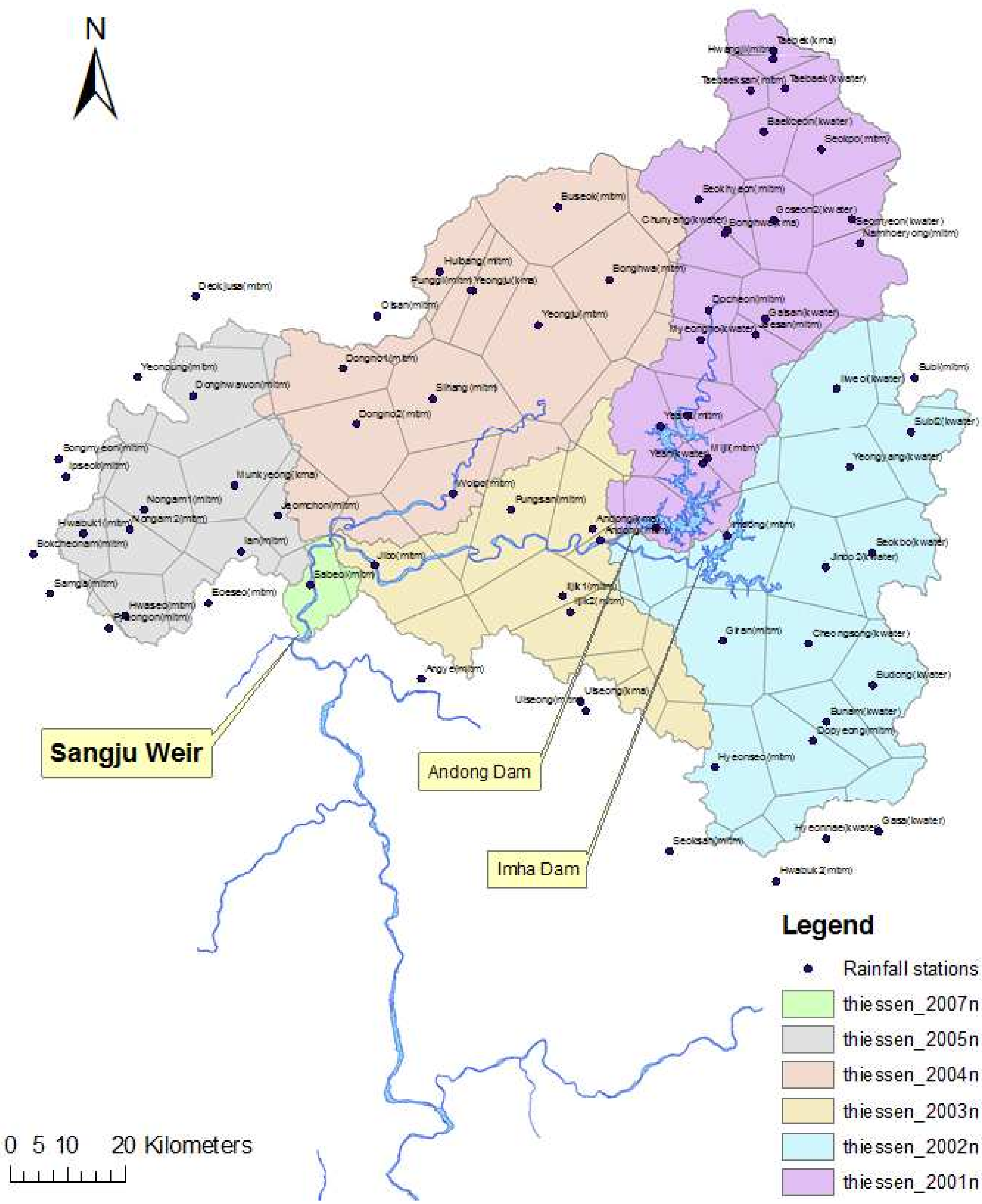


Figure 32: Rainfall stations and Thiessen polygons

Table 6: Table of precipitation stations used for Tank simulation

Station Name	Manager	Lon.	Lat.	Beg. of Obs.	Period (yrs)
Deokjusa	MOLIT	128-05-18	36-51-49	1984	31
Olsan	MOLIT	128-22-19	36-50-23	1984	31
Yeonpung	MOLIT	127-59-51	36-45-45	1962	53
Ipseok	MOLIT	127-53-09	36-38-17	1984	31
Bokcheonam	MOLIT	127-50-06	36-32-26	1984	31
Songmyeon	MOLIT	127-52-28	36-39-36	1996	19
Taebaek	KMA	128-59-21	37-10-13	1985	30
Bonghwa	KMA	128-54-52	36-56-36	1988	27
Jaesan	MOLIT	128-57-42	36-48-57	1962	53
Seokdong	MOLIT	128-48-21	36-34-28	1968	47
Yean2	MOLIT	128-48-48	36-42-04	1968	47
Seokhyeon	MOLIT	128-52-21	36-59-06	1968	47
Mijil	MOLIT	128-53-14	36-39-40	1968	47
Docheon	MOLIT	128-53-19	36-50-47	1968	47
Hwangji	MOLIT	128-59-19	37-09-36	1968	47
Seokpo	MOLIT	129-03-50	37-02-50	1968	47
Namhoeryong	MOLIT	129-07-16	36-55-58	1968	47
Yuicheon	K-water	128-51-21	36-42-52	1978	37
Baekcheon	K-water	128-58-30	37-04-10	1978	37
Galsan	K-water	128-58-36	36-50-10	1978	37
Goseon2	K-water	128-59-26	36-57-33	1978	37
Taebaeksan	MOLIT	128-57-14	37-07-17	1983	32
Myeongho	K-water	128-52-34	36-48-34	1995	20
Yean	K-water	128-52-43	36-39-16	1995	20
Chunyang	K-water	128-55-07	36-56-48	1995	20
Taebaek	K-water	129-00-27	37-07-25	1995	20
Seomyeon	K-water	129-06-43	36-57-37	1995	20
Andong	MOLIT	128-43-09	36-33-31	1916	99
Hyeonseo	MOLIT	128-53-54	36-16-22	1961	54
Giran	MOLIT	128-54-39	36-25-54	1964	51
Imdong	MOLIT	128-55-05	36-33-52	1969	46
Cheongsong	K-water	129-02-38	36-25-42	1987	28
Bunam	K-water	129-04-19	36-19-47	1987	28
Yeongyang	K-water	129-06-32	36-39-01	1987	28
Seokbo	K-water	129-08-36	36-32-33	1987	28
Ilweol	K-water	129-05-19	36-44-54	1992	23
Dopyeong	MOLIT	129-03-05	36-18-24	1998	17
Jinbo2	K-water	129-04-17	36-31-28	2000	15

Budong	K-water	129-08-42	36-22-34	2000	15
Subi2	K-water	129-12-15	36-41-40	2000	15
Andong	KMA	128-42-26	36-34-22	1973	42
Jibo	MOLIT	128-22-02	36-31-37	1962	53
Iljik1	MOLIT	128-39-38	36-29-17	1962	53
Pungsan	MOLIT	128-34-48	36-35-47	1988	27
Iljik2	MOLIT	128-40-20	36-28-05	1988	27
Yeongju	KMA	128-31-00	36-52-18	1972	43
Yeongju	MOLIT	128-37-21	36-49-41	1988	27
Buseok	MOLIT	128-39-12	36-58-32	1961	54
Dongno1	MOLIT	128-19-05	36-46-25	1962	53
Huibang	MOLIT	128-28-08	36-53-43	1984	31
Dongno2	MOLIT	128-20-21	36-42-15	1988	27
Wolpo	MOLIT	128-29-23	36-37-00	1996	19
Sihang	MOLIT	128-27-28	36-44-09	1998	17
Punggi	MOLIT	128-31-12	36-52-14	1998	17
Bonghwa	MOLIT	128-44-03	36-53-05	1998	17
Munkyeong	KMA	128-08-55	36-37-38	1973	42
Nongam1	MOLIT	128-00-26	36-35-47	1961	54
Jeomchon	MOLIT	128-13-00	36-35-22	1962	53
Hwaseo	MOLIT	127-58-42	36-27-49	1969	46
Ian	MOLIT	128-09-32	36-32-38	1969	46
Hwabuk1	MOLIT	127-54-43	36-34-00	1984	31
Donghwawon	MOLIT	128-05-03	36-44-22	1984	31
Nongam2	MOLIT	127-59-09	36-34-20	1988	27
Eoeseo	MOLIT	128-06-28	36-28-45	1969	46
Sabeol	MOLIT	128-16-01	36-30-08	1996	19
Uiseong	KMA	128-41-18	36-21-21	1973	42
Uiseong	MOLIT	128-41-49	36-20-39	1916	99
Angye	MOLIT	128-26-25	36-23-02	1961	54
Seoksan	MOLIT	128-49-38	36-10-00	1982	33
Uiheung	MOLIT	128-42-53	36-10-32	1988	27
Gasa	K-water	129-09-25	36-11-85	1996	19
Hyeonnae	K-water	129-04-33	36-11-59	1996	19
Hwabuk2	MOLIT	128-59-39	36-07-44	1988	27
Subi	MOLIT	129-12-35	36-45-41	1962	53
Pyeongon	MOLIT	127-57-17	36-26-38	1982	33
Samga	MOLIT	127-51-44	36-29-21	1982	33

The seventy-six precipitation stations' historical daily data were collected from Korean Meteorological Administration (KMA, 6), Ministry of Land, Infrastructure and Transport (MOLIT, 51), and Korea Water Resources Corporation (K-water, 19). The missing rainfall data were estimated using the Inverse Distance Weighting (IDW) method (Yoon, 2009). In addition, the gage consistency was checked by the mass curve method (Figure 33) (McCUEN, 1989). The rainfall stations were grouped by watersheds. After that, the average areal rainfalls were estimated using the Thiessen Polygon Method, for every watershed. Figure 34 shows an example of daily average areal rainfall data for one of the sub-basins.

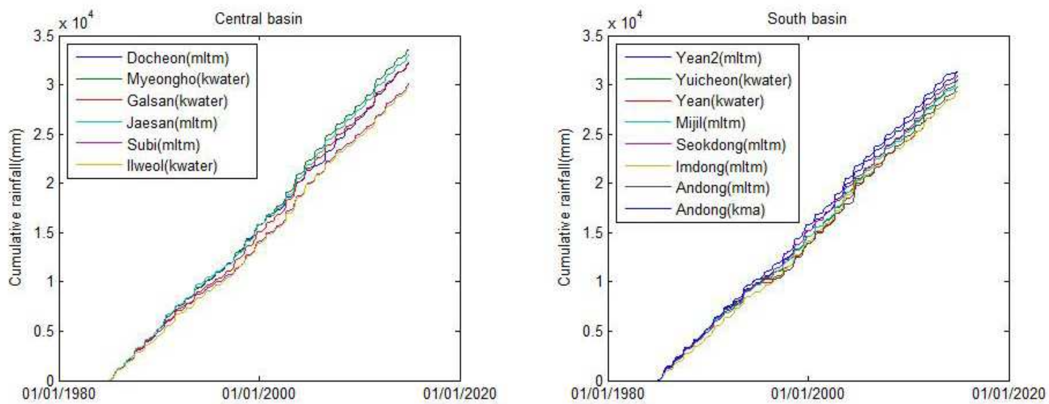


Figure 33: Precipitation accumulated mass curve analysis for 2001 watershed

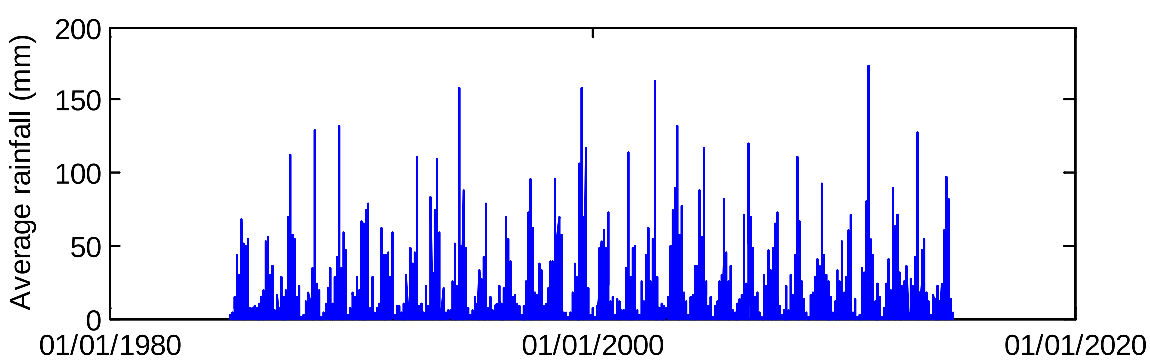


Figure 34: Average daily areal precipitation of Naesung Stream sub-basin

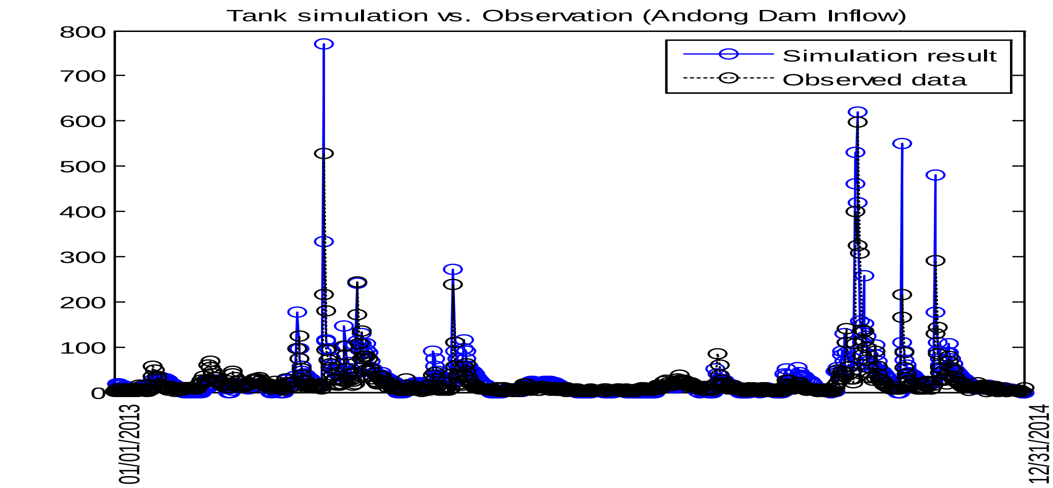
Evaporation data are only available from the Andong station (operated by KMA) in the study area. These data were collected and used for simulation. In addition, parameter values are essential to simulate discharge for ungaged watersheds with TANK. Model parameters from Water Vision 2020 were used, because these were approved official coefficients by the government. These coefficients are shown in Table 7.

Table 7: Tank parameters used in 'Water Vision 2020' (MCT, 2001)

Parameters	A11	A12	B1	A2	A3	B2	A4	B3	H11	H12	H2	H3
Andong	0.500	0.140	0.086	0.125	0.255	0.0511	0.0895	0.00	56.42	25.00	0.00	0.00
Imha	0.500	0.300	0.050	0.300	0.291	0.0185	0.0471	0.00	55.67	25.00	0.00	0.00
Hapcheon	0.491	0.157	0.103	0.119	0.273	0.0218	0.0391	0.00	65.00	22.11	0.00	0.00
Namgang	0.500	0.155	0.125	0.176	0.235	0.0223	0.0248	0.00	65.00	25.00	0.00	0.00
Milyang	0.500	0.300	0.114	0.300	0.151	0.0626	0.0983	0.00	64.82	21.96	0.00	0.00

4.1.2 Stream flow modeling and synthesis

The study area consisted of six watersheds; watershed 2001 (Andong dam watershed), watershed 2002 (Imha dam watershed), watershed 2003 (Nakdong River), watershed 2004 (Naesung Stream), watershed 2005 (Yeong Stream), and watershed 2007 (Sangju Weir watershed). The discharges were simulated for every unit watershed and the discharge of the Nakdong River sub-basin was synthesized from unit watersheds (Han River Flood Control Office, 2015); 2001, 2002, 2003, and 2007. Using average areal rainfall and evaporation records corresponding to sub-basins, the 30 year (1985-2014) series of discharges for (1) Naesung Stream, (2) Yeong Stream, and (3) Nakdong River sub-basin, were generated for verification with observed data; (1) Andong multi-purpose dam inflow data (1985-2014) and (2) Sangju Weir operational data (2013-2014).



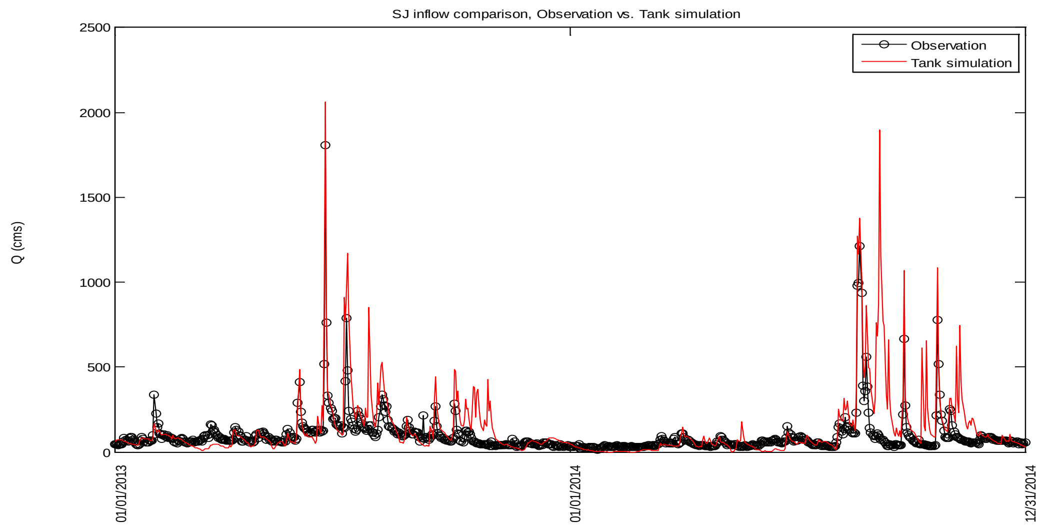


Figure 35: The discharge comparison between Tank simulation and observed data

Figure 35 shows the comparison between TANK simulation and gauged data, which demonstrates the validity of TANK model results for future prediction considering the accordance of results between observed and simulated discharges.

Based on verification for historical data, the 20 year prediction period (2015-2034) discharges for the three sub-basins were simulated. Figure 36 shows the entire period (1985-2034) of discharges used in this study. These discharge data were used for all simulation and calculation related to discharge in this study.

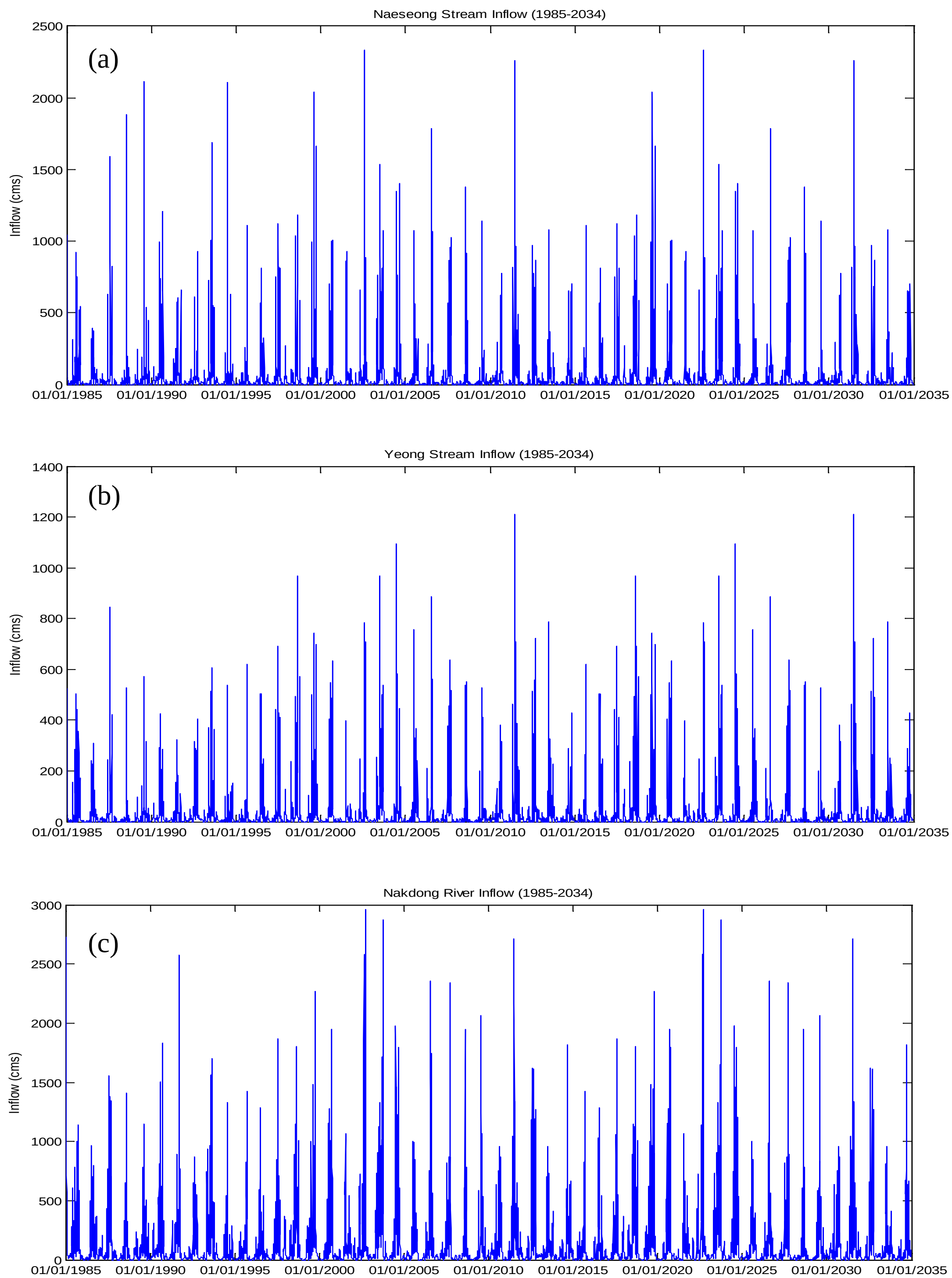


Figure 36: Whole period (1985-2034) of discharges used for simulation; (a) Naesung Stream sub-basin, (b) Yeong Stream sub-basin, and (c) Nakdong River sub-basin

4.2 BED MATERIAL

There are sixty-two bed-material samples in this study area. Upper reach of Naesung Stream has fourteen samples sampled in 2011 and twenty-eight samples were sampled at lower reach of Naesung Stream in 2010. Also, the reach of Nakdong River in this study has 7 samples of bed-material distribution which were sampled in 2009. However, just two samples of bed-material at Joemchon station were performed in Yeong stream in 2010.

Although some spots show coarse bed-material distribution, it is reasonable to assume bed-material in this study area as sand-bed channel. Table 8 shows the summary of bed-material sampling in study area.

Table 8: The status of bedmaterial sampling in study area

River	Year	No.	Specific sampling location
Naesung Stream	2010	24	STA 0, 1+160, 1+970, 2+950, 3+913, 4+850, 5+729, 6+823, 7+794, 8+805, 13+846, 14+863, 15+879, 16+855, 17+845, 18+893, 19+920,20+919, 21+927, 22+955, 23+956, 25+028,26+048, 27+000
	2011	14	STA 0, 2+100, 5+000, 7+1000, 10+000, 12+100, 15+000, 17+200, 20+000, 22+200, 25+000, 27+200, 30+000, 32+250
Yeong Stream	2010	2	Joemchon station
Nakdong River	2009	22	ND-24~45
Total		62	

Bed-material for Naesung Stream and Nakdong River were collected from entire reach when the Korean government established river improvement master plan in 2013 and 2010, respectively. The bed-material from Yeong Stream was examined during the annual hydrological survey in 2013. Figure 37 and Figure 38 show the sampling location and distribution of bed-material, respectively. The distribution shows that bed-material in Naesung Stream is finer than that from the Nakdong River, which has a d_{50} of about 1 mm. The result of Yeong Stream's bed-material analysis states that d_{50} is around 3 mm representing fine gravel.

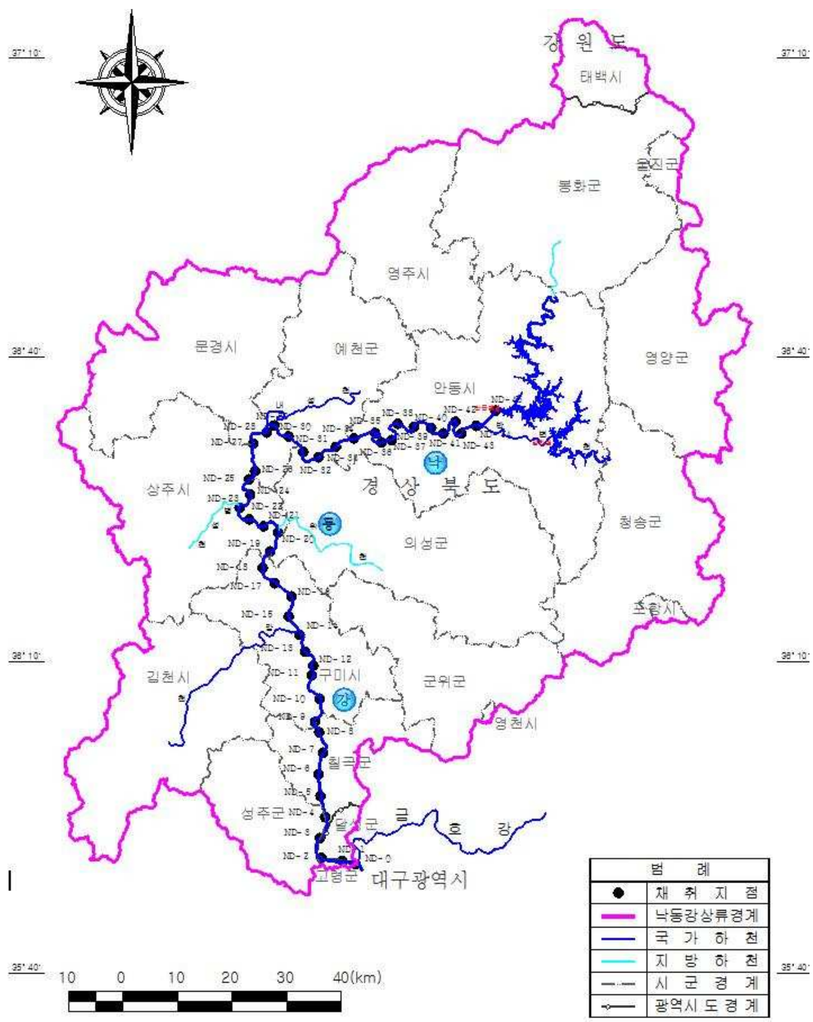


Figure 37: Location of bed-material sampling in study area (Isan Corp. & Dongho Corp., 2009)

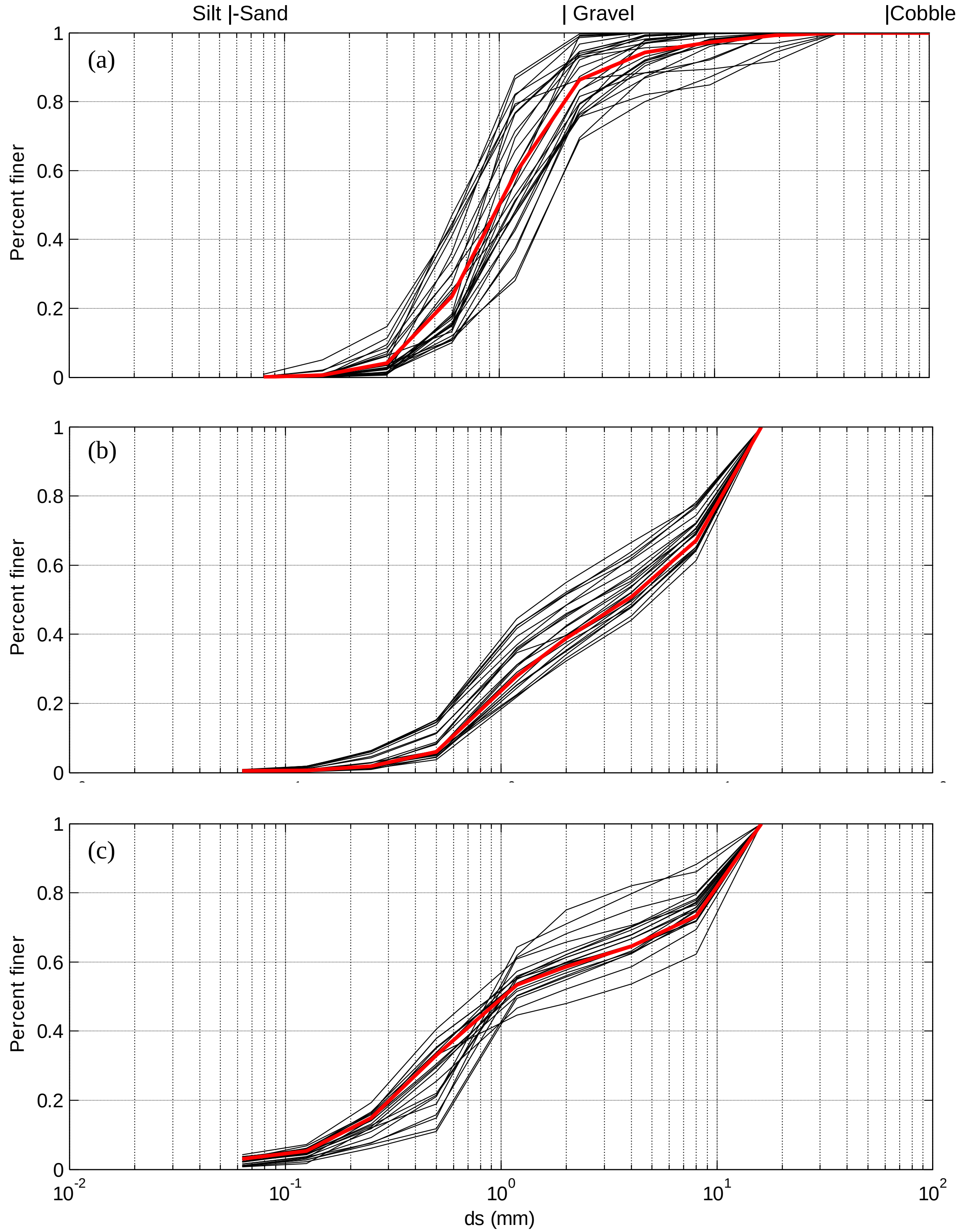


Figure 38: Bed-material distribution of Hyangseok (a), Joemchon (b), Waegwan Station (c)

4.3 SUSPENDED LOAD DISTRIBUTION

133 suspended load samples were used for this study area. Naesung Stream has 100 samples sampled in 2012. Sixteen and seventeen samples were collected for Yeong Stream and Nakdong River respectively. Table 9 shows the summary of suspended load sampling numbers in study area.

Since the previous report does not provide trapped suspended load distribution for Naesung Stream, the suspended load distribution was produced using the Oden curve method. Figure 39 shows the original data sheet from laboratory. These data were used to complete the Oden curve analysis (Figure 40). Table 10 presents the analyzed results.

For obtaining suspended grain size distribution of Yeong Stream and Nakdong River, the Laser Diffraction method was used. Figure 41 shows the distribution of suspended load for the study area.

Table 9: The status of suspended load sampling in study area

River	Year	No.	Specific sampling location	Method
Naesung Stream	2012	100	Hyangseok station	Oden curve method
Yeong Stream	2013	16	Joemchon station	Laser diffraction method
Nakdong River	2013	17	Waegwan station	Laser diffraction method
Total		133		

하천명	낙동강	지점명	점촌	시료번호	1−4	분석자
채취일자	2010.07.11	채취시간		채취온도(℃)		김다솜,정효주 장민우
실험일자	2010.07.12	시료용량(mL)	765	시료온도(℃)	25.7	

1. 농도분석

시료용량(mL) 100

건조 전 중량 (g)	건조 후 중량 (g)	유사중량 (g)	유사농도 (mg/L)
2.1729	2.1737	0.0008	8.0

2. 입도분석

시료용량 (mL)

소요시간 (min)	중량(g)				누가백분율 (%)	부유잔류 백분율(%)
	건조 전 중량	건조 후 중량	유사중량	누가중량		
0					0.0	100.0
1/6	2.0936	2.0937	0.0001	0.0001	2.2	97.8
1/2	2.0752	2.0753	0.0001	0.0002	4.4	95.6
1	2.1356	2.1364	0.0008	0.0010	22.2	77.8
3	2.1767	2.1769	0.0002	0.0012	26.7	73.3
7	2.1143	2.1145	0.0002	0.0014	31.1	68.9
16	2.1040	2.1043	0.0003	0.0017	37.8	62.2
40	2.1346	2.1355	0.0009	0.0026	57.8	42.2
80	2.0997	2.1003	0.0006	0.0032	71.1	28.9
120	2.0937	2.0940	0.0003	0.0035	77.8	22.2
130	2.1025	2.1035	0.0010	0.0045	100.0	0.0

3. Oden Curve

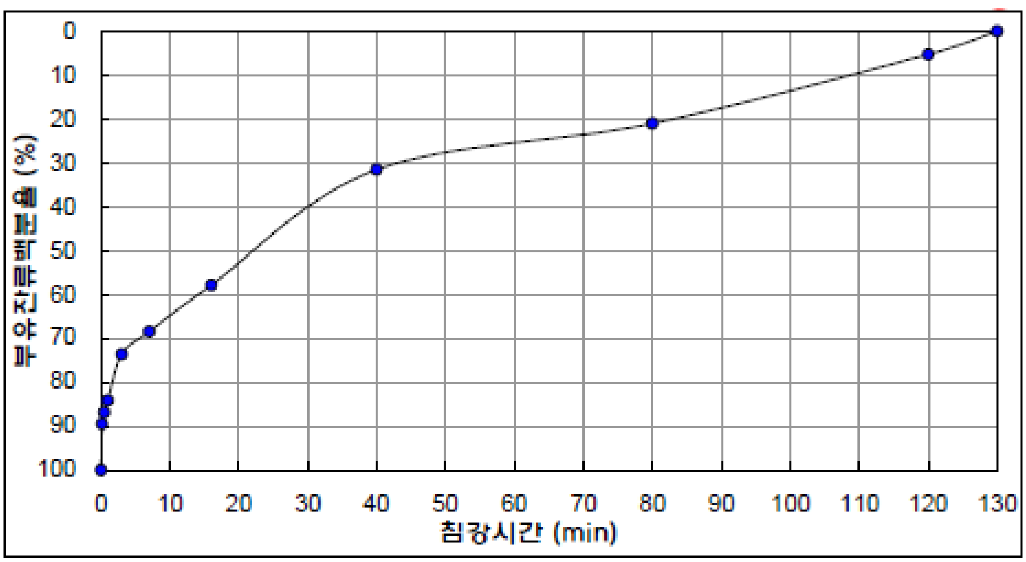


Figure 39: Suspended load analysis sheet and Oden curve at Joemchon Station (MLTM, 2011)

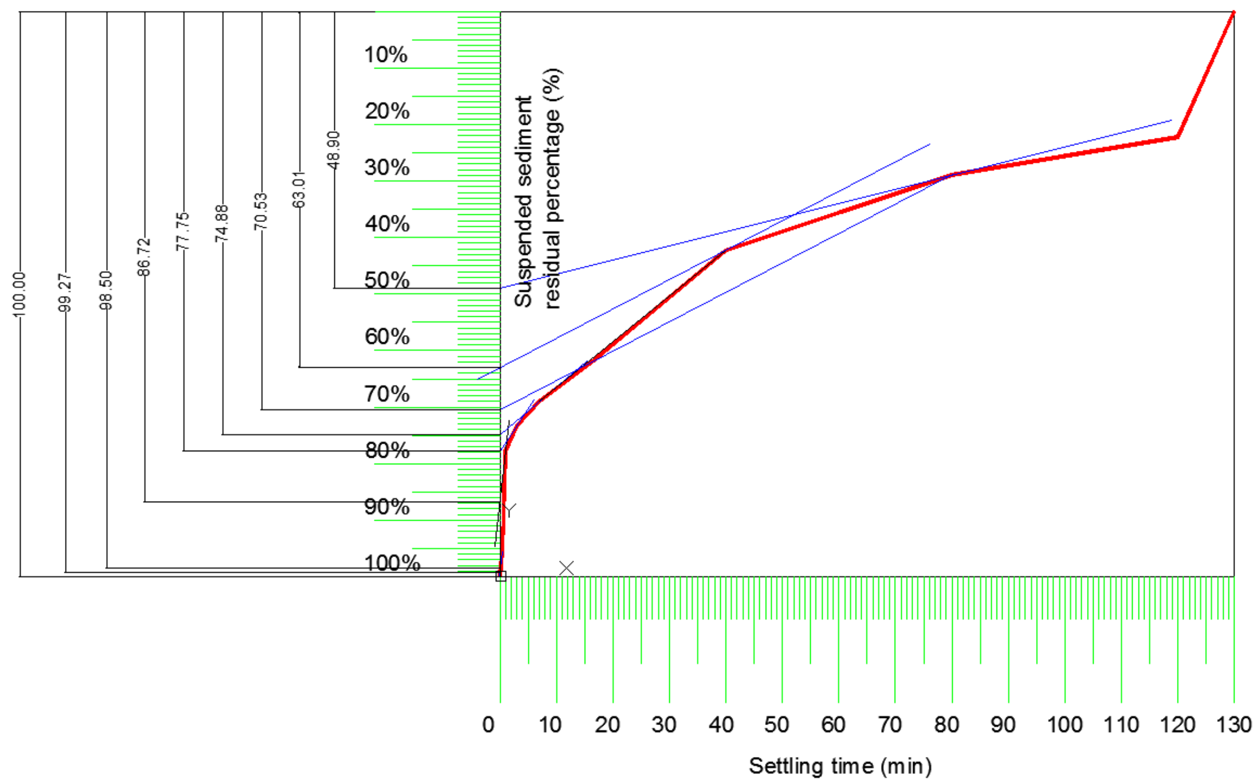


Figure 40: Example of Oden curve analysis for Joemchon station

Table 10: Suspended load particle size distribution example estimated by Oden curve analysis

Grade	Grain size(mm)	w1 (%)	w2 (%)	w1-w2 (%)
1	0.0020-0.0221	63.01	0	63.01
2	0.0222-0.0312	70.53	63.01	7.52
3	0.0313-0.0422	74.88	70.53	4.35
4	0.0423-0.0625	77.75	74.88	2.87
5	0.0626-0.1250	86.72	77.75	8.97
6	0.1251-0.2500	98.5	86.72	11.78
7	0.2501-0.5000	99.27	98.5	0.77
8	0.5001-1.0000	100	99.27	0.73

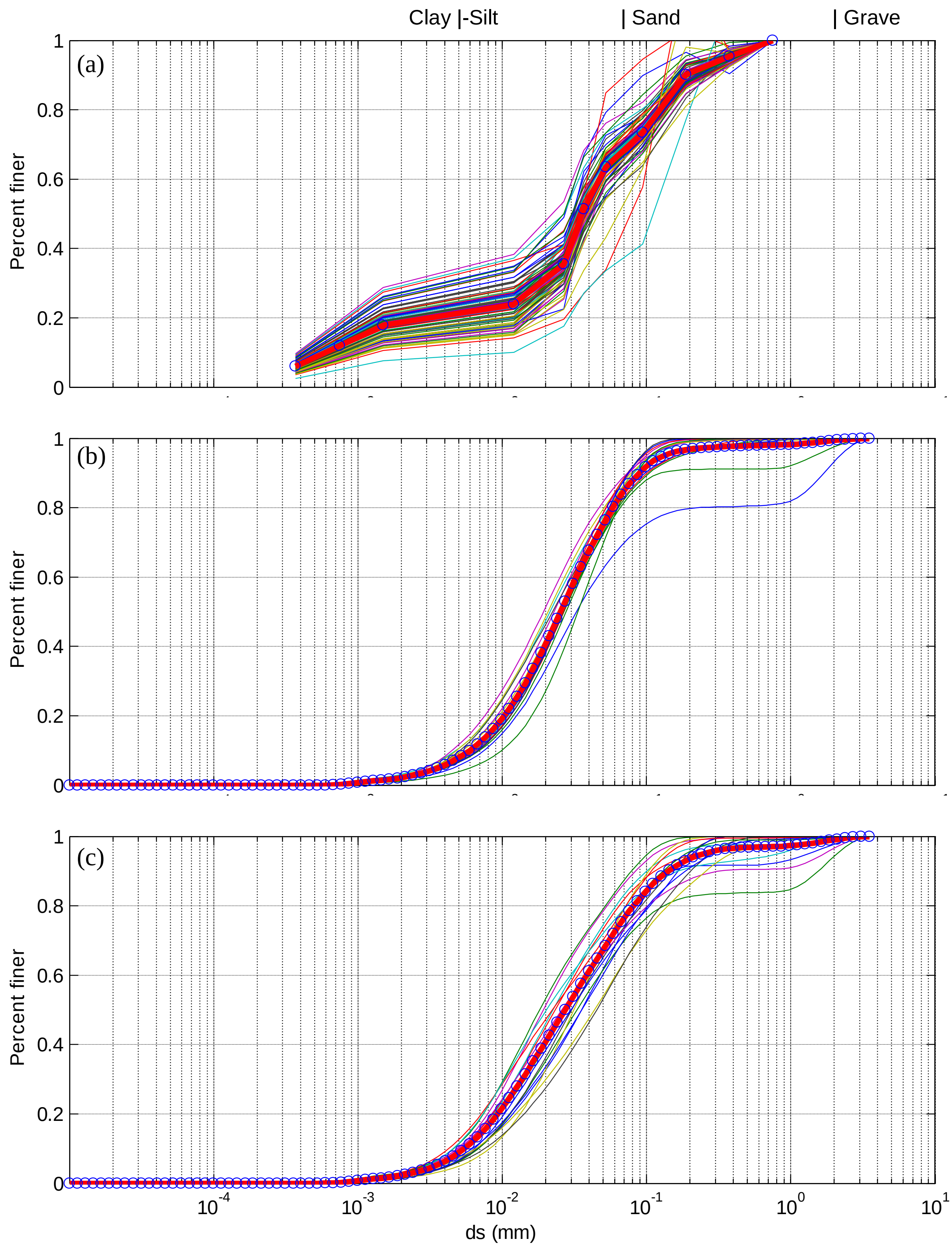


Figure 41: Suspended particle distribution of Hyangseok (a), Joemchon (b), and Waegwan station (c)

4.4 DISCHARGE AND SEDIMENT CONCENTRATION RELATIONSHIP (Q-C)

Three Q-C relationships were defined based on three stations in the study area (Figure 42).

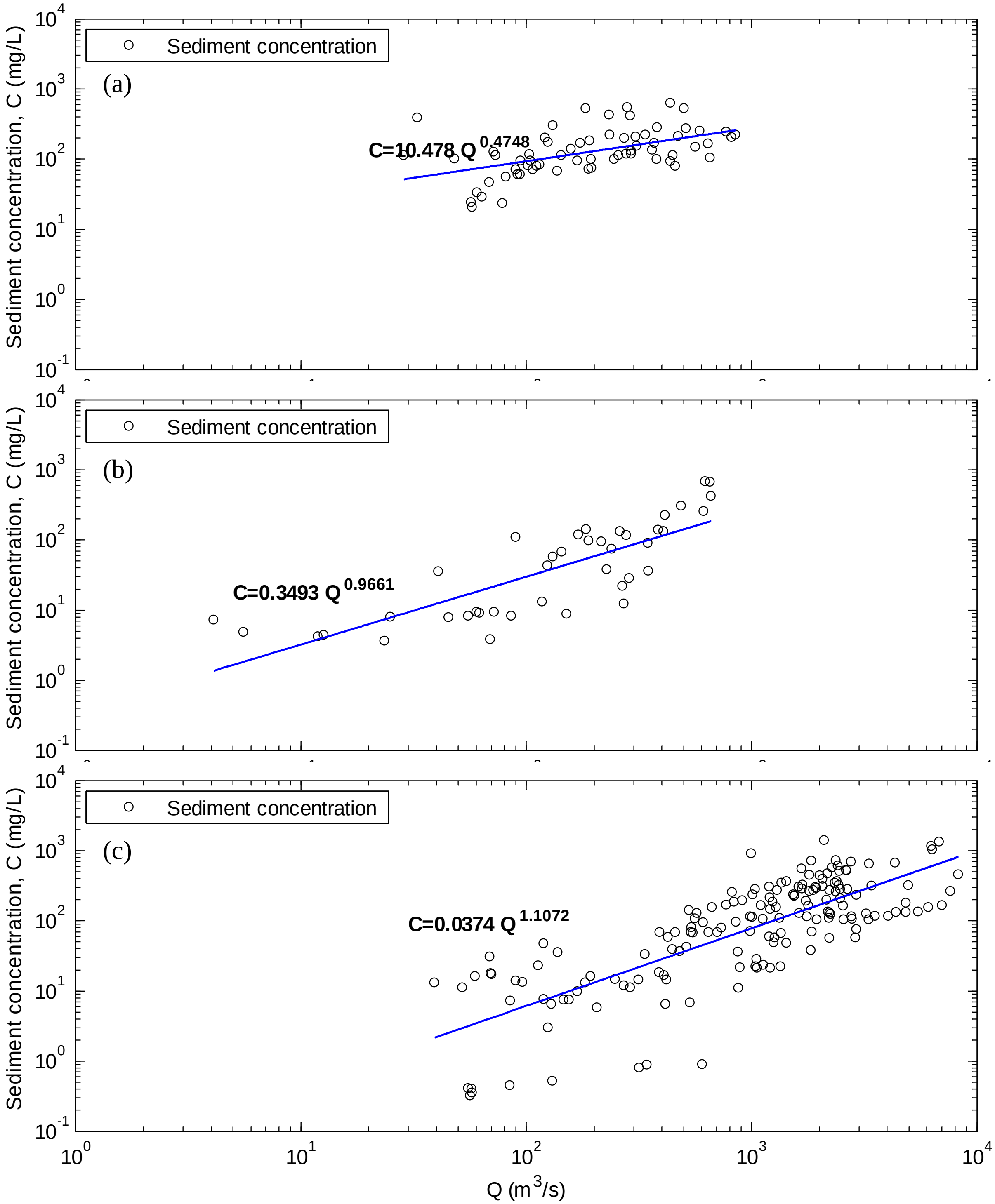


Figure 42: Q-C relationship of Hyangseok (a), Joemchon (b), and Waegwan Station (c)

4.5 LONG-TERM SEDIMENT LOAD

The Flow-Duration/Sediment Rating curve method was used to estimate long-term sediment load for three sub-basins: (1) Naesung Stream sub-basin, (2) Yeong Stream sub-basin, and (3) Nakdong River sub-basin. This method combines a sediment-rating curve (total sediment discharge as a function of water discharge), and a flow-duration curve. Figure 43 shows the procedure for long-term sediment yield.

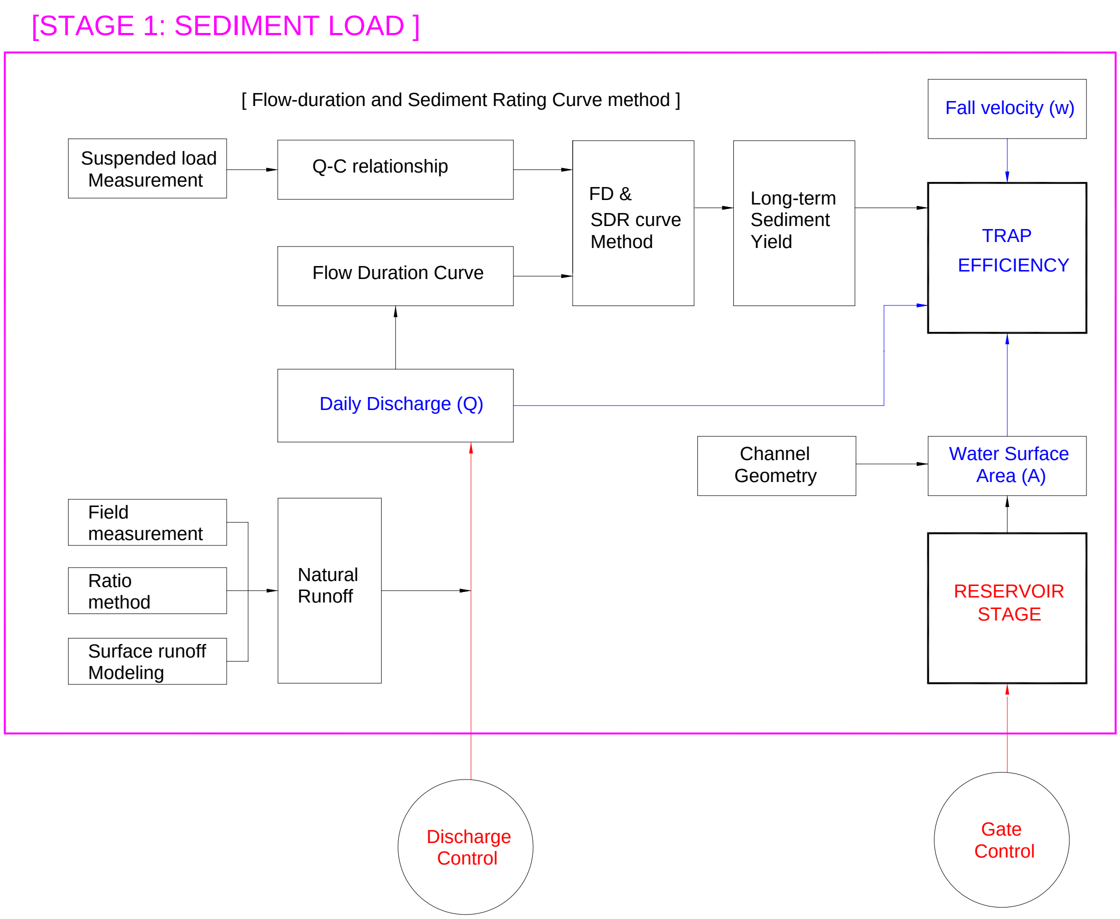


Figure 43: Sediment load estimation process diagram

First, the relationship of discharge and sediment concentration was developed from field measurements for suspended load. Second, the flow duration curves were produced from daily discharge simulated as described in the previous chapter. This curve states the percentage of time a given river discharge is exceeded. Then, these two curves were combined to predict long-term sediment yield at the mouth of every watershed. Finally, trap efficiency calculated as described in the previous chapter was applied to the long-term sediment yield, resulting in the reservoir sedimentation amount at Sangju Weir from every sub-basin. The summation of these is then the total Sangju Weir basin sedimentation.

4.5.1 Flow duration curve

Since the observed inflow records are not continuous or comprehensive for the three sub-basins, simulated stream flow (1985-2014) using the TANKk model was used to develop the flow-duration curve (Figure 44).

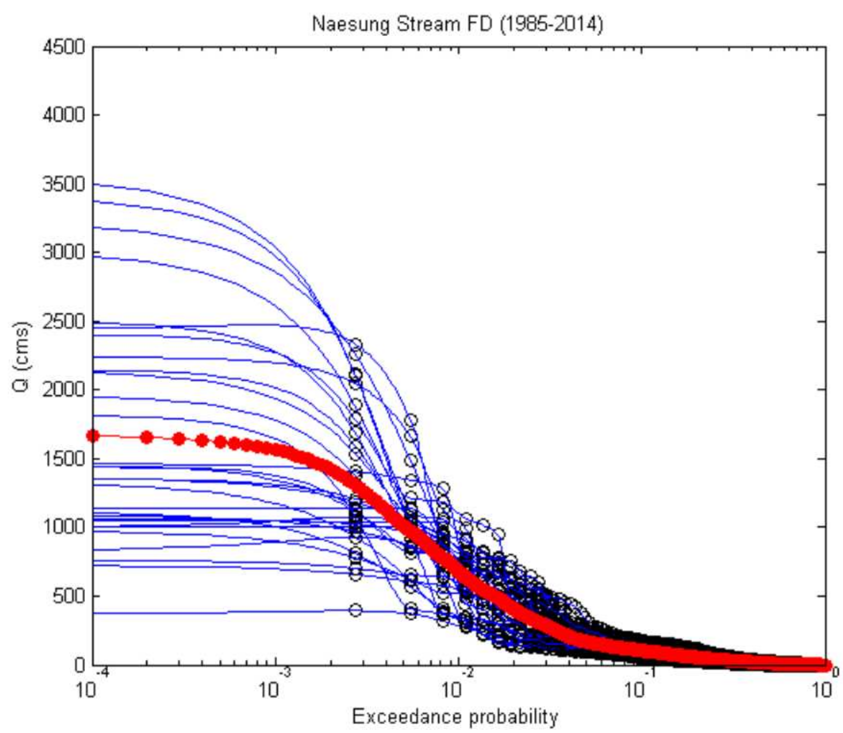


Figure 44: Flow-duration curve of the Naesung Stream, solid lines and red dots represent data from 1985 to 2014 and average data, respectively

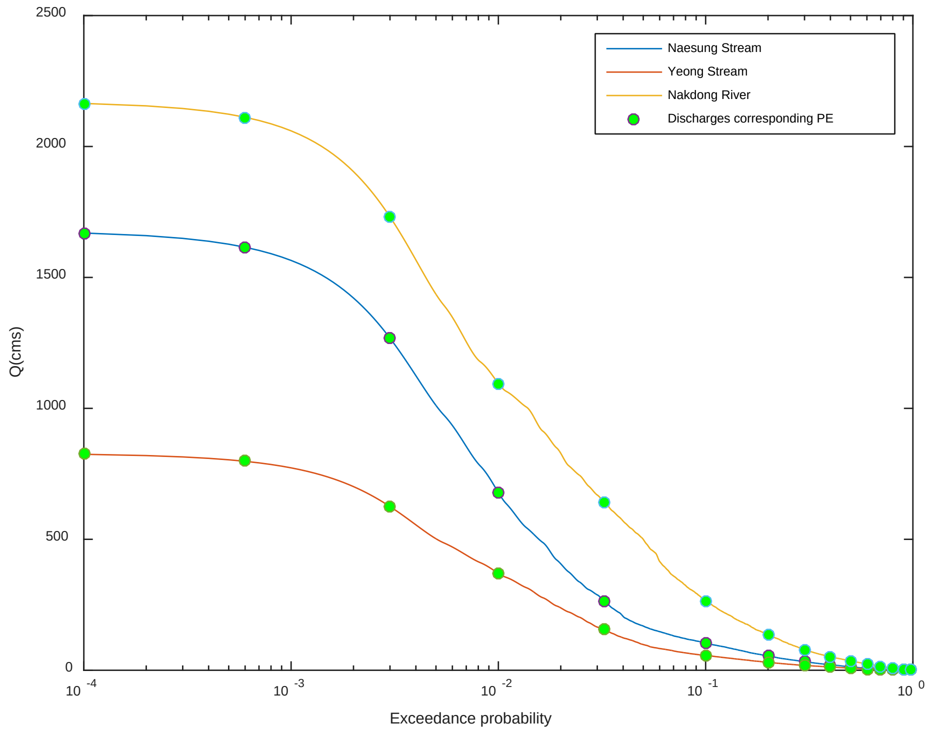


Figure 45: Flow-duration curves of the sub-basins in study area

Table 11: Discharges corresponding interval mid-point for the sub-basins of study area

Mid-point of time exceeded probability	Corresponding discharge (m^3/s)		
	Naesung Stream	Yeong Stream	Nakdong River
0.0001	1669.6	824.7	2164.5
0.0006	1615.3	797.9	2111.6
0.003	1268.0	625.2	1731.2
0.01	678.4	370.2	1095.1
0.0325	262.8	154.8	641.0
0.1	104.0	57.1	265.0
0.2	54.6	30.6	137.1
0.3	33.0	18.4	78.3
0.4	21.0	12.4	51.3
0.5	12.9	8.3	36.0
0.6	7.5	4.9	24.3
0.7	3.0	2.1	15.3
0.8	0.9	0.7	8.4
0.9	0.1	0.1	3.2
0.975	0.0	0.0	0.6

Table 11 shows several data points with the exceedance interval and corresponding discharge, based on the curves shown in Figure 45.

4.5.2 Q-C relationship

Q-C relationships below for Hyangseok, Jeomchon and Waegwan were used to estimate long-term sediment load (Figure 42).

$$C = 10.48\ Q^{0.47} \text{ for Hyangseok station} \quad (42)$$

$$C = 0.35\ Q^{0.97} \text{ for Joemchon station} \quad (43)$$

$$C = 0.04\ Q^{1.11} \text{ for Waegwan station} \quad (44)$$

where,

C = suspended sediment concentration (metric tons/day)

Q = discharge (m^3/s)

4.5.3 Suspended / Measured load (Qsus / Qm)

As a result of combining the Q-C relationship and flow-duration curve, the incoming sediment load was estimated. Table 12-Table 14 present the results of the estimated incoming sediment load at the three sub-basins. The total suspended sediment load was estimated as 387,175 tons/year. The summary is presented in Table 15.

Table 12: Long-term sediment yield for Naesung Stream using flow-duration and sediment-rating curve method

Time intervals (%) (1)	Interval mid-point (%) (2)	Interval ΔP(%) (3)	Discharge Q (m^3/s) (4)	Concentration C (mg/L) (5)	Q × Δ P (6)	Sediment Load Qs × ΔP (tons/yr) (7)	
0 ~ 0.02	0.01	0.02	1,670	355	0.3	3,361	2%
0.02 ~ 0.1	0.06	0.08	1,615	350	1.3	14,360	7%
0.1 ~ 0.5	0.3	0.4	1,268	312	5.1	50,218	23%
0.5 ~ 1.5	1	1	678	231	6.8	49,574	23%
1.5 ~ 5	3.25	3.5	263	148	9.2	42,972	20%
5 ~ 15	10	10	104	95	10.4	31,181	15%
15 ~ 25	20	10	55	70	5.5	12,151	6%
25 ~ 35	30	10	33	55	3.3	5,728	3%
35 ~ 45	40	10	21	44	2.1	2,916	1%
45 ~ 55	50	10	13	35	1.3	1,436	1%
55 ~ 65	60	10	7	26	0.7	574	0%
65 ~ 75	70	10	3	18	0.3	170	0%
75 ~ 85	80	10	1	10	0.1	32	0%
85 ~ 95	90	10	0	0	0.0	0	0%
95 ~ 100	97.5	5	0	0	0.0	0	0%
Total						214,673	100%

Table 13: Long-term sediment yield for Yeong Stream using flow-duration and sediment-rating curve method

Time intervals (%) (1)	Interval mid-point (%) (2)	Interval ΔP(%) (3)	Discharge Q (m^3/s) (4)	Concentration C (mg/L) (5)	Q × Δ P (6)	Sediment Load Qs × ΔP (tons/yr) (7)	
0 ~ 0.02	0.01	0.02	825	230	0.2	1,452	3%
0.02 ~ 0.1	0.06	0.08	798	222	0.6	4,204	10%
0.1 ~ 0.5	0.3	0.4	625	176	2.5	13,886	31%
0.5 ~ 1.5	1	1	370	106	3.7	12,378	28%
1.5 ~ 5	3.25	3.5	155	46	5.4	7,840	18%
5 ~ 15	10	10	57	17	5.7	3,058	7%
15 ~ 25	20	10	31	10	3.1	987	2%
25 ~ 35	30	10	18	6	1.8	341	1%
35 ~ 45	40	10	12	4	1.2	151	0%
45 ~ 55	50	10	8	3	0.8	76	0%
55 ~ 65	60	10	5	2	0.5	32	0%
65 ~ 75	70	10	2	1	0.2	6	0%
75 ~ 85	80	10	1	0	0.1	0	0%
85 ~ 95	90	10	0	0	0.0	0	0%
95 ~ 100	97.5	5	0	0	0.0	0	0%
Total						44,402	100%

Table 14: Long-term sediment yield for Nakdong River using flow-duration and sediment-rating curve method

Time intervals (%) (1)	Interval mid-point (%) (2)	Interval ΔP(%) (3)	Discharge Q (m^3/s) (4)	Concentration C (mg/L) (5)	Q × Δ P (6)	Sediment Load Qs × ΔP (tons/yr) (7)	
0 ~ 0.02	0.01	0.02	2,165	184	0.4	2,323	2%
0.02 ~ 0.1	0.06	0.08	2,112	179	1.7	9,604	8%
0.1 ~ 0.5	0.3	0.4	1,731	144	6.9	31,358	25%
0.5 ~ 1.5	1	1	1,095	87	10.9	29,928	23%
1.5 ~ 5	3.25	3.5	641	48	22.4	33,933	26%
5 ~ 15	10	10	265	18	26.5	15,054	12%
15 ~ 25	20	10	137	9	13.7	3,891	3%
25 ~ 35	30	10	78	5	7.8	1,231	1%
35 ~ 45	40	10	51	3	5.1	483	0%
45 ~ 55	50	10	36	2	3.6	227	0%
55 ~ 65	60	10	24	1	2.4	76	0%
65 ~ 75	70	10	15	1	1.5	47	0%
75 ~ 85	80	10	8	0	0.8	0	0%
85 ~ 95	90	10	3	0	0.3	0	0%
95 ~ 100	97.5	5	1	0	0.1	0	0%
Total						128,155	100%

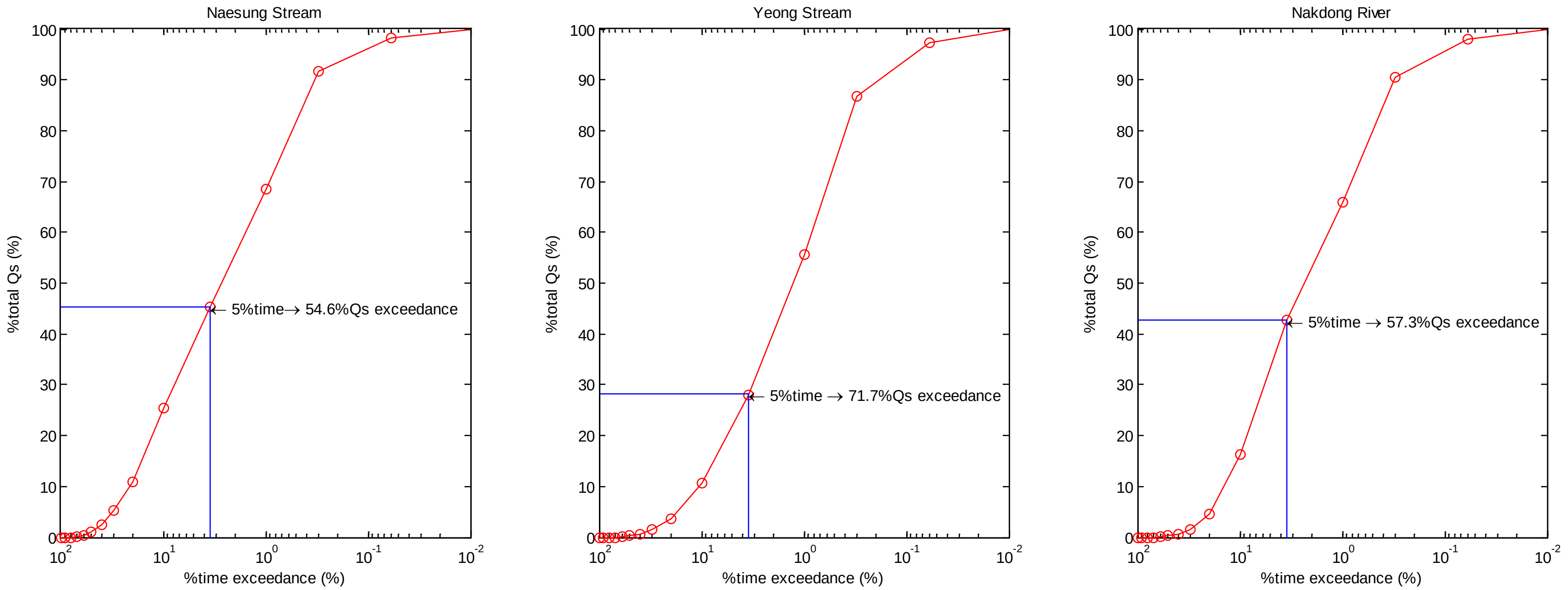


Figure 46: The relationship between %time exceedance and %total load

Table 15: Estimation of incoming suspended (measured) load

Sub-basin	Suspended load (Qsus, Qm, tons/year)
Naesung Stream	214,673
Yeong Stream	44,402
Nakdong River	128,155
Total	387,230

4.5.4 Total load (Q_{TOT})

The sediment yield estimated in the previous section was only based on measured suspended sediment concentration which represents to the measured portion (q_m) in Figure 47B. The integral of the product of velocity and sediment concentration resulted in the total sediment load. However, the sediment load estimated does not represent the total sediment load because the unmeasured loads are not considered. Thus, in order to estimate the total load, compensation for unmeasured load is required.

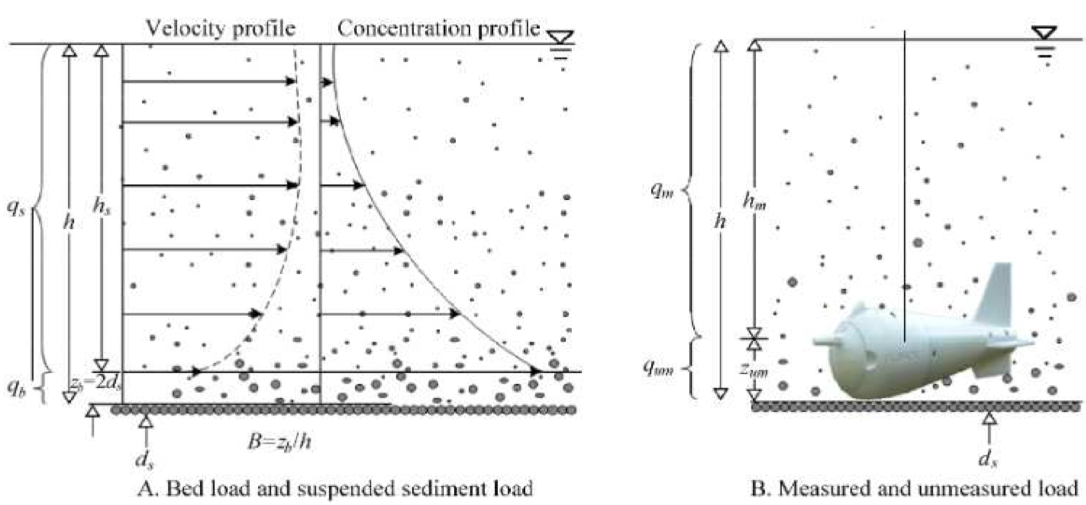


Figure 47: Definition sketch for sediment measurements in suspension (Shah-Fairbank & Julien, 2015)

Shah-Fairbank and Julien (Shah-Fairbank & Julien, 2015) proposed the relationship among the relative sampling depth (h_m/h), ratio of shear velocity to fall velocity (u_* / ω), and ratio of partial to total sediment discharge (q_p/q_t). Figure 48 and Table 16 show measured relative sampling depth and calculation of the ratio velocity to fall velocity for this study area.

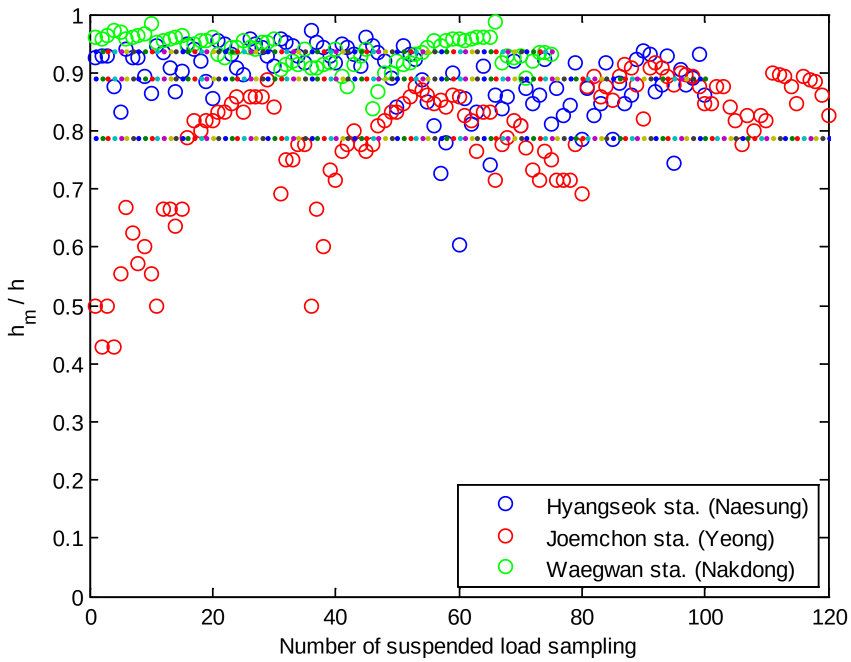


Figure 48: Relative sampling depth estimation

Table 16: Calculation of relative sampling depth and ratio of shear velocity to fall velocity

Div.	Naesung Stream	Yeong Stream	Nakdong River
d_{50} (mm)	0.035	0.025	0.027
h_m (m)	1.56	0.96	3.42
h (m)	1.71	1.16	3.61
h_m/h (%)	91.2	82.8	94.7
h/d_{50}	44,571	38,400	126,667
u_* (m/s)	0.143	0.164	0.145
ω (m/s)	0.001	0.001	0.001
u_* / ω	130.1	291.3	220.6
S	0.0012	0.0024	0.0006

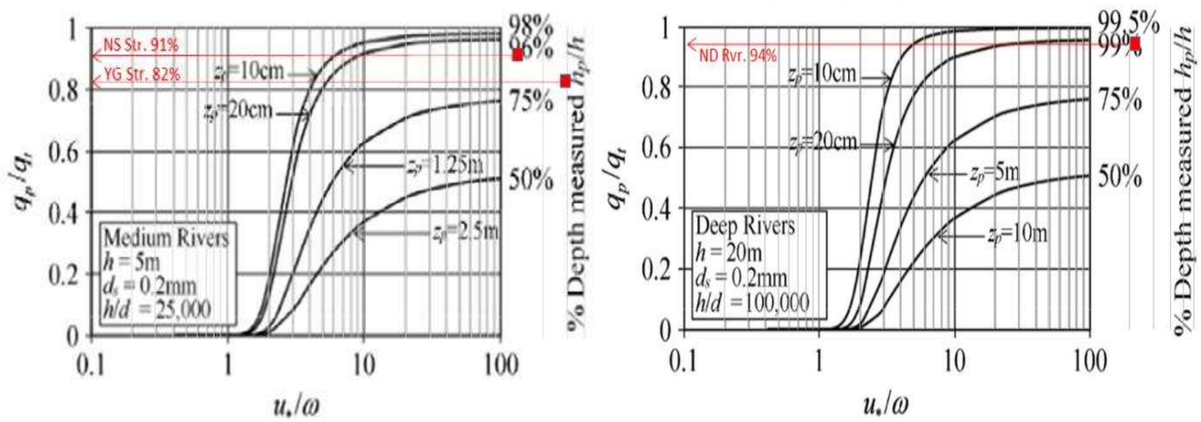


Figure 49: Estimation of the ratio of partial sediment discharge to total discharge for (a) Naesung Stream and Yeong Stream and (b) Nakdong River

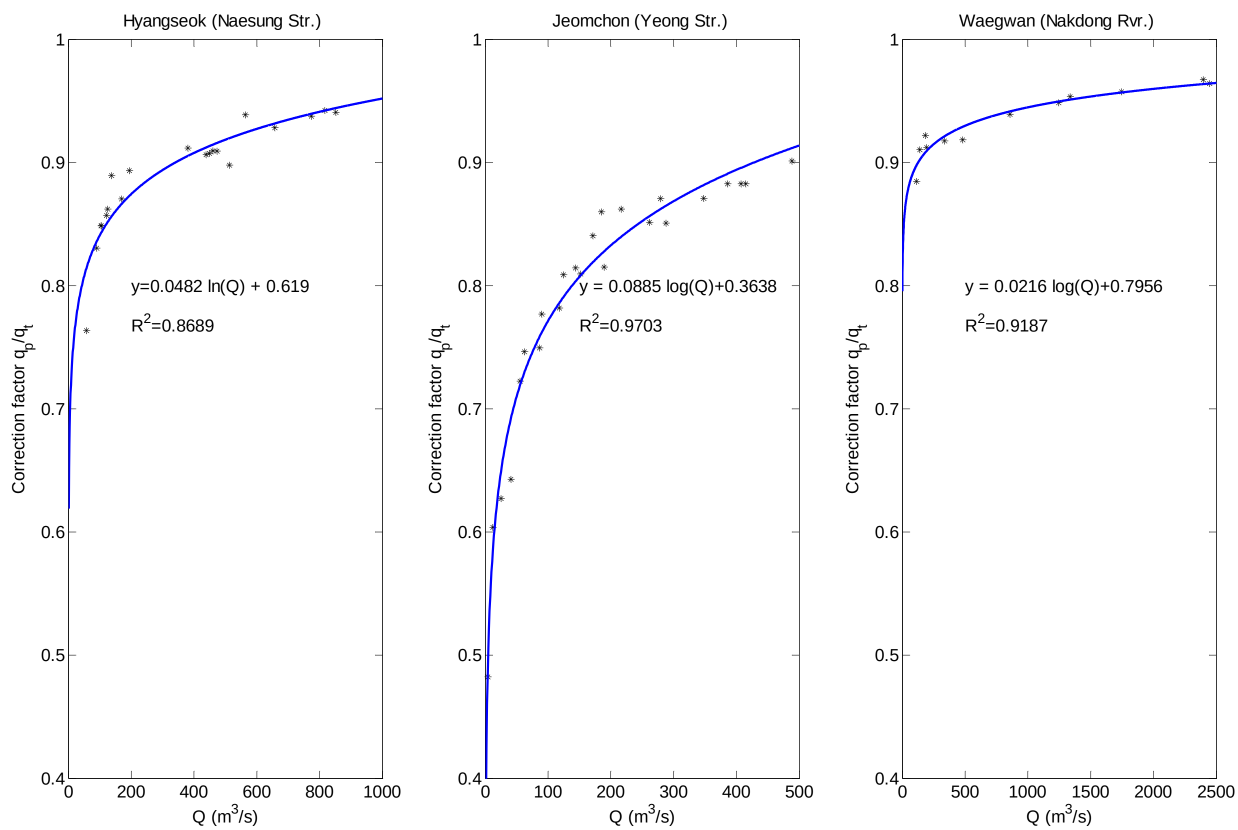


Figure 50: The SEMEPP correction facter and discharge relationship

Figure 49 shows the ratio of partial to total sediment discharge (q_p/q_t) corresponding to average sampling ratio (h_p/h) and the ratio of shear velocity to the grain fall velocity (u_*/ω) for three sub-basins acoordance with SEMEPP. It was examined through data analysis of field measurement that the SEMEPP correction factors at sediment discharge gauging stations have strong relation with discharge. Figure 50 shows the relationship between discharge and SEMEPP correction factors at every sediment discharge gauging station. The SEMEPP correction factor can be expressed as a function of discharge. The average ratio of partial (measured suspended) sediment discharge to the total were estimated as 90.2% for Naesung Stream, 86.7% for Yeong Stream, and 94.1% for Nakdong River. Finally, multiplying these q_p/q_t ratios to measured suspended load (Q_m), the total sediment load was estimated as below (Table 17).

Table 17: Total incoming sediment load for Sangju Weir basin

Sub-basin	Measured suspended load (Q_P, 10^3 tons/year)	q_p/q_t vs. Q relationship	Average q_p/q_t ratio (%)	Total sediment yield (Q_T , 10^3 tons/year)
Naesung Stream	214,673	q_p/q_t = 0.05 lnQ + 0.62	90.2%	237,912
Yeong Stream	44,402	q_p/q_t = 0.09 lnQ + 0.36	86.8%	51,143
Nakdong River	128,155	q_p/q_t = 0.02 lnQ + 0.80	94.1%	136,155
Total	387,230		91.1%	425,210

4.6 TRAP EFFICIENCY OF SANGJU WEIR

To calculate trap efficiency, three components: (1) surface area; (2) discharge; and (3) fall velocity are required (Eq. 456, Figure 43 and Figure 51).

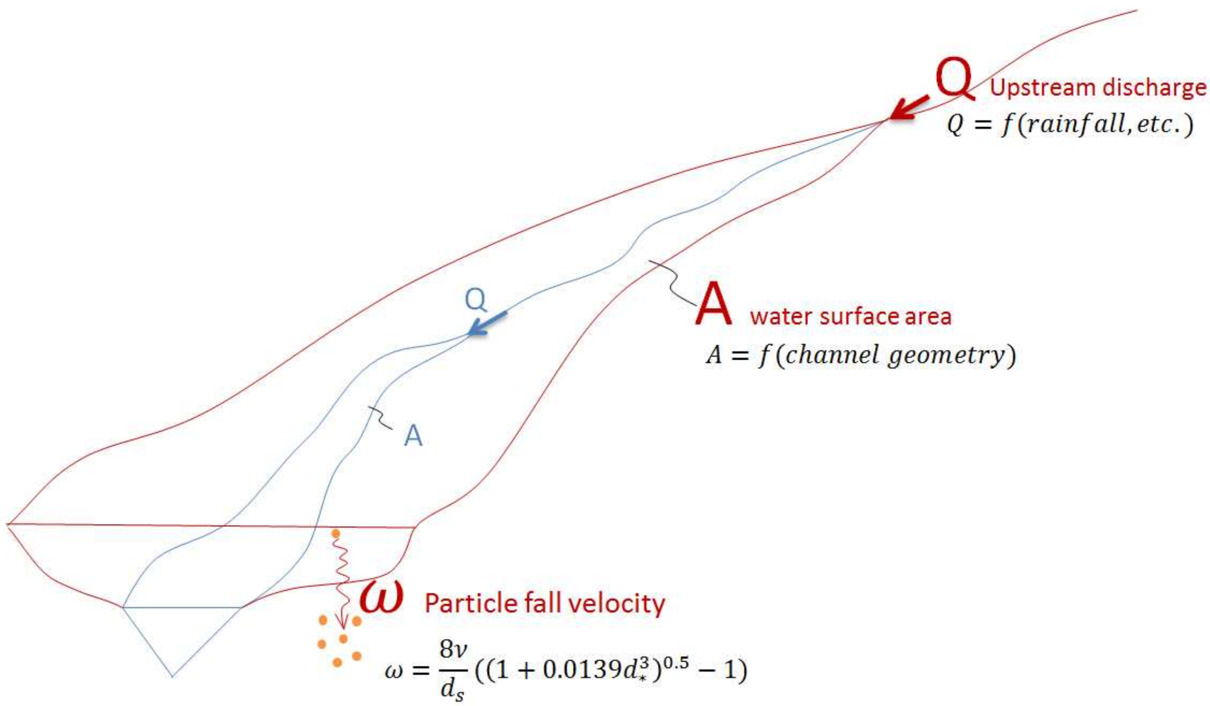


Figure 51: Concept diagram of trap efficiency

$$T_E = 1 - \exp\left(-\frac{\omega A}{Q}\right) \tag{46}$$

where T_E = trap efficiency,

ω = particle fall velocity (m/s),

A = water surface area (m^2),

Q = discharge (m^3/s)

4.6.1 Water surface area (A)

The reservoir surface area as a function of water stage was estimated by the cross-sectional survey data from weir construction and the Nakdong river improvement plan (Saman Corp. & Isan Corp., 2013). The volume was estimated by combining all cross sections (Figure 52) located upstream of Sangju Weir, which was varied according to changing water stages. The surface and capacity curve is presented in Table 18 and Figure 53.

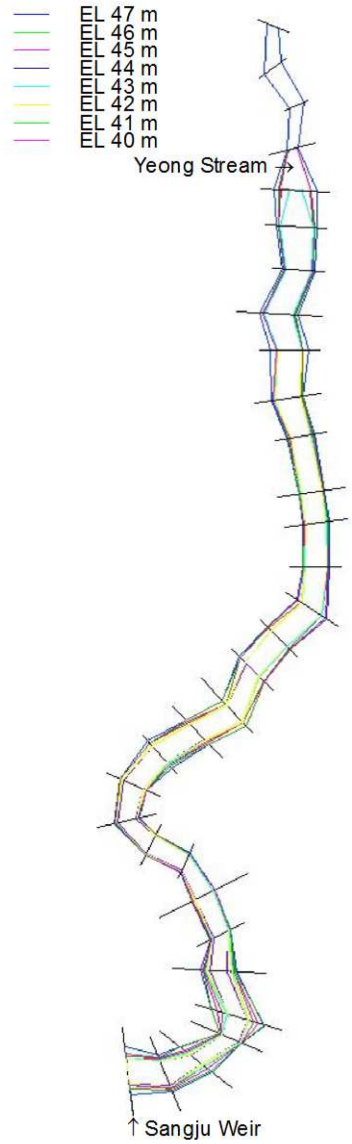


Figure 52: Surface area according to stages and cross sections upstream of Sangju Weir

Table 18: Surface area according to different water stages

Stage (EL.m)	Area (m^2)	Volume (m^3)
47.0	5,417,615	26,081,987
46.5	5,047,975	23,465,589
46.0	4,678,335	21,034,012
45.5	4,506,393	18,737,830
45.0	4,334,451	16,527,619
44.5	4,119,568	14,414,114
44.0	3,904,686	12,408,051
43.5	3,720,473	10,501,761
43.0	3,536,260	8,687,578
42.5	3,169,206	7,011,211
42.0	2,802,151	5,518,372
41.5	2,370,114	4,225,306
41.0	1,938,077	3,148,258
40.5	1,778,556	2,219,100
40.0	1,619,034	1,369,703
39.5	1,331,971	927,052
39.0	1,044,908	570,520
38.5	757,846	300,107
38.0	470,783	115,813
37.2	-	-

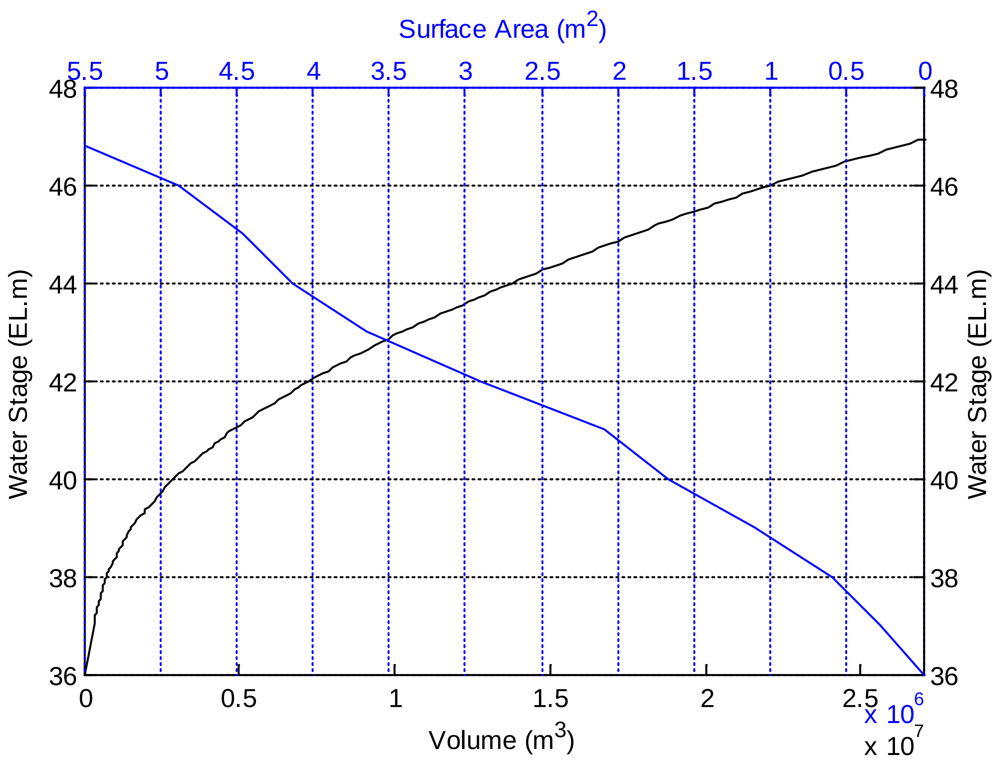


Figure 53: Area and capacity curve of Sangju Weir

4.6.2 *Fall velocity* (ω)

Fall velocity is the function of grain size, kinematic viscosity, and dimensionless grain size as below:

$$\omega = \frac{8\nu}{d_s}\left[(1 + 0.0139\, d_*^3\,)^{0.5} - 1\right] \tag{47}$$

$$d_* = d_s\left[\frac{(G-1)g}{\nu^2}\right]^{\frac{1}{3}} \tag{48}$$

where ω = fall velocity (m/s),

d_* = dimension less grain size,

ν = kinematic viscosity (1 x 10^{-6} m^2/s at 20 ^oC).

Table 19: Fall velocity calculation for various particle sizes

Lower limit of Grain Size Class	ds (mm)	ds (m)	d_*	ω(m/s)
Small Cobble	64	0.064	1,619	0.960
Very Coarse Gravel	32	0.032	809	0.679
Coarse Gravel	16	0.016	405	0.479
Medium Gravel	8	0.008	202	0.338
Fine Gravel	4	0.004	101	0.238
Very Fine Gravel	2	0.002	51	0.166
Very Coarse Sand	1	0.001	25	0.112
Coarse Sand	0.5	0.0005	13	0.070
Medium Sand	0.25	0.00025	6	0.036
Fine Sand	0.125	0.000125	3	0.013
Very Fine Sand	0.0625	0.0000625	2	0.003
Coarse Silt	0.031	0.000031	1	0.001
Medium Silt	0.016	0.000016	0	0.000
Fine Silt	0.008	0.000008	0	0.000
Very Fine Silt	0.004	0.000004	0	0.000
Coarse Clay	0.002	0.000002	0	0.000
Medium Clay	0.001	0.000001	0	0.000
Fine Clay	0.0005	0.0000005	0	0.000
Very Fine Clay	0.00024	0.00000024	0	0.000

4.6.3 Discharge (Q)

The stream flows for three sub-basins were represented by simulated discharge described previously in Section 4.1.

4.6.4 Trap efficiency (T_E)

Trap efficiency was calculated using fall velocity, surface area, and discharge. With increases in inflow, the trap efficiency curves move to the left in Figure 54. Trap efficiency curves show significant variation in trap efficiency with water stage. Trap efficiency curves for the lowest water stage are shown in gray on Figure 54.

Figure 55-Figure 57 and Figure 104- Figure 106 (see Appendix B) show trap efficiency curves with respect to various discharges with EL. 47.0 m and EL. 37.2 m of water stage at Sangju Weir. The curves of suspended particle size distribution, and bed-material distribution are also presented in the same Figures.

Average trap efficiencies were calculated by analyzing suspended particle size distribution at 10% increments and corresponding discharges were read from trap efficiency curves (see green line and red square marks in figures) and table in the lower right corner of Figure 55-Figure 57 and Figure 104 - Figure 106 (see Appendix B).

The results also show that most of the sediment load comes from high flow discharge. Column (10) denotes averaged trap efficiencies at Sangju Weir according to various discharges. The sediment yield at the mouth of Naesung Stream will be trapped at Sangju Weir with different rates as shown at column (11) (Table 20 - Table 21 and Table 30-Table 33 (see Appendix B)

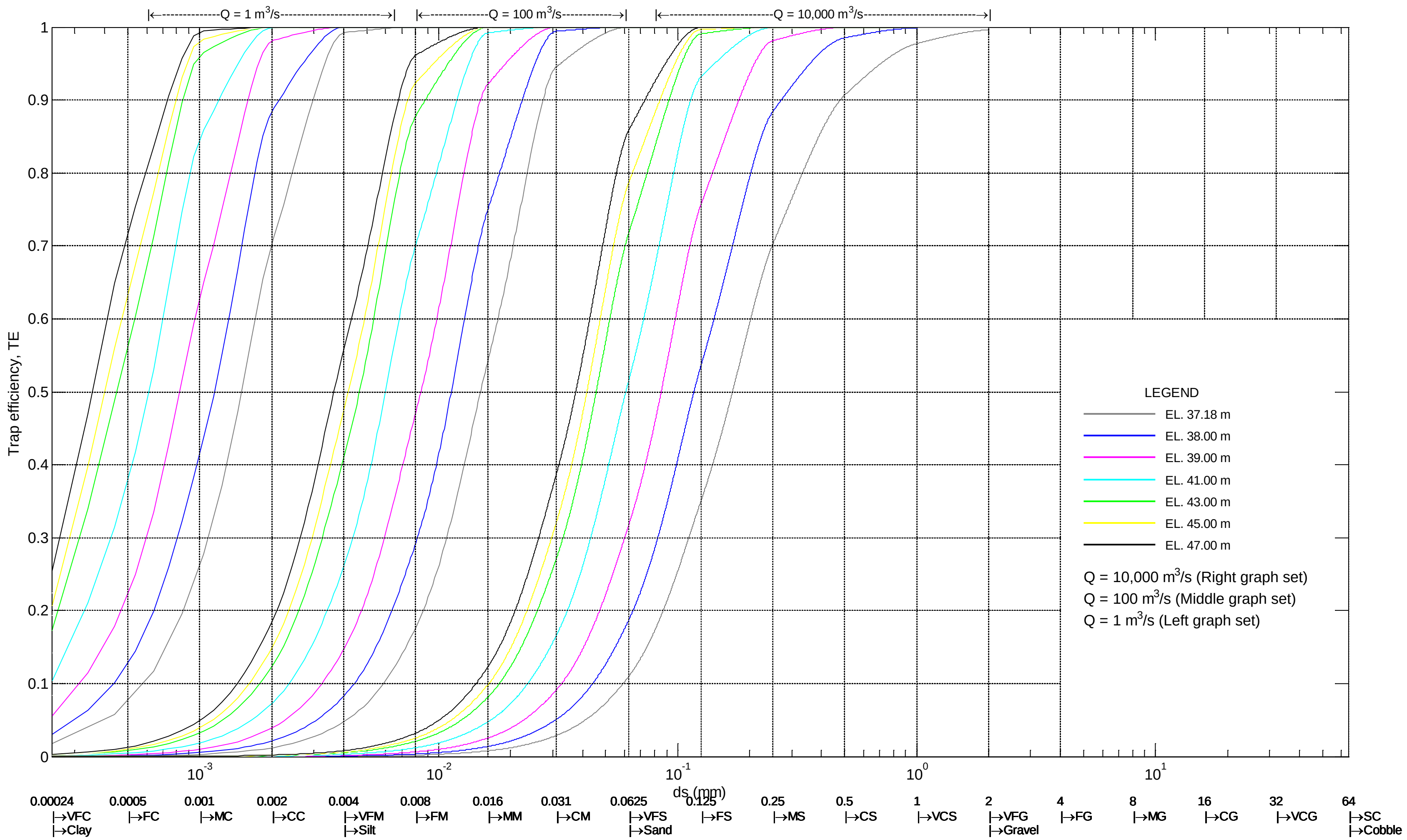


Figure 54: Trap efficiency curves under various discharge (Q) and stages (El. m)

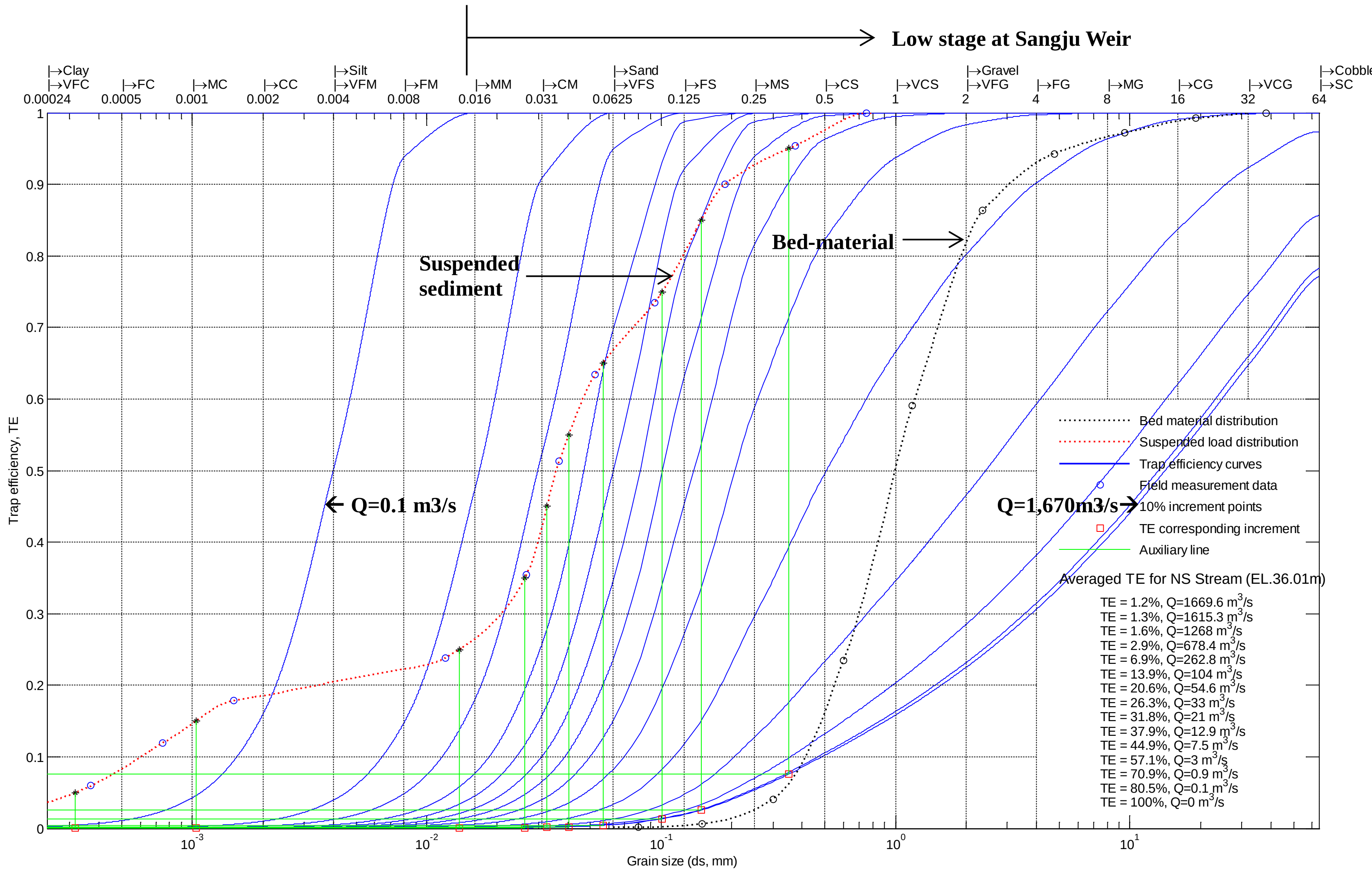


Figure 55: Trap efficiency curve with respect to various discharges when EL36.0m

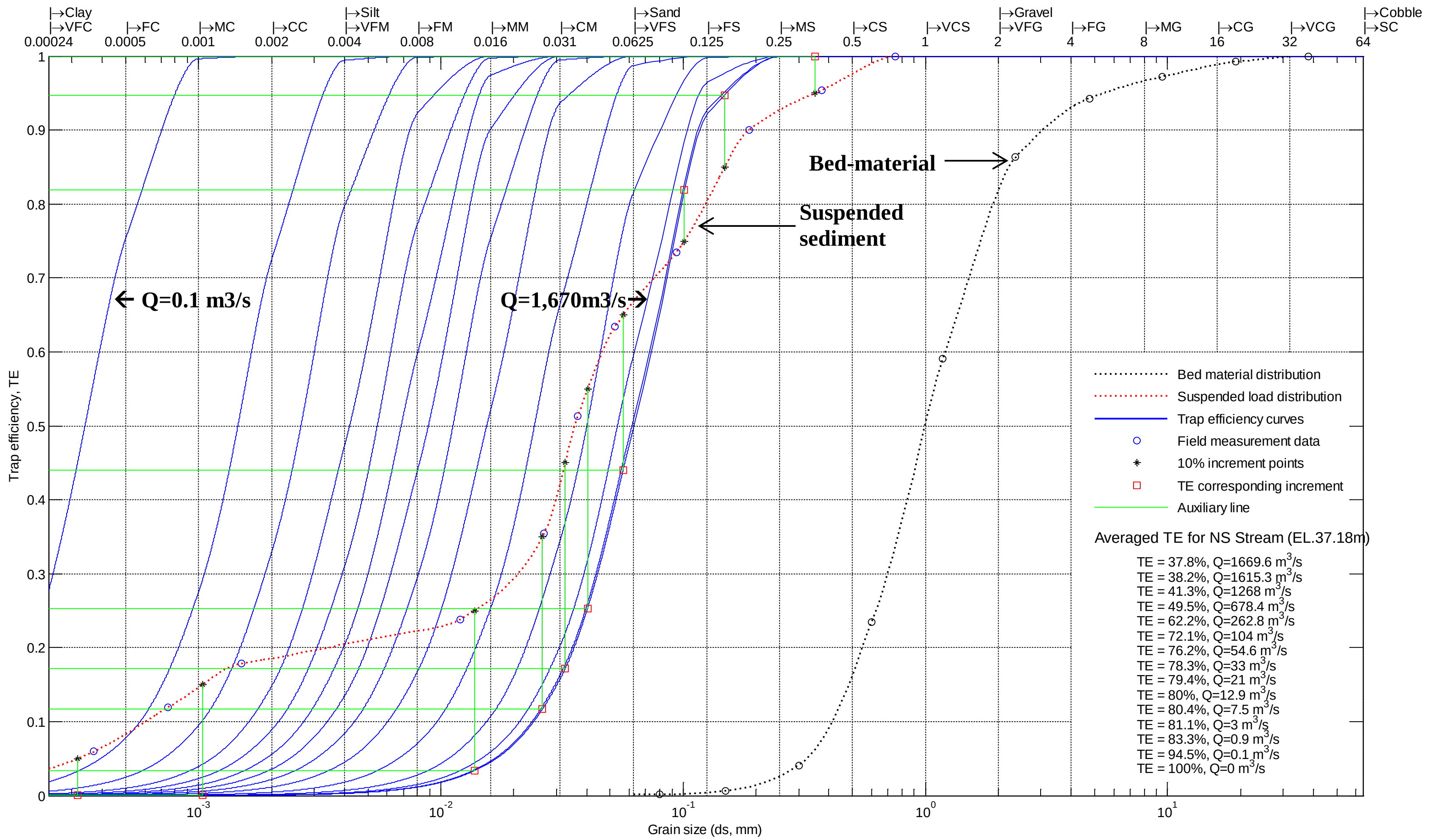


Figure 56: Trap efficiency curve with respect to various discharges when EL37.18m, suspended load, and bed-material distribution curves for Naesung Stream

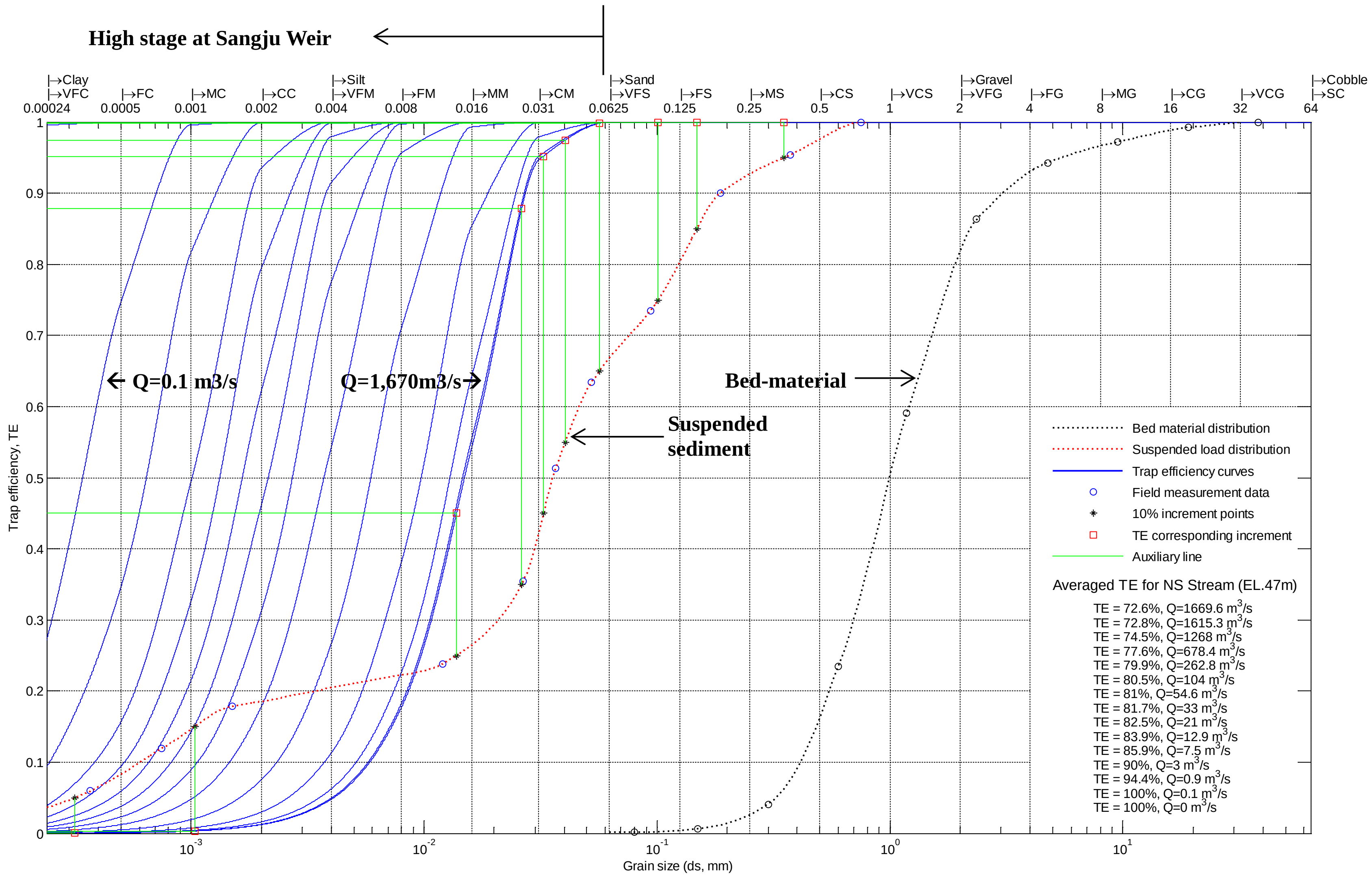


Figure 57: Trap efficiency curve with respect to various discharges when EL47 m, suspended load, and bed-material distribution curves for Naesung Stream

Table 20: Long-term sediment yield for Naesung Stream using flow-duration and sediment-rating curve method when the stage is EL. 37.2 m

Time intervals (%) (1)	Interval mid-point (%) (2)	Interval ΔP(%) (3)	Discharge Q (m^3/s) (4)	Concentration C (mg/L) (5)	Q × ΔP (6)	Sediment Load Qs× ΔP (tons/yr) (7)		q_p/q_t ratio (%) (8)	Sediment Load Qs × ΔP (tons/yr) (9)		Average T_E (%) (10)	Qs×T_E (tons/yr) (11)=(9)*(10)	
0 ~ 0.02	0.01	0.02	1,670	355	0.3	3,361	2%	97.7%	3,440	1%	37.8	1,300	1%
0.02 ~ 0.1	0.06	0.08	1,615	350	1.3	14,360	7%	97.5%	14,728	6%	38.2	5,626	4%
0.1 ~ 0.5	0.3	0.4	1,268	312	5.1	50,218	23%	96.3%	52,147	22%	41.3	21,537	16%
0.5 ~ 1.5	1	1	678	232	6.8	49,574	23%	93.3%	53,134	22%	49.5	26,301	20%
1.5 ~ 5	3.25	3.5	263	148	9.2	42,972	20%	88.8%	48,392	20%	62.2	30,100	22%
5 ~ 15	10	10	104	95	10.4	31,181	15%	84.3%	36,988	15%	72.1	26,668	20%
15 ~ 25	20	10	55	70	5.5	12,151	6%	81.2%	14,964	6%	76.2	11,403	9%
25 ~ 35	30	10	33	55	3.3	5,728	3%	78.8%	7,269	3%	78.3	5,692	4%
35 ~ 45	40	10	21	44	2.1	2,916	1%	76.6%	3,807	2%	79.4	3,023	2%
45 ~ 55	50	10	13	35	1.3	1,436	1%	74.3%	1,933	1%	80.0	1,546	1%
55 ~ 65	60	10	7	26	0.7	574	0%	71.3%	805	0%	80.4	647	1%
65 ~ 75	70	10	3	18	0.3	170	0%	67.2%	253	0%	81.1	205	0%
75 ~ 85	80	10	1	10	0.1	32	0%	61.9%	52	0%	83.3	43	0%
85 ~ 95	90	10	0	0	0.0	0	0%	50.8%	0	0%	94.5	0	0%
95 ~ 100	97.5	5	0	0	0.0	0	0%	50.8%	0	0%	00.0	0	0%
Total						214,673	100%	90.2%	237,912	100%	56.4%	134,091	100%

Table 21: Long-term sediment yield for Naesung Stream using flow-duration and sediment-rating curve method when the stage is EL. 47.0 m

Time intervals (%) (1)	Interval mid-point (%) (2)	Interval ΔP(%) (3)	Discharge Q (m^3/s) (4)	Concentration C (mg/L) (5)	Q × ΔP (6)	Sediment Load Qs× ΔP (tons/yr) (7)		q_p/q_t ratio (%) (8)	Sediment Load Qs × ΔP (tons/yr) (9)		Average T_E (%) (10)	Qs×T_E (tons/yr) (11)=(9)*(10)	
0 ~ 0.02	0.01	0.02	1,670	355	0.3	3,361	2%	97.7%	3,440	1%	72.6	2,497	1%
0.02 ~ 0.1	0.06	0.08	1,615	350	1.3	14,360	7%	97.5%	14,728	6%	72.8	10,722	6%
0.1 ~ 0.5	0.3	0.4	1,268	312	5.1	50,218	23%	96.3%	52,147	22%	74.5	38,850	21%
0.5 ~ 1.5	1	1	678	232	6.8	49,574	23%	93.3%	53,134	22%	77.6	41,232	22%
1.5 ~ 5	3.25	3.5	263	148	9.2	42,972	20%	88.8%	48,392	20%	79.9	38,665	21%
5 ~ 15	10	10	104	95	10.4	31,181	15%	84.3%	36,988	15%	80.5	29,775	16%
15 ~ 25	20	10	55	70	5.5	12,151	6%	81.2%	14,964	6%	81.0	12,121	7%
25 ~ 35	30	10	33	55	3.3	5,728	3%	78.8%	7,269	3%	81.7	5,939	3%
35 ~ 45	40	10	21	44	2.1	2,916	1%	76.6%	3,807	2%	82.5	3,141	2%
45 ~ 55	50	10	13	35	1.3	1,436	1%	74.3%	1,933	1%	83.9	1,622	1%
55 ~ 65	60	10	7	26	0.7	574	0%	71.3%	805	0%	85.9	691	0%
65 ~ 75	70	10	3	18	0.3	170	0%	67.2%	253	0%	90.0	228	0%
75 ~ 85	80	10	1	10	0.1	32	0%	61.9%	52	0%	94.4	49	0%
85 ~ 95	90	10	0	0	0.0	0	0%	50.8%	0	0%	100.0	0	0%
95 ~ 100	97.5	5	0	0	0.0	0	0%	50.8%	0	0%	100.0	0	0%
Total						214,673	100%	90.2%	237,912	100%	78.0%	185,532	100%

4.7 RESERVOIR SEDIMENTATION RATE

Since reservoir sedimentation is varied according to trap efficiency of Sangju Weir, two extreme cases were examined to figure out the differences among highest (EL 47 m: management water stage) and lowest condition (EL 37.2 m: overflow height when the gates is fully opened). The total sediment load was estimated as 425,000 tons/year. Deposition ratio, however, has a significant difference owing to the management water stage at Sangju Weir. The trap efficiency varies from 50.1 % to 78.1 % according to the stage. Thus, the amount of reservoir sedimentation and reservoir filling rate also has shown different values as 0.76% and 0.49%, respectively.

Table 22 presents the summary of all computations from this chapter, including measured sediment load, total load, trap efficiency, reservoir sedimentation and reservoir filling rate with sediment, when the mangement stages are EL 47.0m, and EL 37.2m, respectively.

Table 22: The summary of sediment yield when the management stage is El. 47.0 m

<table>
<tr><th rowspan="2">Sub-basin</th><th rowspan="2">Measured load ,Q_P, (10^3t/yr)</th><th rowspan="2">q_P/q_t ratio (%)</th><th rowspan="2">Total load, Q_T (10^3t/yr)</th><th colspan="4">High stage (EL. 47.0m)</th><th colspan="4">Low stage (EL. 37.2m)</th></tr>
<tr><th>T_E (%)</th><th>Res. Sed. in ton (10^3t/yr)</th><th>Res. Sed. in vol.* (10^3m^3/yr)</th><th>Res. filling rate** (%)</th><th>T_E (%)</th><th>Res. Sed. in ton (10^3t/yr)</th><th>Res. Sed. in vol.* (10^3m^3/yr)</th><th>Res. filling rate** (%)</th></tr>
<tr><td>Naesung</td><td>215</td><td>90%</td><td>238</td><td>78.0%</td><td>186</td><td>116</td><td rowspan="4">0.76%</td><td>56.4%</td><td>134</td><td>84</td><td rowspan="4">0.49%</td></tr>
<tr><td>Yeong</td><td>44</td><td>87%</td><td>51</td><td>86.2%</td><td>44</td><td>27</td><td>49.9%</td><td>26</td><td>16</td></tr>
<tr><td>Nakdong</td><td>128</td><td>94%</td><td>136</td><td>75.3%</td><td>102</td><td>64</td><td>39.1%</td><td>53</td><td>33</td></tr>
<tr><td>Total</td><td>387</td><td>91%</td><td>425</td><td>78.1%</td><td>332</td><td>207</td><td>50.1%</td><td>213</td><td>133</td></tr>
</table>

Note:
* Res. Sed. in vol. is the Reservoir sedimentation in volume m^3/year calculated by dividing Res. Sed. in ton (tons/yr) into unit weight of sand (1.6 ton/m^3).
** Res. Filling rate is the annual rate of reservoir sedimentation calculated by dividing summation of Res. Sed. in vol. into total reservoir volume (27.4 mil. m^3)

5 CHAPTER V – BENEFIT AND COST ANALYSIS

A two-year daily simulation was performed to find out the threshold to balance hydropower revenue and excavation cost using a Benefit and Cost Analysis (BCA). A BCA is a systematic approach to estimating the strengths and weaknesses of alternatives that satisfy activities or functional requirements for a business. In this case, a BCA is used to diagnose the current condition and determine a threshold of discharge affecting sediment deposition. Only two variables from many possible, excavation cost and hydropower revenues, were selected for simulation because they are the main variables. Figure 58 presents the BCA process.

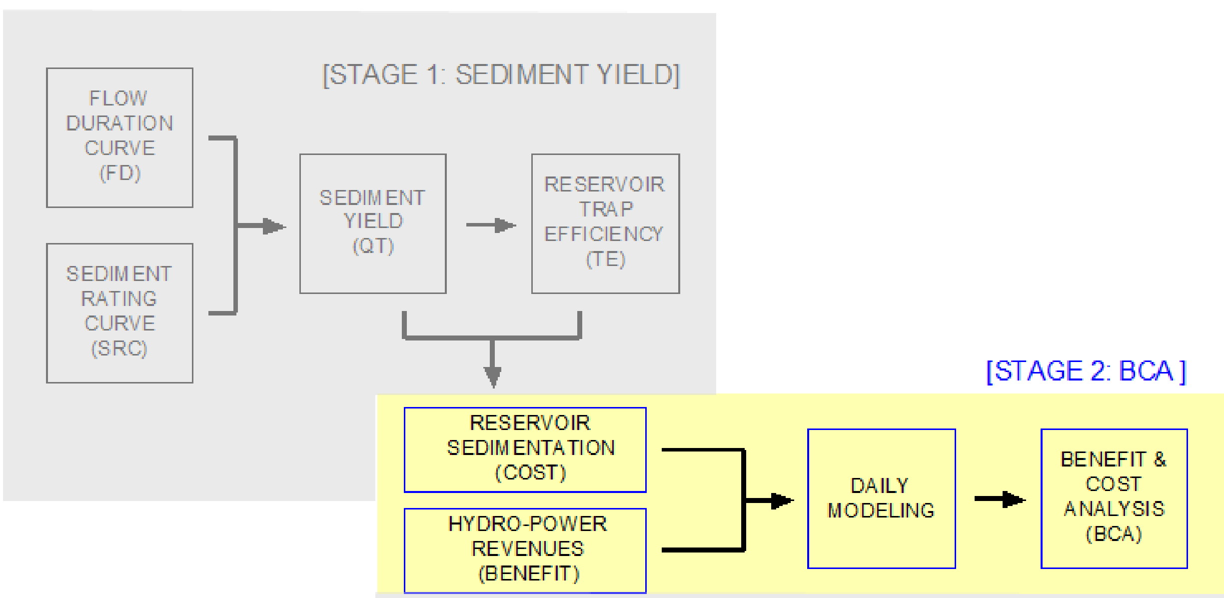
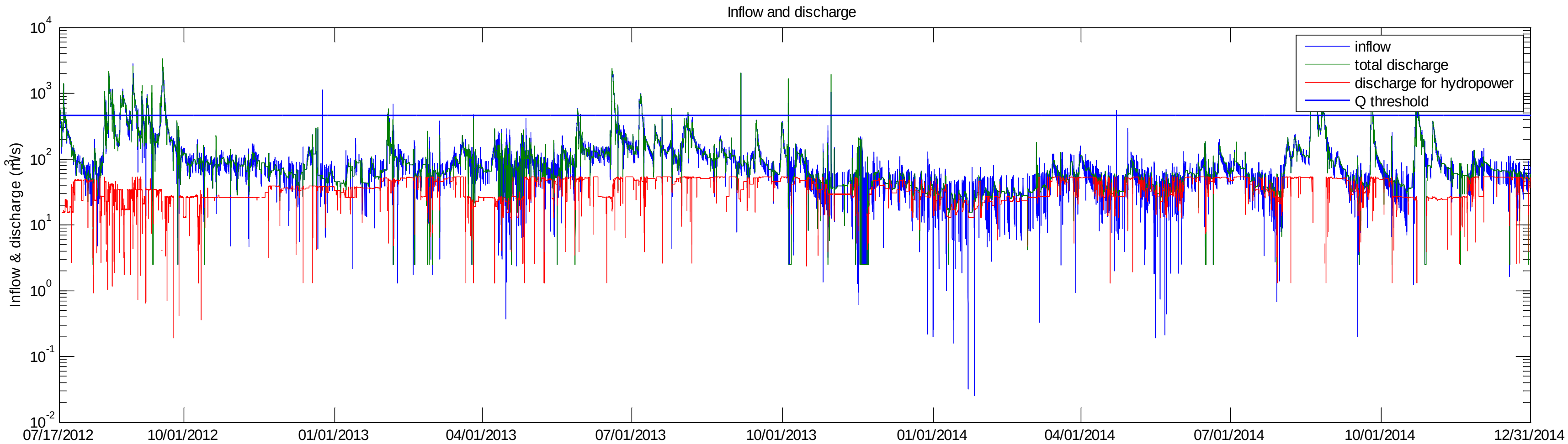


Figure 58: A Benefit and Cost Analysis process



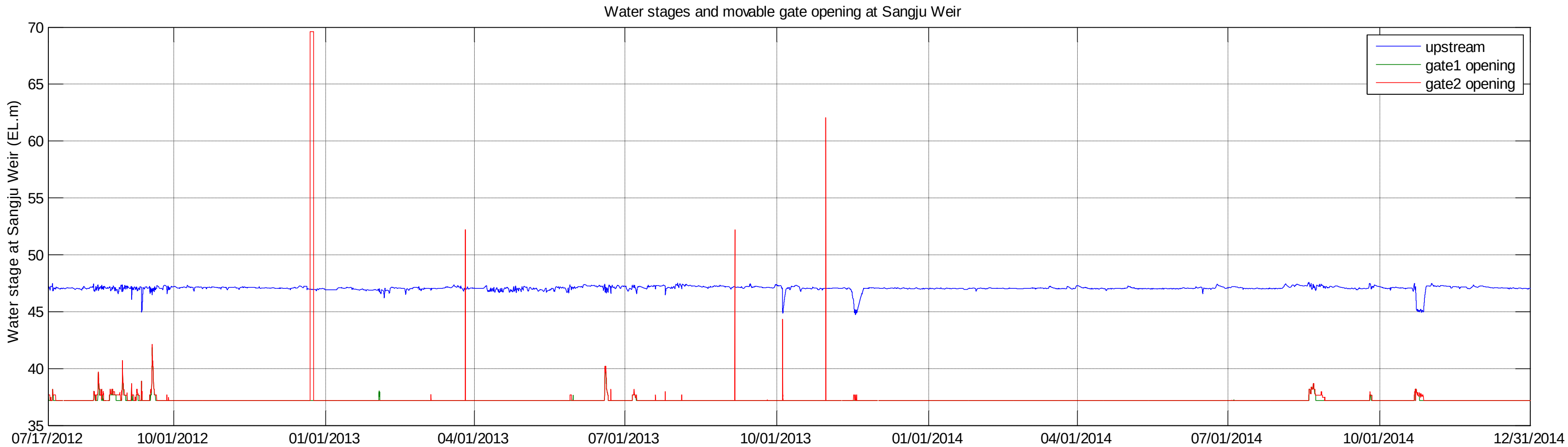


Figure 59: Discharge and threshold, many discharge values exceed the threshold which means increasing dredging cost with times, whereas hydropower production is almost constant because required discharges (red line on Figure) for the hydropower plant are less than normal discharge

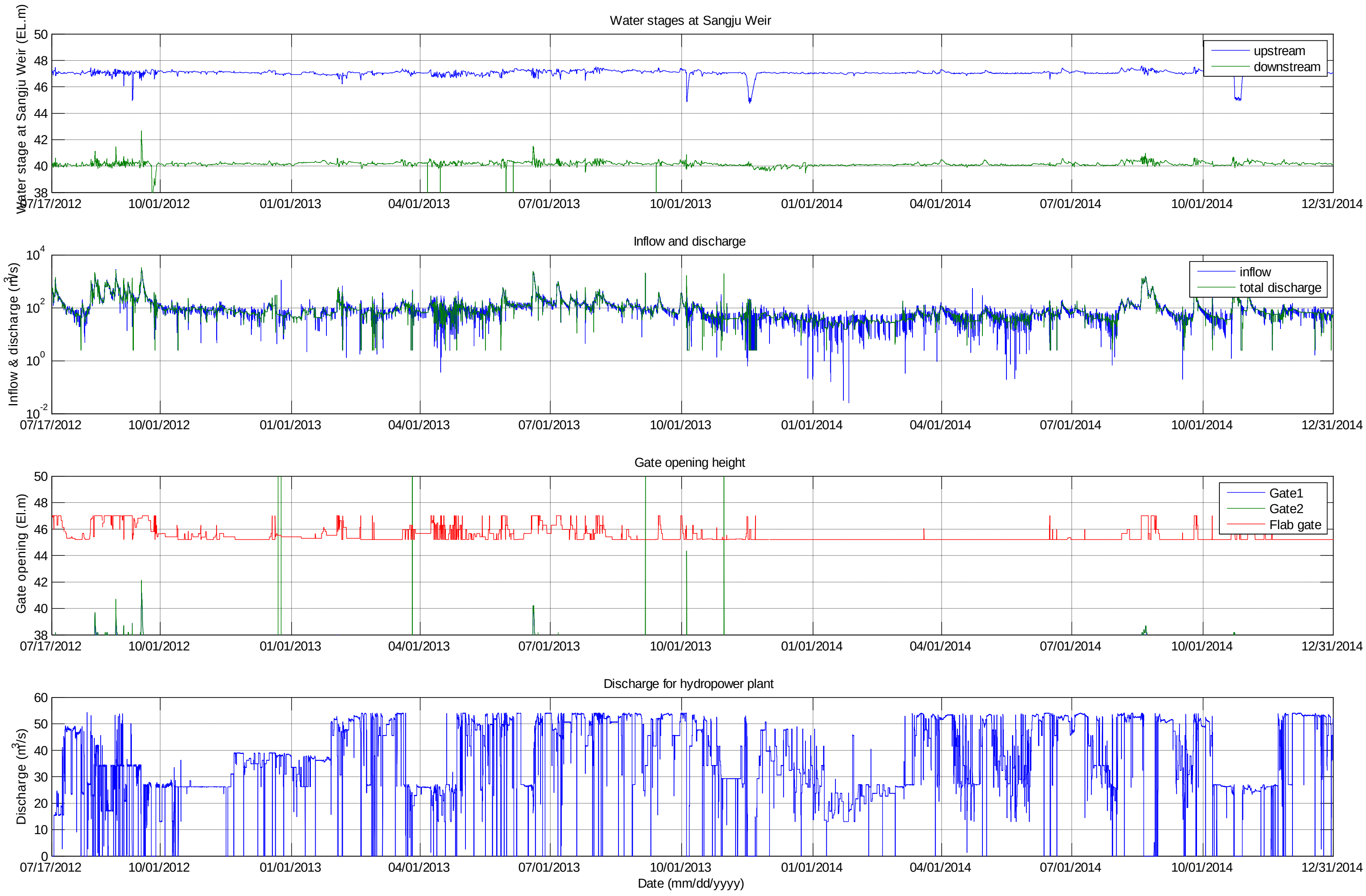


Figure 60: Historical operation records, although relatively high inflows occur, water stages were kept high, which leads to deposition of much sediment in the reservoir. In addition, the flap gate was operated very frequently.

5.1 HISTORICAL RECORD

Sangju Weir began to operate in July 2012. The 10-minute operational data from January 1st, 2013 to Dec. 31st, 2014 were collected to validate the data generated by surface runoff modeling for a Benefit and Cost Analysis (BCA). The records include water stage, total release, discharges for hydropower generation, and gate opening. Figure 59 and Figure 60 show the historical water stage, discharge, and gate opening.

5.2 HYDRO POWER GENERATION REVENUE

The amount of hydropower production depends on water discharge, head, and operating periods as below:

$$\mathrm{P_i}\ (kW) = 9.81\ \eta\ Q_a\ H_a \qquad (49)$$

Where, $\mathrm{P_i}$ = capacity (kW)

η = overall efficiency of power plant

Q_a = discharge for generation (m^3/s)

H_a = effective head (m)

The hydropower generation capacity of Sangju Weir is 3,000 kW and annual mean hydropower production was estimated to be 15,931 MWh (Korea Engineering Consultants Corp., 2009).

To reach annual hydropower production, the generator has to run 221 days in a year, which will require high water stage at Sanju Weir. If the head, H_a, is lower than 4.07 m, the generator will be stopped due to the low head.

According to historical power generation and sales, unit cost of sales for hydropower generation was estimated as 0.13 USD per kWh (Table 23).

Table 23: Hydropower generation and benefit for sales (Jan. 1st, 2014 - Jun. 25th, 2014) (K-water, 2014).

Station (Weir)	Production and benefit			Unit cost of sales	
	kWh	benefit(KRW)	benefit(USD)	KRW	USD
Ipo	8,860,334	1,300,789,226	1,182,536	146.81	0.13
Yeoju	15,357,166	2,254,892,048	2,049,902	146.83	0.13
Gangcheon	13,578,798	1,999,770,772	1,817,973	147.27	0.13
ChangnyeongHaman	12,477,036	1,835,708,000	1,668,825	147.13	0.13
HapcheonChangnyeong	11,071,818	1,635,389,829	1,486,718	147.71	0.13
Dalseong	6,256,469	927,271,216	842,974	148.21	0.13
GangjeongGoryeong	5,555,653	819,125,677	744,660	147.44	0.13
Chilgok	7,911,156	1,167,732,722	1,061,575	147.61	0.13
Gumi	7,508,179	1,109,538,905	1,008,672	147.78	0.13
Nakdan	8,172,434	1,200,586,255	1,091,442	146.91	0.13
Sangju	8,003,863	1,179,135,245	1,071,941	147.32	0.13
Baekje	3,920,442	571,326,278	519,388	145.73	0.13
Gongju	5,918,918	863,089,717	784,627	145.82	0.13
Sejong	4,033,143	583,418,450	530,380	144.66	0.13
Juksan	2,342,777	344,276,886	312,979	146.95	0.13
Seugchon	1,256,290	184,103,565	167,367	146.55	0.13
Total	122,224,476	17,976,154,791	16,341,959	147.07	0.13

Note: 1 USD = 1,100 KRW

5.3 DREDGING COST

K-water has excavated the bottom of the Nakdong River Estuary Barrage reservoir from 1990 to 2010. According to the records excavation cost for unit volume is calculated as 6.31 USD/m^3 (Table 2).

5.4 DIAGNOSING CURRENT CONDITION

Using historical (2013-2014) and predicted (2015-2034) data, keeping the historical pattern for water stages, hydropower production benefit and excavation cost, and B/C ratio were calculated as shown in Table 24.

Based on this result, hydropower production profit is higher than the cost of sediment dredging. However, the B/C ratio can change as time goes by, because dredging cost is much higher than hydropower generation revenue and because the current operation rule has been problematic with reservoir sedimentation.

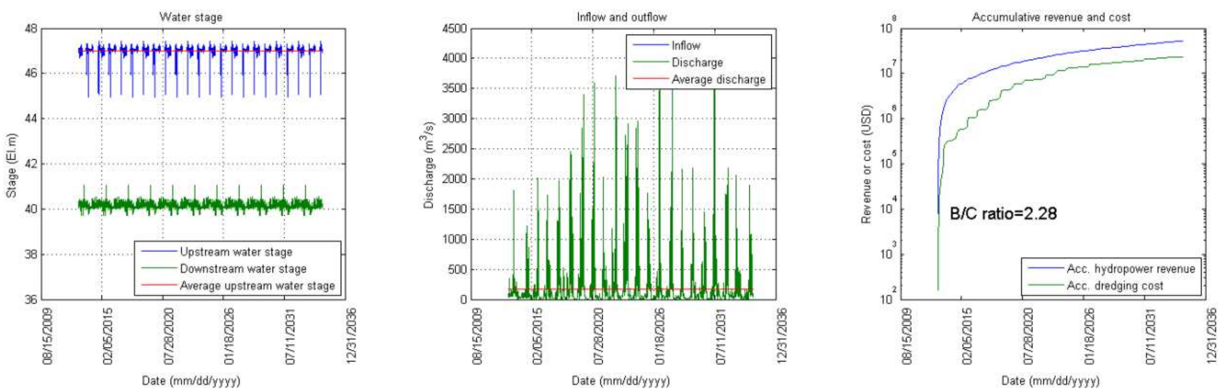


Figure 61: Modeling conditions (water stages and discharges) and B/C ratio for diagnosing when keeping the current operation rule

Table 24: Daily modeling result for historical data

Avg.P (kW)	HP (GWh)	Revenue (mil. USD)	Q_T (mil. tons)	avg.T_E	Dep. (mil. tons)	Dep. (mil m^3)	Cost (mil USD)	B/C ratio
2,106	407	52.8	7.4	80%	5.9	3.7	23.2	2.28

5.5 THRESHOLDS

Using historical and predicted operational data, thresholds with respect to water stage and discharge were estimated, which are balancing hydropower production revenue and excavation cost. Thresholds of discharge and water stage corresponding to a B/C ratio equal to 1 were calculated as 600 m^3/s and EL 43.6 m, respectively.

5.5.1 Discharge threshold

Through daily modeling with the current operational condition, maximizing water stage regardless of season, hydropower revenues and sediment excavation costs were generated. The discharge threshold that balances revenues and costs was graphically found as 620 m^3/s.

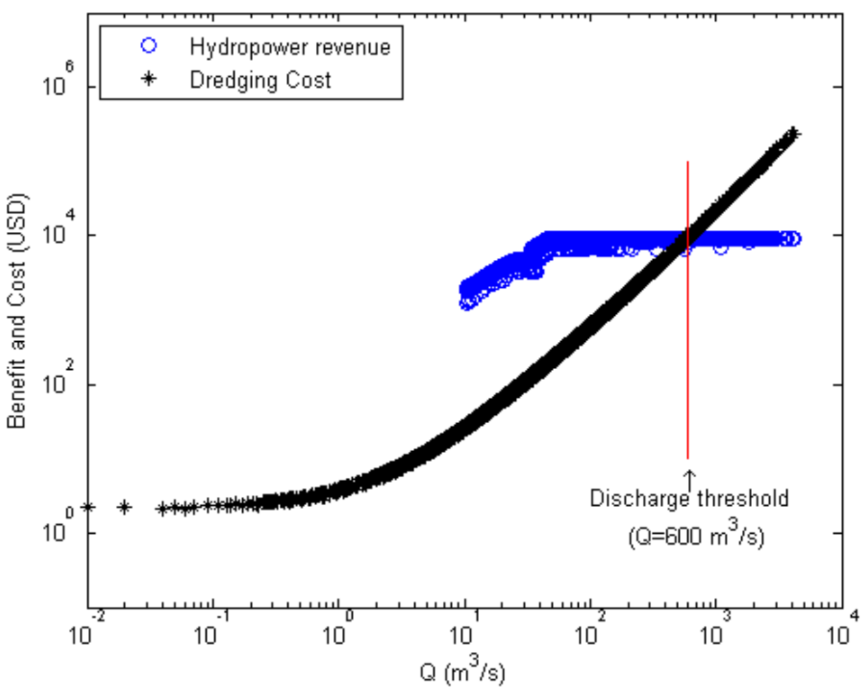


Figure 62: Finding discharge threshold

Figure 62 shows how to get the discharge threshold graphically. Hydropower production revenue and dredging cost depend on stream flow at Sangju Weir. As the flow rate increases, excavation cost increases proportionally, whereas hydropower generation revenue has a constant value after approximately 54 m^3/s.

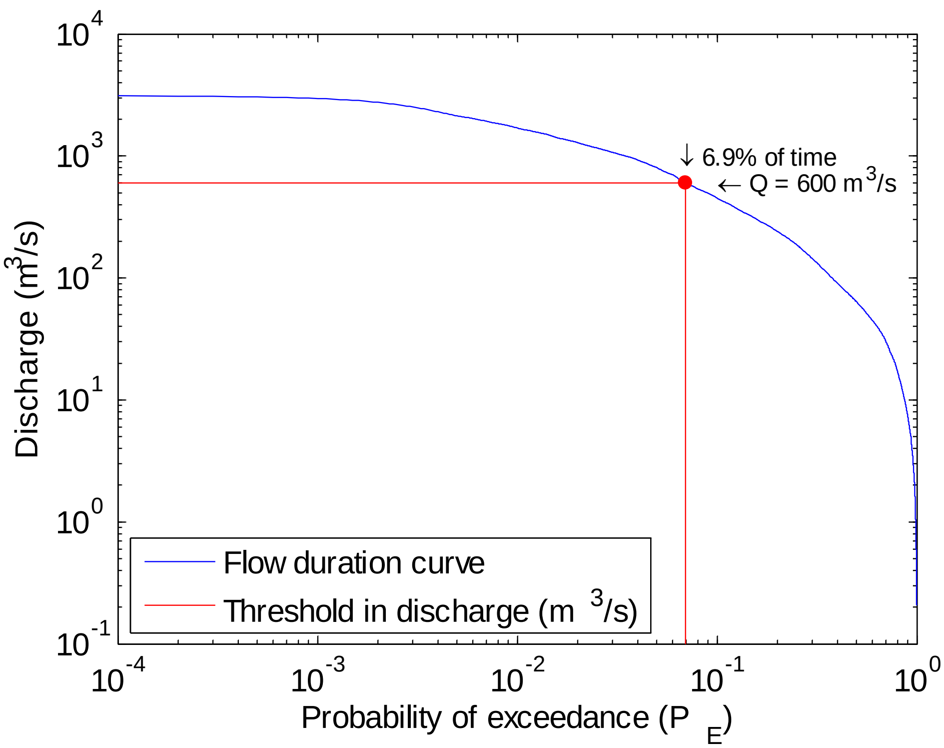


Figure 63: Sangju Weir flow-duration curve and discharge threshold

The discharge threshold for a B/C ratio equal to 1 was exceeded 6.9% of the time in the Sangju Weir flow duration curve for the analysis period (Figure 63). The discharges exceeding only 6.9% of the time cause tremendous excavation costs.

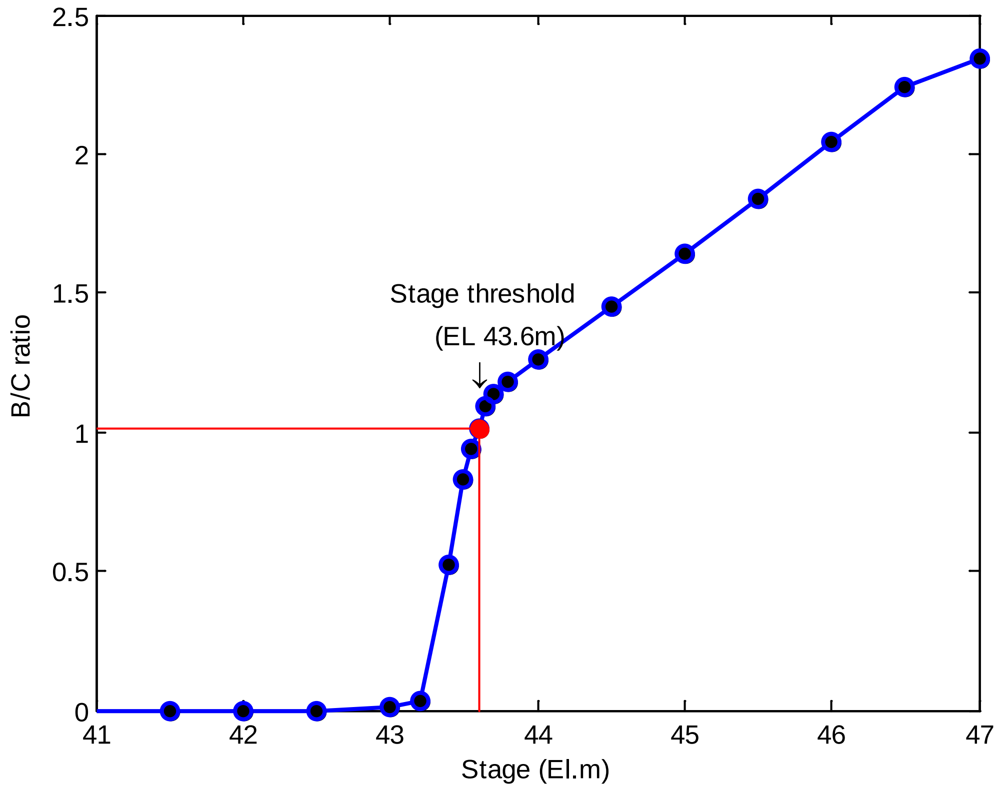


Figure 64: Estimation of water stage threshold

5.5.2 Water stage threshold

After daily modeling with fixed water stage for a range of stages (EL 37.2m-EL 47.0m), B/C ratios were calculated for every stage. The simulation results are shown in Figure 64 and Table 25. Demonstrated that the threshold water stage at Sangju Weir should be EL43.6m. It means that the water stage should be kept above this threshold level when the flow discharges below the discharge threshold. During floods, the operational stage at Sangju Weir should be kept as low as possible.

Table 25: Water stage threshold in view of sedimentation and hydropower production

Stage (El.m) (1)	HP (kW) (2)	HP production (kWh) (3)	Benefit (USD) (4)	Sediment Yield (tons) (5)	Trap efficiency (6)	Sediment Deposition (tons) (7)	Sediment Deposition (m^3) (8)	Cost (USD) (9)	BC ratio (10)
43.00	5	940,226	122,229	7,188,417	0.770	5,537,209	3,460,756	21,837,369	0.01
43.20	30	5,702,664	741,346	7,188,417	0.772	5,551,957	3,469,973	21,895,531	0.03
43.40	454	87,552,519	11,381,827	7,188,417	0.774	5,565,006	3,478,129	21,946,992	0.52
43.50	727	140,120,469	18,215,661	7,188,417	0.775	5,570,980	3,481,863	21,970,554	0.83
43.55	821	158,362,989	20,587,189	7,188,417	0.775	5,573,844	3,483,652	21,981,847	0.94
43.60	889	171,416,365	22,284,127	7,188,417	0.776	5,576,630	3,485,394	21,992,833	1.01
43.65	957	184,638,640	24,003,023	7,188,417	0.776	5,579,341	3,487,088	22,003,527	1.09
43.70	999	192,699,302	25,050,909	7,188,417	0.777	5,581,982	3,488,739	22,013,941	1.14
43.80	1,039	200,357,372	26,046,458	7,188,417	0.777	5,587,063	3,491,915	22,033,982	1.18
44.00	1,108	213,716,523	27,783,148	7,188,417	0.779	5,596,512	3,497,820	22,071,244	1.26
44.50	1,281	247,103,806	32,123,495	7,188,417	0.781	5,615,490	3,509,681	22,146,090	1.45
45.00	1,457	280,939,598	36,522,148	7,188,417	0.784	5,632,928	3,520,580	22,214,858	1.64
45.50	1,636	315,458,375	41,009,589	7,188,417	0.786	5,651,751	3,532,345	22,289,094	1.84
46.00	1,822	351,279,251	45,666,303	7,188,417	0.789	5,673,584	3,545,990	22,375,196	2.04
46.50	2,011	387,835,316	50,418,591	7,188,417	0.794	5,706,797	3,566,748	22,506,181	2.24
47.00	2,117	408,150,113	53,059,515	7,188,417	0.798	5,738,610	3,586,631	22,631,642	2.34

Note: (2) $Pi = 9.81\, \eta\, Q_a\, H_a\ (kW)$;
(4) Hydropower generation revenue = Pi (3,000 kW) * operating hrs (24 hrs) * unit price (0.13 USD/kWh);
(9) Excavation Cost = Reservoir sedimentation * Excavation unit cost (6.61 USD/m^3);
(10) Benefit and cost ratio, B/C = Revenue / Cost.

6 CHAPTER VI – MULTI-CRITERION DECISION ANALYSIS (MCDA)

There are many criteria associated with various decision makers in reservoir operation. Accordingly, it is nearly impossible to establish reservoir operation rules that satisfy all decision makers.

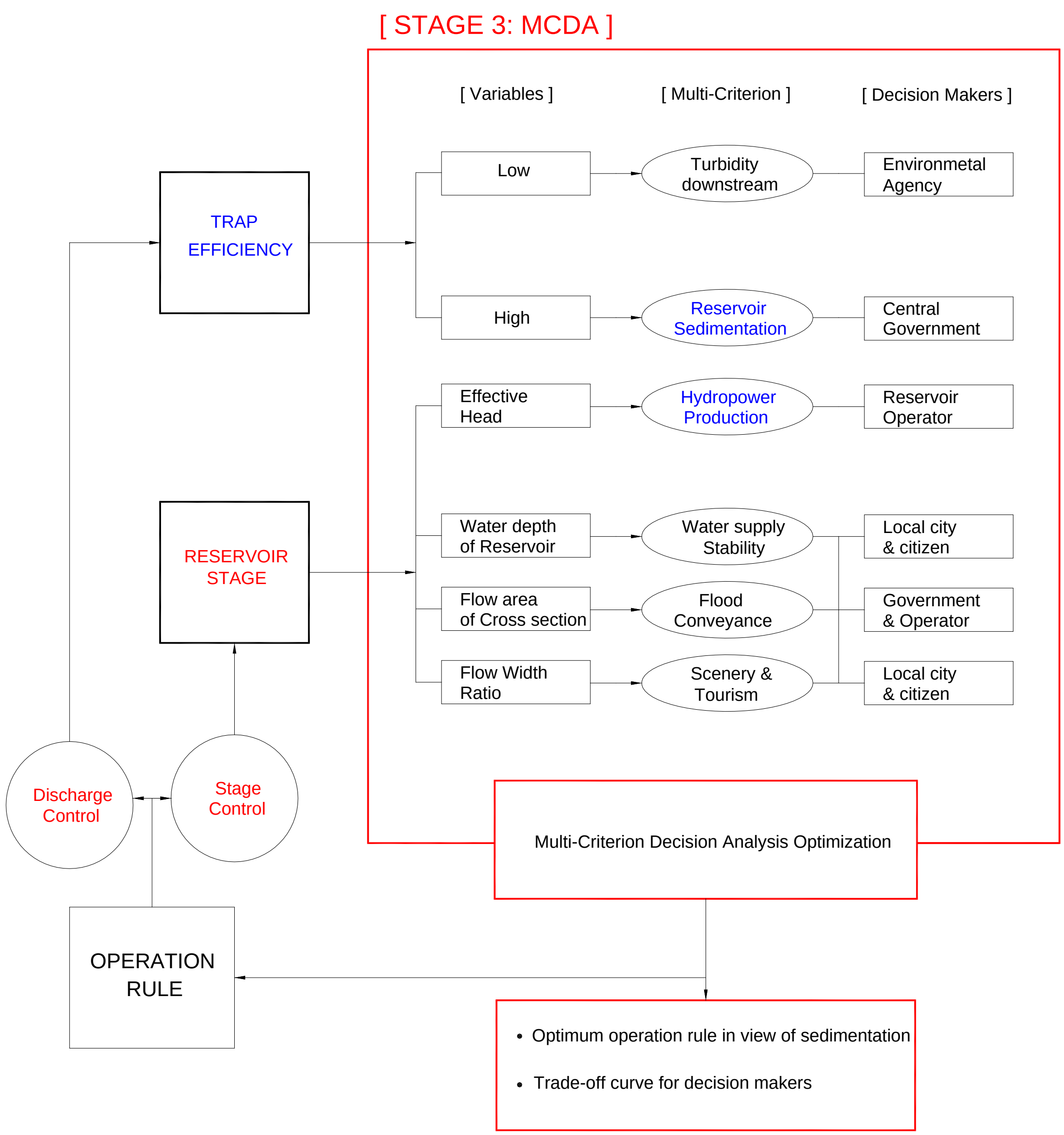


Figure 65: Criteria and decision makers entangled in reservoir operation

The current operation rules of Sangju Weir seem not to take consideration for the sediment issue, which could lead to a substantial sediment problem in the future, and problems for various decision makers' in regard to flood conveyance, hydropower generation, water supply from stored water in upstream, and others (Figure 65). Therefore, we need to introduce a multi-objective optimization technique to solve this problem. Since this case has many decision makers, the Multi-Criterion Decision Analysis (MCDA) technique is necessary to develop a 'best-case' operation rule for all parties.

6.1 DEFINITION AND CHARACTERISTICS OF MCDA

MCDA refers to decision making to choose the best alternative in situation where multiple criteria are conflicting. The greatest challenge is the trade-offs between conflicting criteria. Therefore, various analyses are required to make decisions in extensive and complex multi-criteria problems.

MCDA method has some advantages and characteristics as below:

- Systematic process for analyzing discrete decisions
- Based on the familiar concept of an overall score for an alternative
- Provides a way to document and audit decisions
- Iterative procedure that can easily be adapted to new information

According to the expression of Ackoff (1978), MCDA problems are complex, interconnected and disharmonious, i.e. having incompatible criteria. The role of MCDA is to identify and define the status of issues that could not be 'cleaned up', and presenting the problem itself clearly to decision makers. In conclusion, the core role of MCDA is helping the “Decision makers group” by providing the problem-solving process clearly based on a mathematic tool, not by solving the problem itself.

6.2 WHAT ARE THE CONFLICTS?

The amount of sediment in the reservoir depends on sediment load (Q_s) and trap efficiency (T_E) which vary according to water stage, particle fall velocity, and inflow rate. If there is small inflow and a high water stage condition, the trap efficiency reaches 100% and all sediment from upstream watersheds will be captured in the reservoir. For example, reservoir levels are kept high to provide more storage to mitigate drought conditions and to increase hydropower generation. However, this increases the risk of reservoir sedimentation and flooding if a wet period occurs. Figure 66 shows that there are many kinds of decision makers related to reservoir operation.

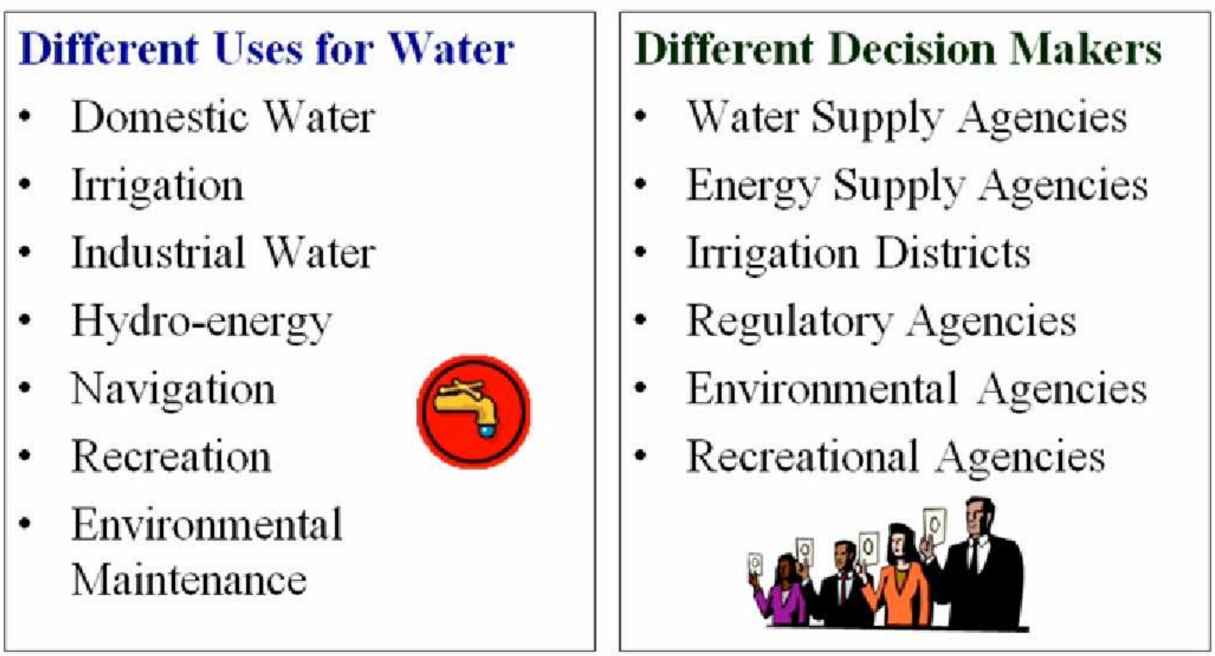


Figure 66: Reservoir operation conflicts (Fontane, 2014)

6.3 MCDA PROCEDURE

The systematic process is one of the characteristics of MCDA. In order to reach the conclusion, MCDA follows several steps. There are five steps in MCDA, used for this study analysis, listed below.

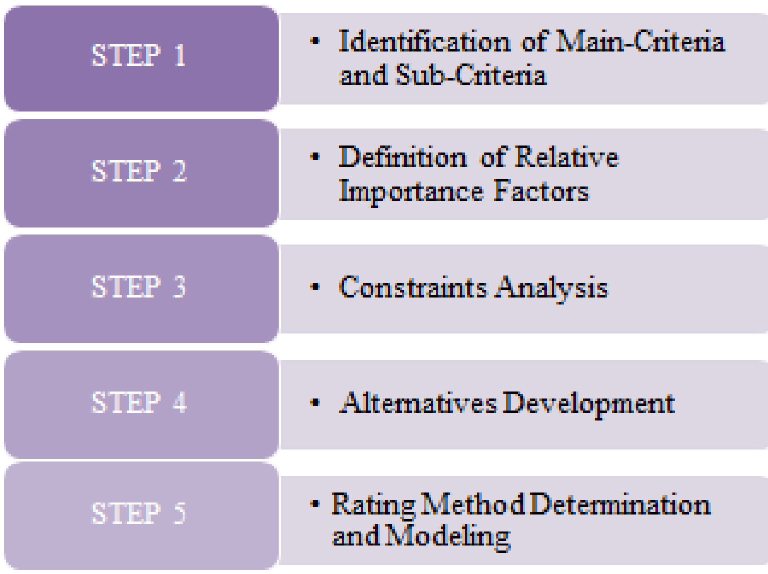


Figure 67: MCDA procedure

6.4 CRITERIA AND OBJECTIVE FUNCTION IDENTIFICATION

Criteria are the objectives or measures or metrics used to evaluated the performance of the potential alternatives. Five main criteria were selected for the decision making process of Sangju Weir operation: (1) Reservoir sedimentation, (2) hydropower energy production, (3) water supply stability, (4) flood protection and conveyance, and (5) environmental. Each of main criteria can have sub-criteria, which were selected to define metrics for the simulation. In this study, 14 sub-criteria were selected.

Table 26: Main and sub-criteria with relative importance factor

Main-Criteria (1)	RIF (2)	Sub-Criteria (3)	RIF (4)	Max/Min (5)	Function (6)
Reservoir sedimentation (Minimize)	4	Trap efficiency (T_E, %)	3	Min	$T_E = 1 - e^{-\frac{\omega A}{Q}}$
		Water Stage (WS, El.m)	1	Min	
		Water surface area (A, m^2)	2	Min	$A = f(stage)$
		Reservoir sedimentation (S_{dep}, m^3)	4	Min	$S_{dep} = S_y \times T_E$
Hydropower production (Maximize)	3	Stage difference (dH, m)	1	Max	
		Discharge for hydropower (Q_a, m^3/s)	1	Max	
		Hydropower production (HP, kWh)	4	Max	$P = 9.81 \times \eta \times Q_a \times H_a$
Water supply stability (Maximize)	3	Storage above intake facility ($V_{storage}$, m^3)	1	Max	
		Water supply stability	4	Max	$Stability = f(V_{storage})$
Flood protection (Maximize)	2	Empty space above water stage (V_{empty}, m^3)	2	Max	
		Available cross sectional area (A_{xs}, m^2)	2	Max	
		Flood control and drainage effect	4	Max	$Flood\ Effect = f(V_{empty}, A_{xs})$
Riverside environment and stream ecology	1	Turbidity downstream (T, NTU)	4	Min	$Tur = f(discharge)$
		Good view station ratio (GVSR, %)	4	Max	$GVSR = f(stage)$

Note: (2): Relative Importance Factor for main-criteria, (4): Relative Importance Factor for sub-criteria, (6): function for sub-criteria

6.4.1 Reservoir sedimentation

Reservoir sedimentation is one of the most important objectives in this study, which is affected mostly by trap efficiency of the reservoir. To prevent reservoir sedimentation, the trap efficiency function (Eq. 50) has to be minimized. This can be achieved by minimizing water surface area (A) and maximizing discharge (Q), when the grain fall velocity (ω) can be assumed a constant value.

$$T_E = 1 - \exp\left(-\frac{\omega A}{Q}\right) \tag{50}$$

where T_E = trap efficiency,

ω = particle fall velocity (m/s),

A = water surface area (m^2),

Q = discharge (m^3/s)

Stream flow of Sangju Weir consists of natural inflow from upstream watersheds and controlled releases from upstream large-scale dams. Typically, multi-purpose dams have a seasonal release pattern. For example, dam operators release more water in the irrigation season, March-June, than other seasons. Although we can control amount of discharge at a large dam, weirs have a relatively small amount of extra storage for flood control when their stage is low. This is because the Weirs were constructed for keeping water level control not for storage. However, a variable we can control at the Weir is water stage. Water stage affects various aspects such as trap efficiency, water supply stability, flow width ratio, and others. As the water surface area (A, in Eq. 50) is also function of water stage, water stage control eventually changes the reservoir trap efficiency (T_E).

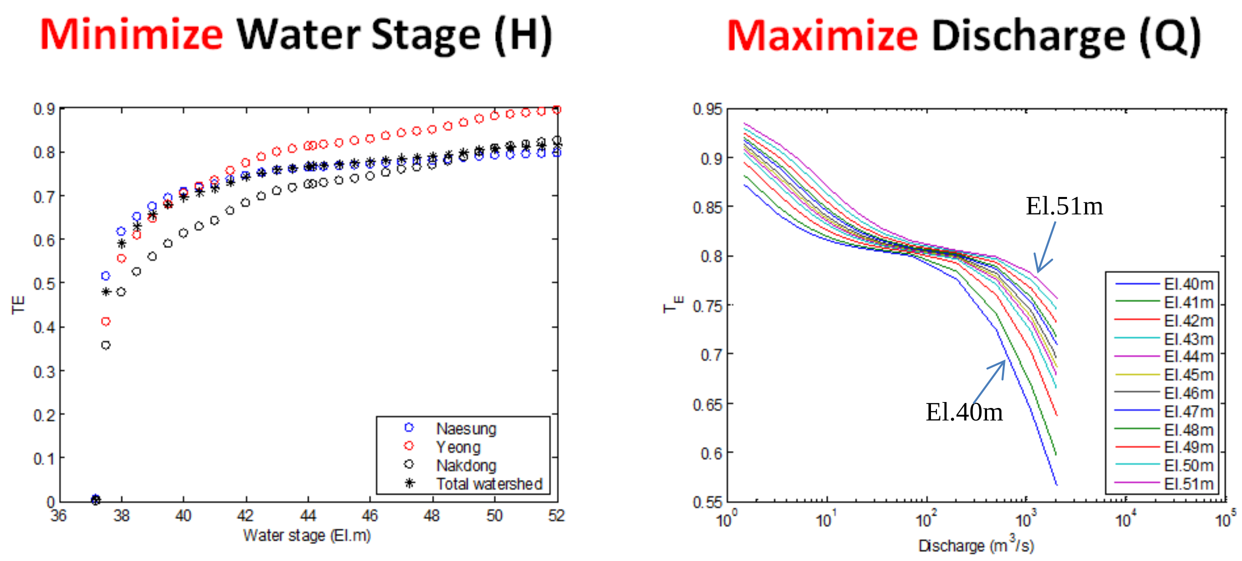


Figure 68: Trap efficiency sub-criterion which has two main variables: H and Q

Figure 68 presents the relationships between trap efficiency (T_E) and water stage (H), and discharge (Q). This shows that when the water stage is low and discharge is high, the trap efficiency decreases and reservoir sedimentation also decreases.

Thus, water stage (H), discharge (Q), trap efficiency (T_E), and the reservoir sediment excavation cost (Cost_dred) were selected as sub-criteria for the Multi-Criterion Decision Analysis (MCDA).

6.4.2 Hydropower generation

Sangju Weir has a hydropower plant that has a 3,000 kW of capacity. Hydropower generation is very important because this is the only revenue from reservoir operation. So, hydropower production decision makers group wants to maximize the hydropower revenue in reservoir operation. Hydropower production is a function of discharge (Q), stage difference (dH) between upstream and downstream, and power plant efficiency (η).

$$P = 9.81\,\eta\,Q_a\,H_a \quad (51)$$

where P = hydropower production (kW),

η = gear efficiency (η_G) × turbine efficiency (η_T),

Qa= discharge (m^3/s),

Ha= stage difference between upstream and downstream (m)

Eq. 51 shows the function of hydropower production. Both components are proportional to the hydropower production. Thus, discharge (Qa), stage difference (Ha), and the hydropower generation revenue (HP_bene) were selected as sub-criteria for the MCDA method. The maximum or optimal operational condition is determined using the turbine performance hill chart. Figure 69 shows the ideal values of Qa, Ha, and η, respectively.

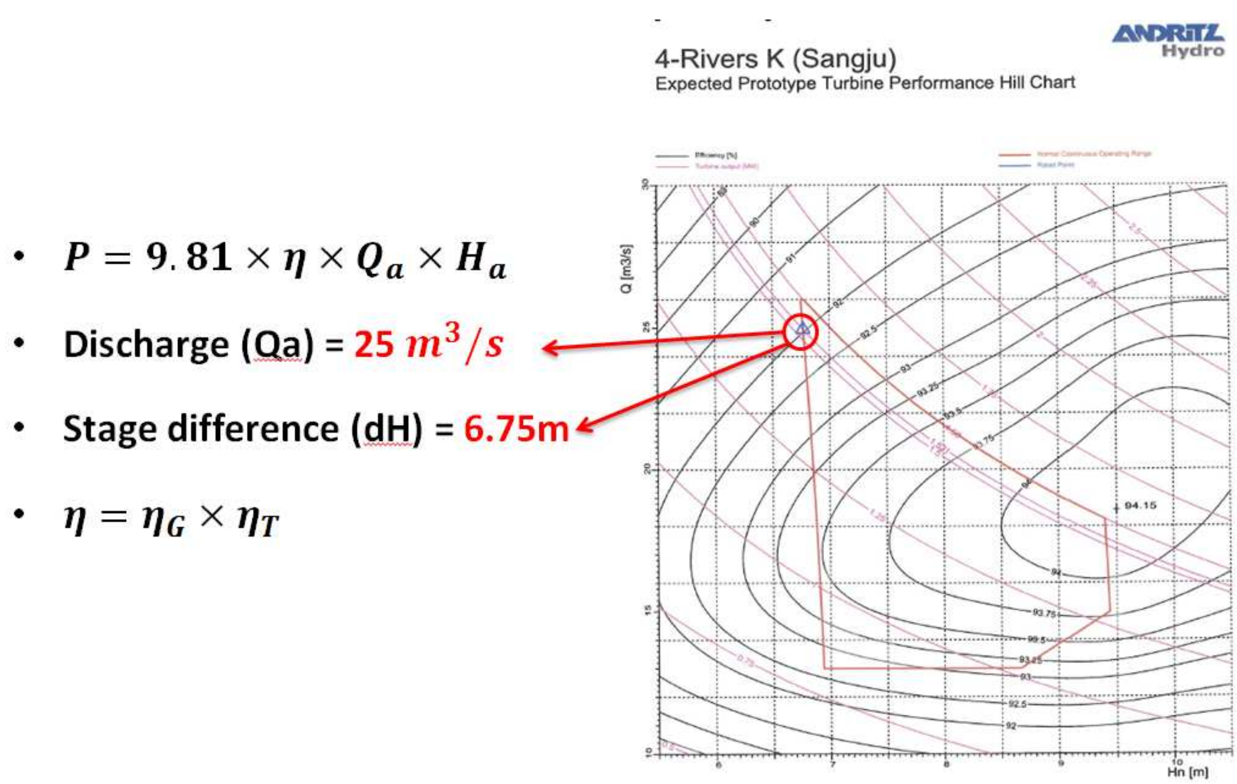


Figure 69: Hydropower production criterion and turbine performance hill chart (Andritz Hydro, 2010)

6.4.3 Water supply stability

Eight intake facilities provide drinking and irrigation water from Sangju Weir. Two of them, including Pungyang intake station, are run as annual base supply. And the others have operational periods for agriculture. In Sangju City, the local government, and the Korea Rural Community Corporation (KR) are in charge of these facilities. Their goal is to secure as much water as possible for water supply stability. The reservoir storage depends on the water stage (H). So, water stage (H) and the available storage (Vstorage) are chosen as sub-criteria of water supply stability. Figure 70 presents the relationship between water stage and available storage for water supply. The higher water stage leads to more water storage. Thus, maximizing water stage is desirable for the water supply decision makers group.

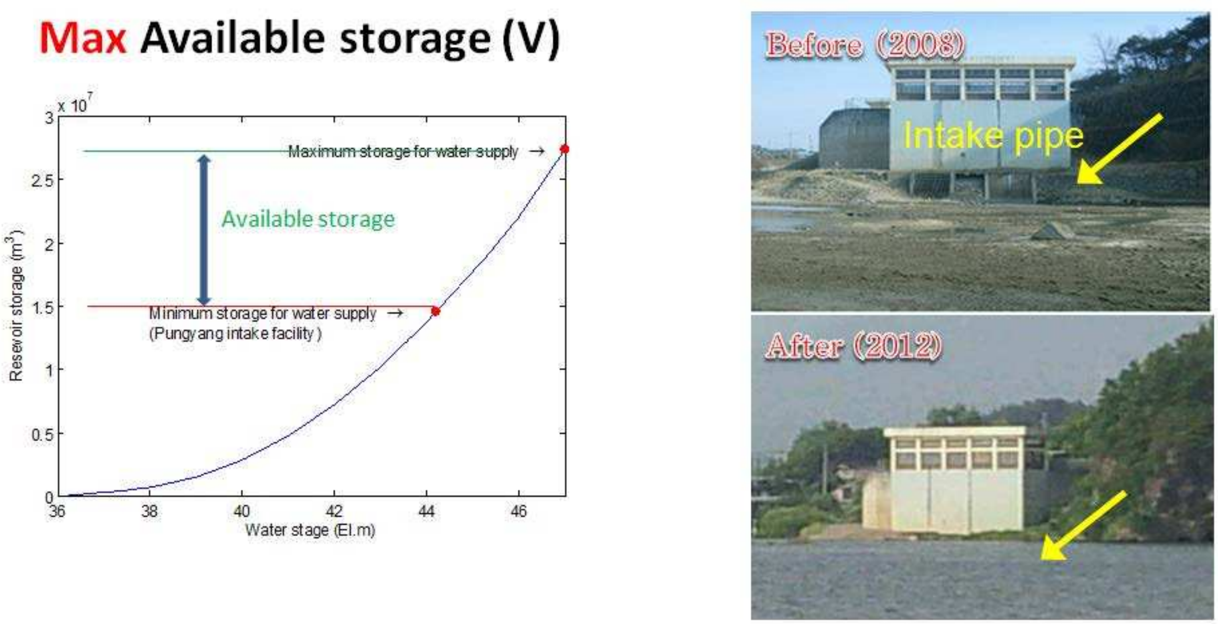


Figure 70: Water supply criteria and H and Vstorage relationship

6.4.4 Flood prevention

In contrast to water supply criteria, keeping the water stage high may not be desirable for everyone. The reservoir operator and the government aim to empty the reservoir as much as possible during the rainy season, in order to prevent flood damage. There are also 19 agricultural drainage facilities located…, which are operated by the Korea Rural Community Corporation (KR); thereby KR functions in water supply and water drainage roles in the study area.

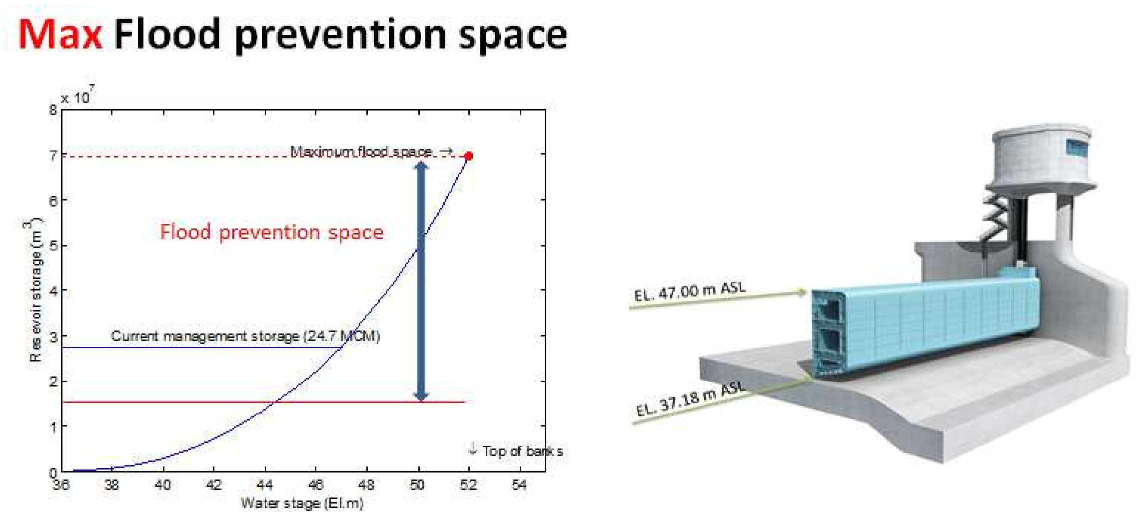


Figure 71: Flood prevention criteria and H and Vempty relationship

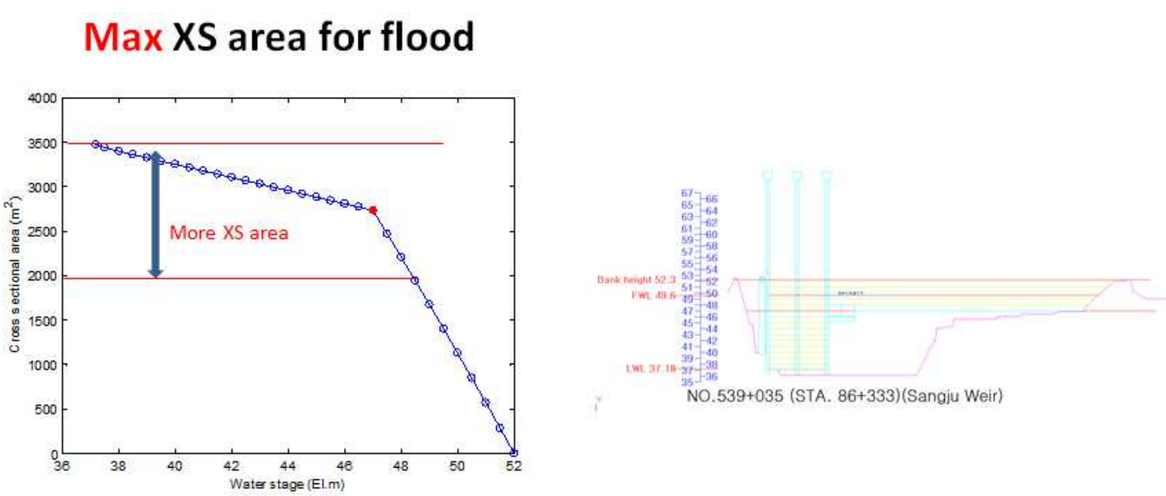


Figure 72: Flood prevention criteria and H and conveyance relationship

In fact, the flood conveyance ability is more important than the flood prevention storage in weir operation (in contrast to large dam operation). The cross sectional area at Sangju Weir depends on the gate opening which also determines the water stage control. In the view of flood prevention, it is better for the reservoir water level to be low, which conflicts directly with the water supply criteria. Figure 71 and Figure 72 present the relationship between water stage (H) and flood prevention volume (Vempty) and cross sectional area (Axs), respectively.

6.4.5 Riverside environment and stream ecology

Turbidity is one of key factors for environmentalists. The high turbidity causes an increase in the use of coagulation chemicals in Water Treatment Plant (WTP). Turbidity varies with discharge (Q) and was selected as the main environmental criterion. Figure 73 shows the relationship and an example.

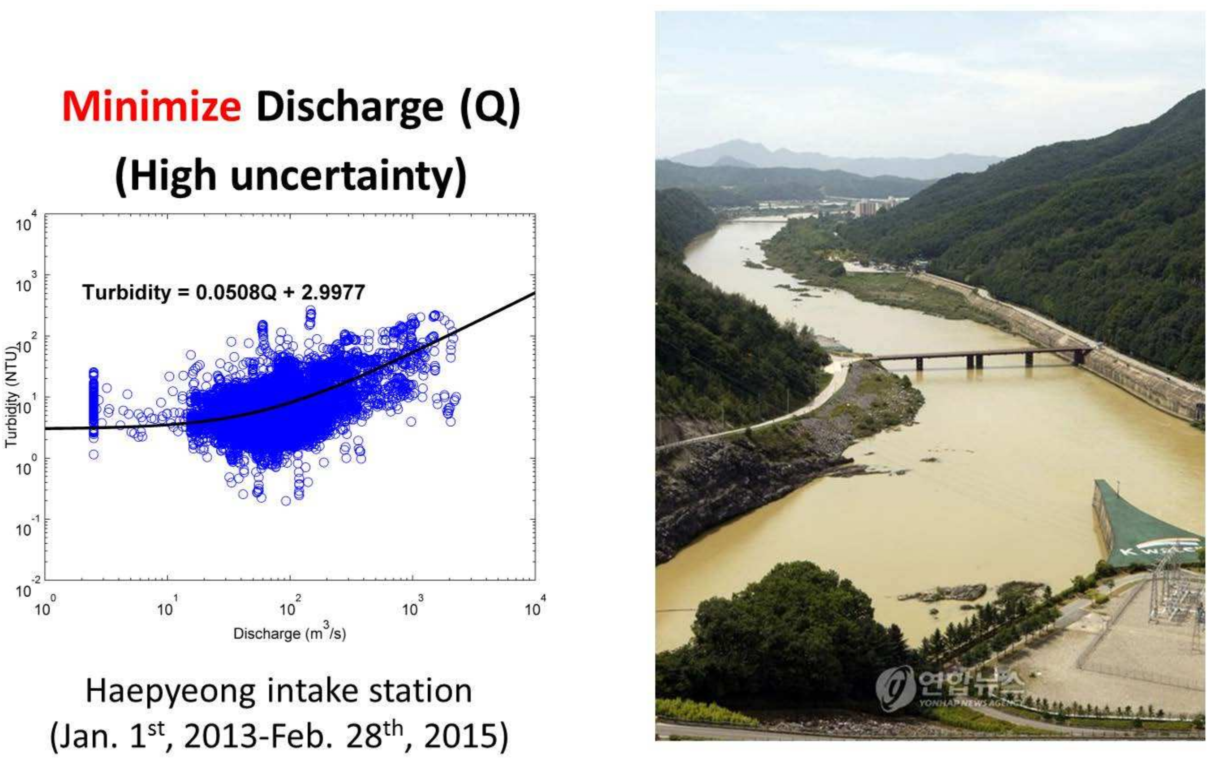


Figure 73: Turbidity criteria and example picture of turbidity flow from Imha multi-purpose dam

The river view for sightseeing was chosen as the last criteria of MCDA. People go to the riverside for hiking, biking, and other activities. For this purpose, the Good-View Section Ratio (GVSR) was defined as Eq. 52.

$$GVSR = \frac{No. of\ Good\ view\ sections}{Total\ number\ of\ sections} \times 100\ (\%) \qquad (52)$$

GVSR is the ratio of the number of stations which have comfortable amenity in terms of water surface width ratio as compared to the total number of stations. Sangju Weir has 63 upstream sections (Figure 74).

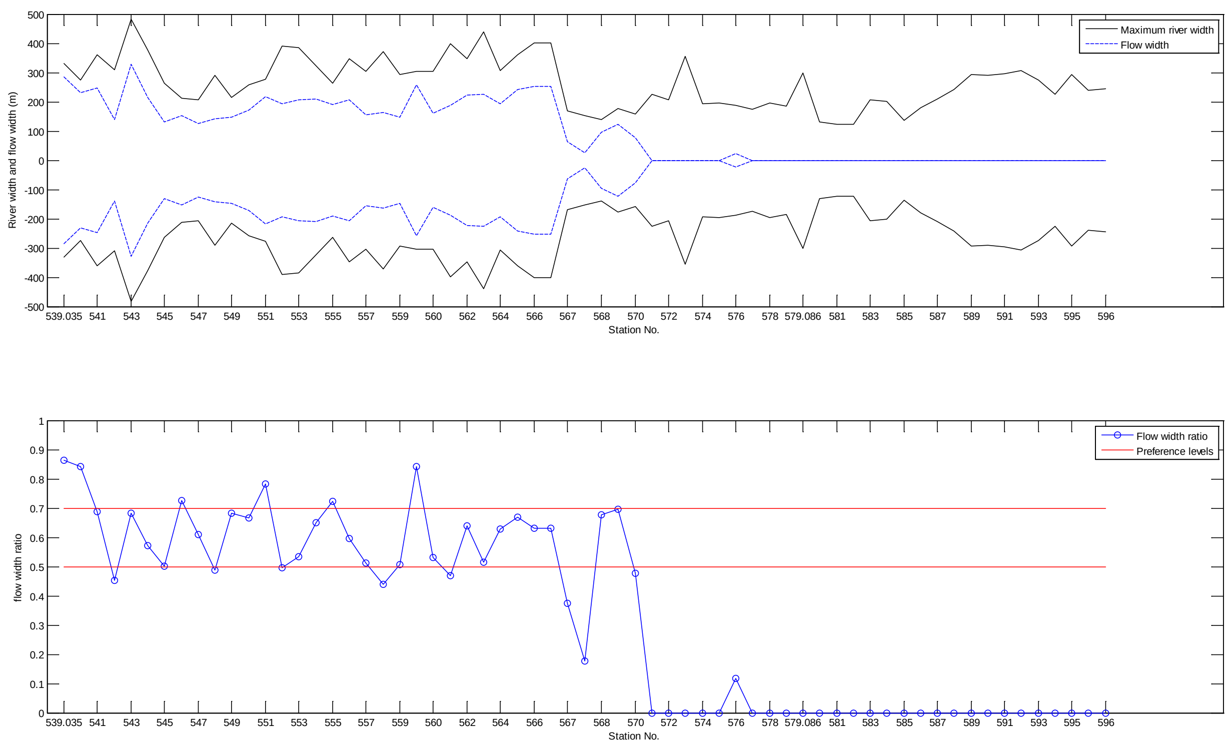


Figure 74: Ratio of water surface width upstream of Sangju Weir

According to a survey among Korea residents (K-water, 2012), the best riverside recreation environment occurs when the water surface width ratio to the river width is between 0.5 and 0.7. The good view section numbers represent the station numbers falling into the preference slot (0.5-0.7).

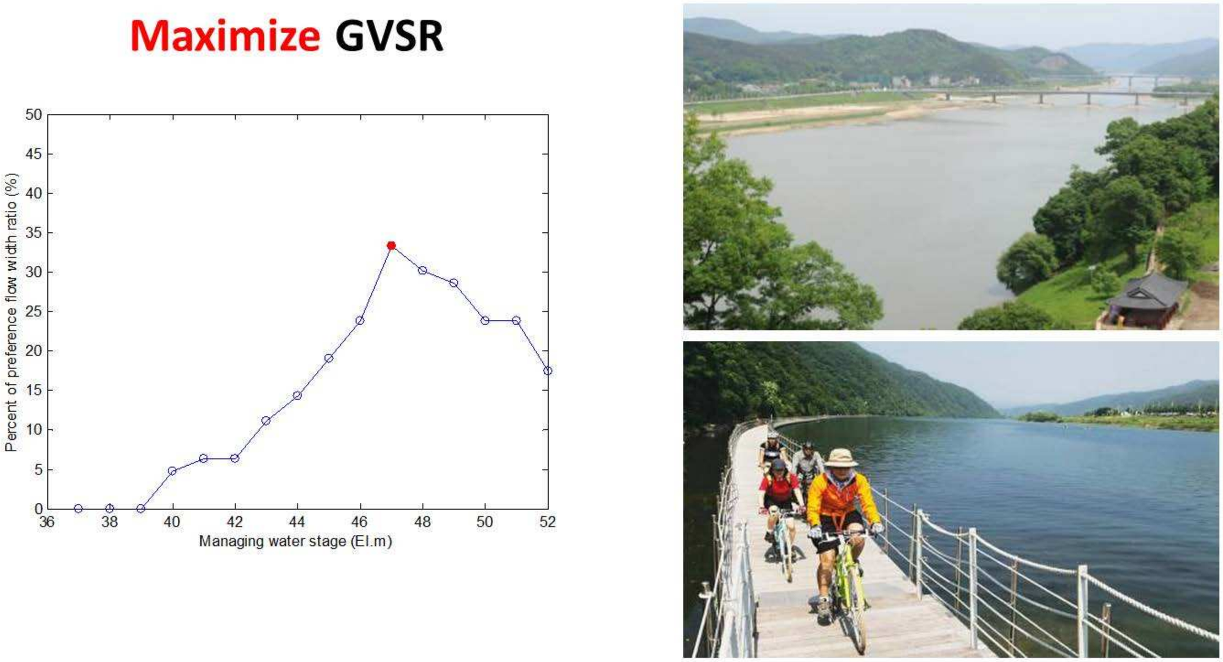
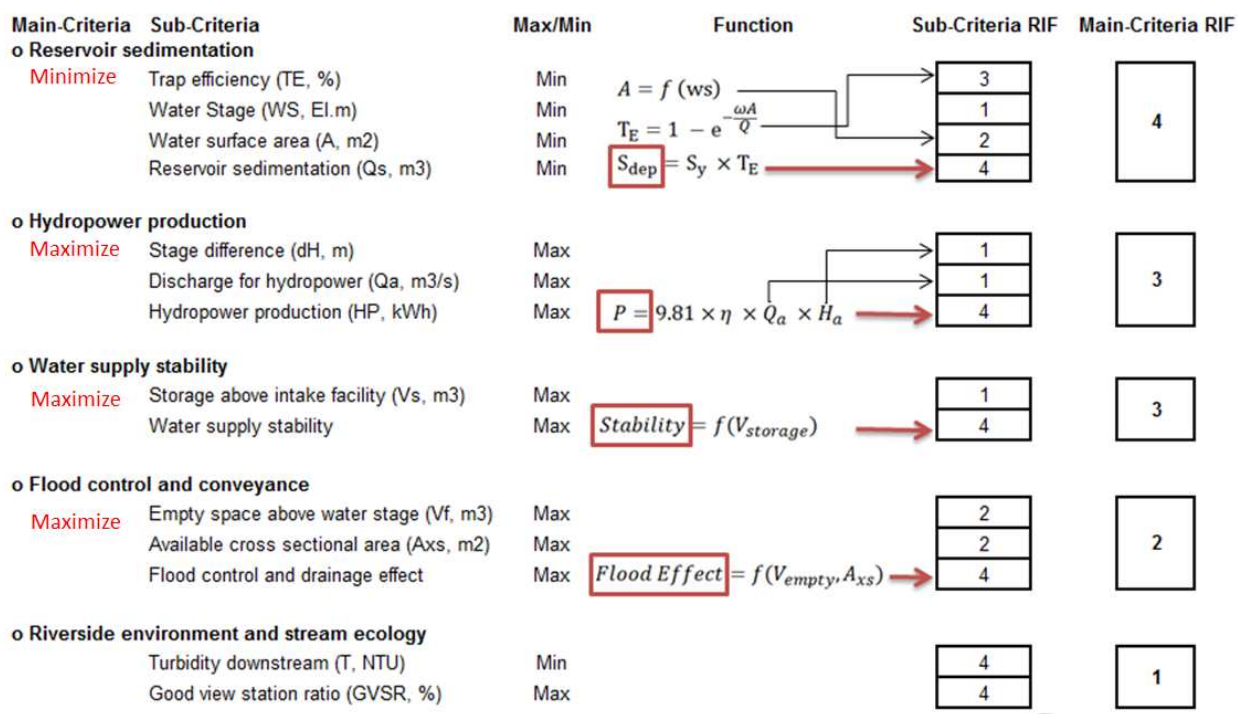


Figure 75: The relationship between stage and water surface width ratio

Figure 75 presents the relationship between water stage (H) and good view station ratio (GVSR), which varies as the reservoir level changes. The GVSR was selected as one of the sub-criteria for riverside environment and stream ecology criterion.

6.5 RELATIVE IMPORTANCE FACTORS (RIF) DEFINITION

The Relative Importance Factor (RIF) is the relative importance of each criterion, or the ratio of the importance of each criterion as compared to the least important criteria. The least important criterion has a Relative Importance Factor (RIF) of 1 (one). The criterion having an RIF of 2 means that this criterion has twice more importance than that with an RIF of 1. For a case where the relative importance among criteria cannot be decided, the same relative importance factor of 1 can be used for all criteria. In this study, a total of seven RIF-sets were developed based on decision-maker groups: (1) reservoir operator group, (2) reservoir operator group with sedimentation emphasis, (3) reservoir sedimentation management group, (4) hydropower production group, (5) water supply responsibility group, (6) flood control agency group, and (7) riverside environment and stream ecology group.



Main-Criteria	Sub-Criteria	Max/Min	Sub-Criteria RIF	Main-Criteria RIF
Reservoir sedimentation (Minimize)	Trap efficiency (TE, %)	Min	3	4
	Water Stage (WS, El.m)	Min	1	
	Water surface area (A, m2)	Min	2	
	Reservoir sedimentation (Qs, m3)	Min	4	
Hydropower production (Maximize)	Stage difference (dH, m)	Max	1	3
	Discharge for hydropower (Qa, m3/s)	Max	1	
	Hydropower production (HP, kWh)	Max	4	
Water supply stability (Maximize)	Storage above intake facility (Vs, m3)	Max	1	3
	Water supply stability	Max	4	
Flood control and conveyance (Maximize)	Empty space above water stage (Vf, m3)	Max	2	2
	Available cross sectional area (Axs, m2)	Max	2	
	Flood control and drainage effect	Max	4	
Riverside environment and stream ecology	Turbidity downstream (T, NTU)	Min	4	1
	Good view station ratio (GVSR, %)	Max	4	

Figure 76: Relative importance factor for sub-criteria considering functions

Then, 14 sub-criteria were assigned using two approaches, one with the same RIF (case 1) and one using different weights (case 2) in order to evaluate the relative importance to the main criteria. Normalized weightings were computed by dividing the RIF for a specific criterion, by the sum of the relative importance factors for all criteria. RIF were set according to the variable's functions, which mean that the final objective variables are assigned as the highest values (Figure 76). Figure 76 presents the main and sub criteria, target function for sub-criteria, corresponding RIF for sub-criteria and those for main-criteria.

Main Criteria \ Decision makers	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
Reservoir sedimentation	1	4	4	1	1	1	1	2	3	4
Hydropower production	1	3	1	4	1	1	1	1	3	2
Water supply stability	1	3	1	1	4	1	1	3	4	1
Flood control and conveyance	1	2	1	1	1	4	1	3	1	2
Environment and riverside amenity	1	1	1	1	1	1	4	2	2	2

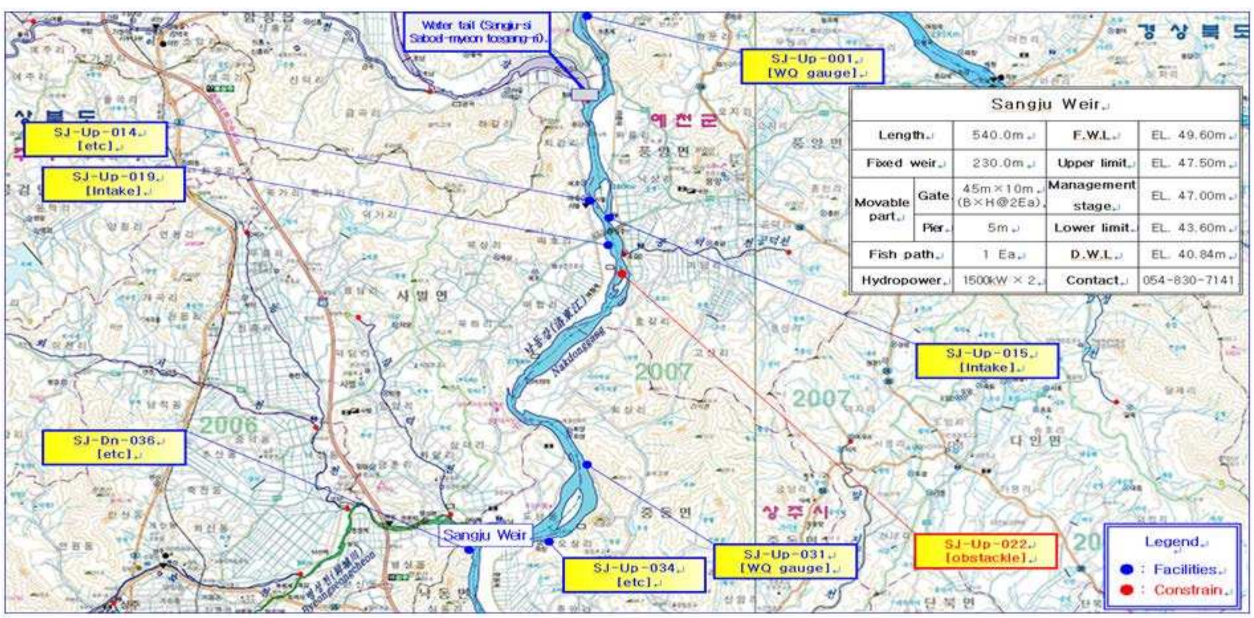
G1: Reservoir operator group
G2: Reservoir operator group with sedimentation emphasis
G3: Reservoir sedimentation management group
G4: Hydropower production group
G5: Water supply responsibility group
G6: Flood control agency
G7: Riverside environment & stream ecology group
G8: MCDA variability 1
G9: MCDA variability 2
G10: MCDA variability 3

Figure 77: Relative importance factor for main criteria considering various decision makers' interests

The RIF for main-criteria varies depending on the decision makers' group. Figure 77 shows the Relative Importance Factors (RIF) for the five main-criteria according to the seven various decision makers' groups. They all have different interests, which sometimes create conflicts. This study focuses on the reservoir operation rules in view of the reservoir operator group with a sedimentation emphasis to evaluate the sedimentation problem.

6.6 CONSTRAINTS ANALYSIS

The reservoir operators have to consider many constraints which exist upstream and downstream of Sangju Weir. The constraints can be sorted into categories related to various purposes like drinking water, irrigation, flood drainage, riverside amenities, environmental issues, and others. Sangju Weir has been examining annually the constraints which could affect the reservoir operations since the construction period. According to the annual Sangju Weir operation constraints survey (Sangju Weir Operation Office, K-water, 2014), there are 27 upstream constraints. These are related to water supply and flood damage mitigation issues. Figure 78 presents the summary of the constraints survey result. Through the constraints analysis, possible or desirable operational zones for water stage and discharge were studied. Two main components of the constraints analysis are the water stage analysis and the discharge analysis.



Total	Water Supply Constraints		Flood Constraints
	Drinking Facility	Irrigation Facility	Drainage Facility
27	2	6	19

Figure 78: Location of Sangju Weir's constraints

6.6.1 *Reservoir stage constraints*

In terms of water supply, to satisfy the water intake condition for the drinking water facilities, the reservoir stage has to be kept above EL 44.2 m above the mean sea level. But for consistent irrigation, the water level must keep at least above EL 45.0 m during the irrigation period (May-September).

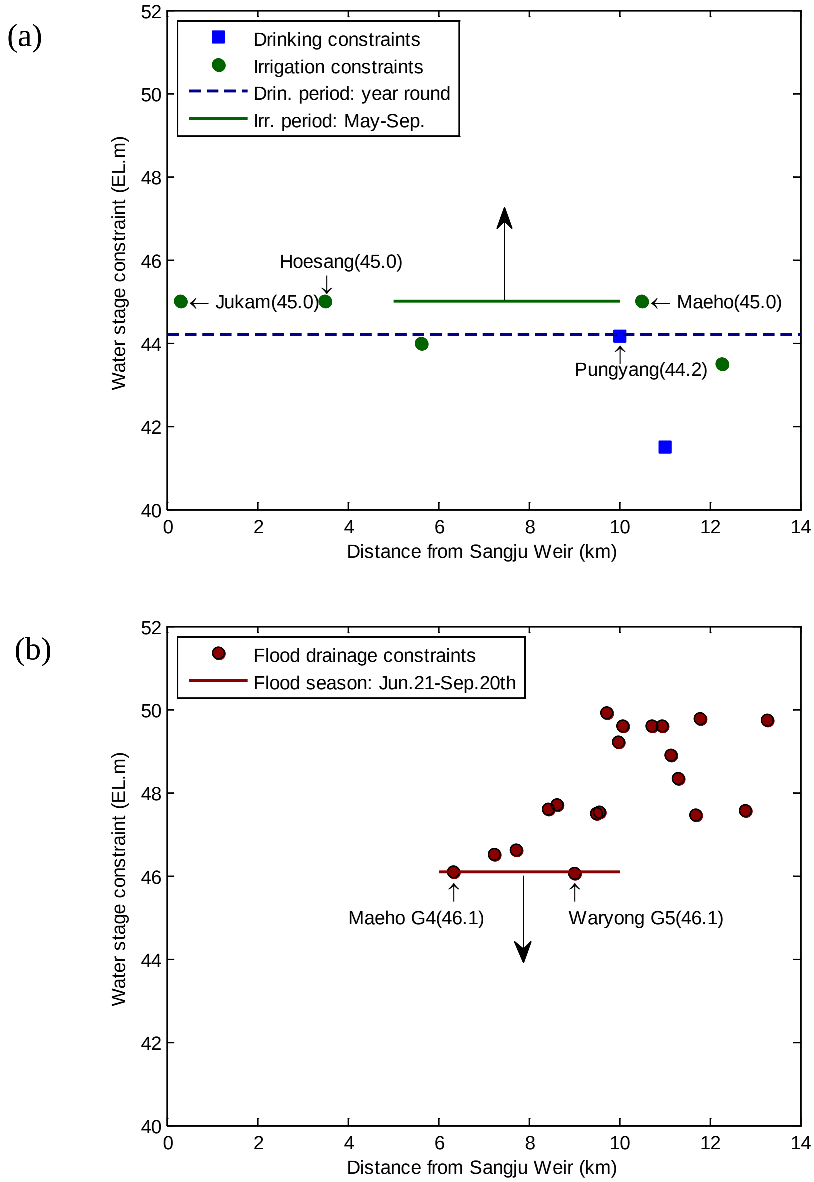


Figure 79: Water supply constraints and flood drainage constraints of upstream of Sangju Weir

In contrast to the water supply issue, some constraints force the reservoir operators to keep the water level low. There are 19 flood drainage facilities which are draining high water from their own watershed to Nakdong River (Sangju Weir upstream) during the flood season (June-September). If the Sangju Weir's water stage is greater than El. 46.1m, flooding occurs in these upstream watersheds, including in paddy fields which cannot drain effectively into the river. Hence, these two water stages have to be considered for developing operational alternatives. Figure 79 presents the water stage constraints for water supply and flood control.

6.6.2 Discharge constraints

The other important constraint is the flow discharge. Discharge influences many aspects like turbidity at the downstream water treatment plant, hydropower generation, trap efficiency, and others. First, hydropower has to be considered. The turbines are designed to exert maximum performance when the discharge is 25m^3/s. Since there are two generators, at least 50 m^3/s of discharge (green color line in Figure 79) is necessary to achieve optimum hydropower performance. Secondly, downstream turbidity issue is an important factor. High concentration of sediment flow may damage the water treatment facilities located downstream of Sangju Weir. The relationship between discharge (Q) and turbidity (Tub) in Figure 80 is from Haepyeong intake facility where is located in downstream of Sangju Weir. From this relationship, exceeding 1,000 m^3/s of discharge (yellow line in Figure 79) leads to high turbidity. Finally, the last discharge constraint is related to reservoir sedimentation issue. The break-even discharge was calculated as 620 m^3/s (orange color line in Figure 79), which balances the dredging cost and hydropower revenues. The discharges below the break-even point cause more reservoir sediment excavation cost than hydropower revenue.

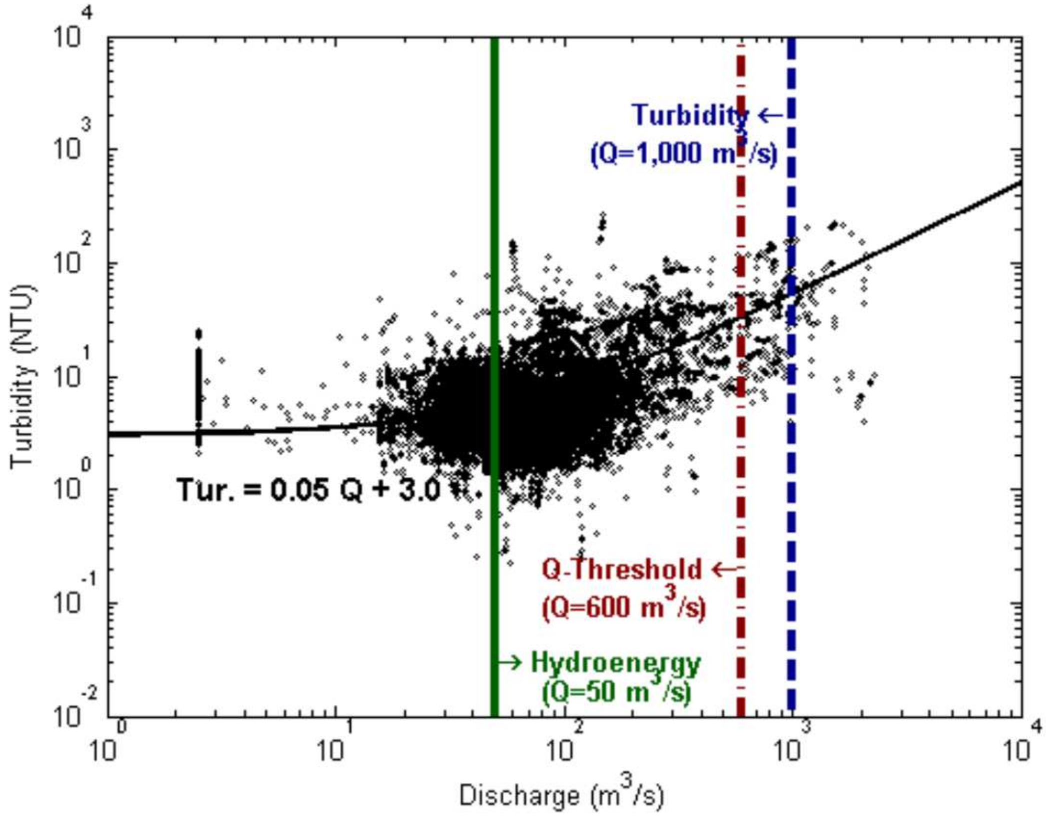


Figure 80: Discharge versus turbidity relationship at Haepyeong intake and discharge constraints

6.6.3 Constraints for alternative development

Considering the previous sections' constraints analysis, the constraints filtering zone were determined as follow:

$$50 < Q < 600\ (m^3/s),\ \text{and}\ 44.2 < H < 47.0\ (El.m).$$

Figure 81 show the result of constraints analysis, which was used for alternatives developments for MCDA modeling.

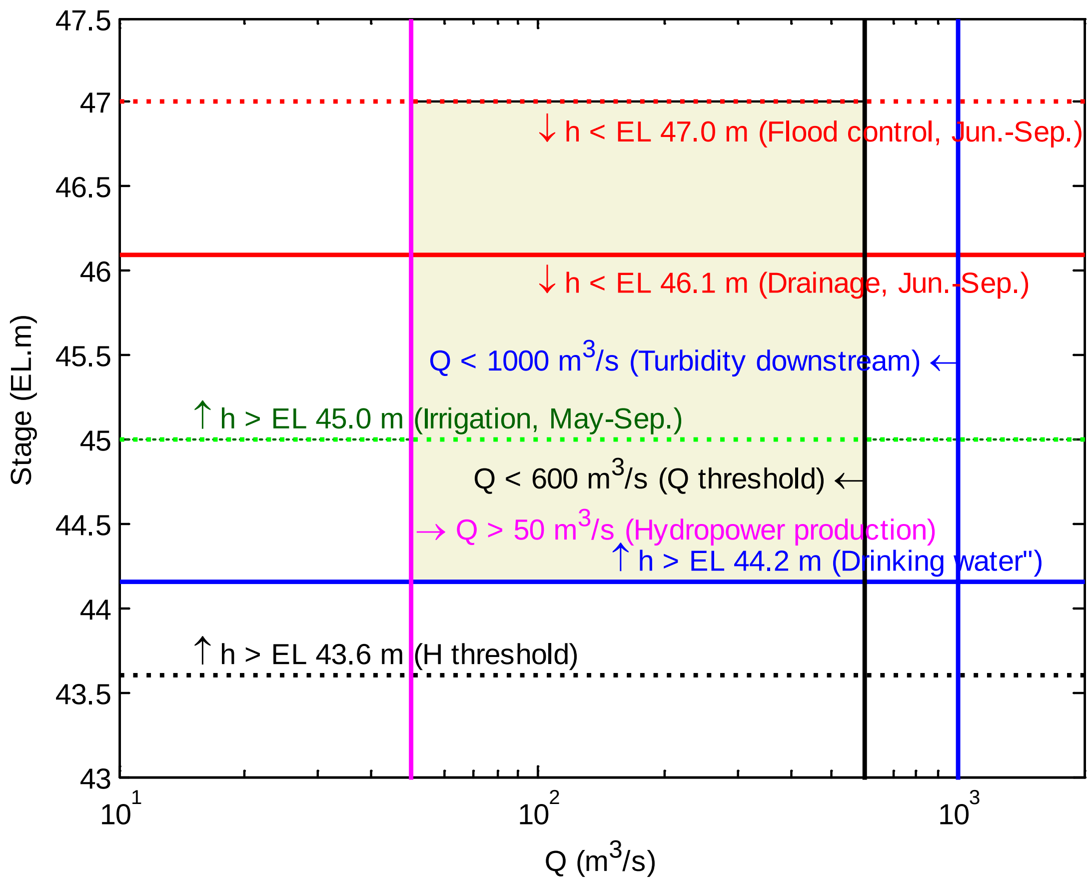


Figure 81: Constraints with respect to water stage and discharge

6.7 ALTERNATIVES DEVELOPMENT

Based on constraints analysis, a total of five alternatives were developed as follows:

- Alt. 1: Full water stage operation (EL 47.0 m, current operation rule)
- Alt. 2: Medium water stage operation (EL 43.6 m, break-even point)
- Alt. 3: Lowest water stage operation (EL 37.2 m)
- Alt. 4: Seasonal water stage control
    - Normal season (EL 47.0 m)
    - Flood season (EL 46.0 m)

- Alt. 5: Seasonal stage control considering upstream inflow
    - Normal season (EL 47.0 m)
    - Flood season:

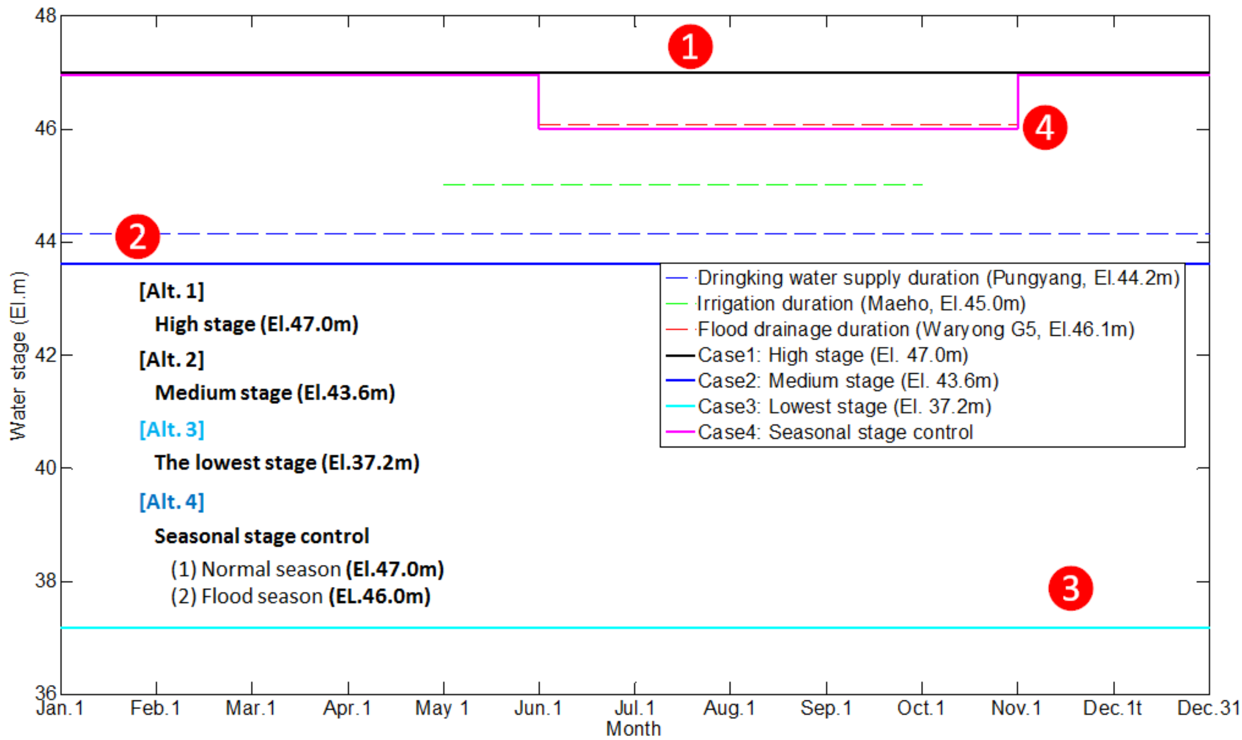
      $Q \leq 50\ m^3/s \rightarrow$ El. 47.0 m

      $50 < Q \leq 600\ m^3/s \rightarrow$ El. 46.0 m

      $Q > 600\ m^3/s \rightarrow$ El. 44.5 m.

Alt. 1-3 have fixed management water stage (high, medium, low) regardless of season. In Alt. 4, the water stage is dropped to EL 46.0m for flood drainage facilities in the flood season. If the reservoir operators used the Alt. 4, water can be drained more effectively than with current condition.

Alt. 5 is the most advanced alternative for mitigation of the sedimentation problem. The most attractive feature of this alternative is that the reservoir sediment trap efficiency can be reduced when the stream flow rate is high.



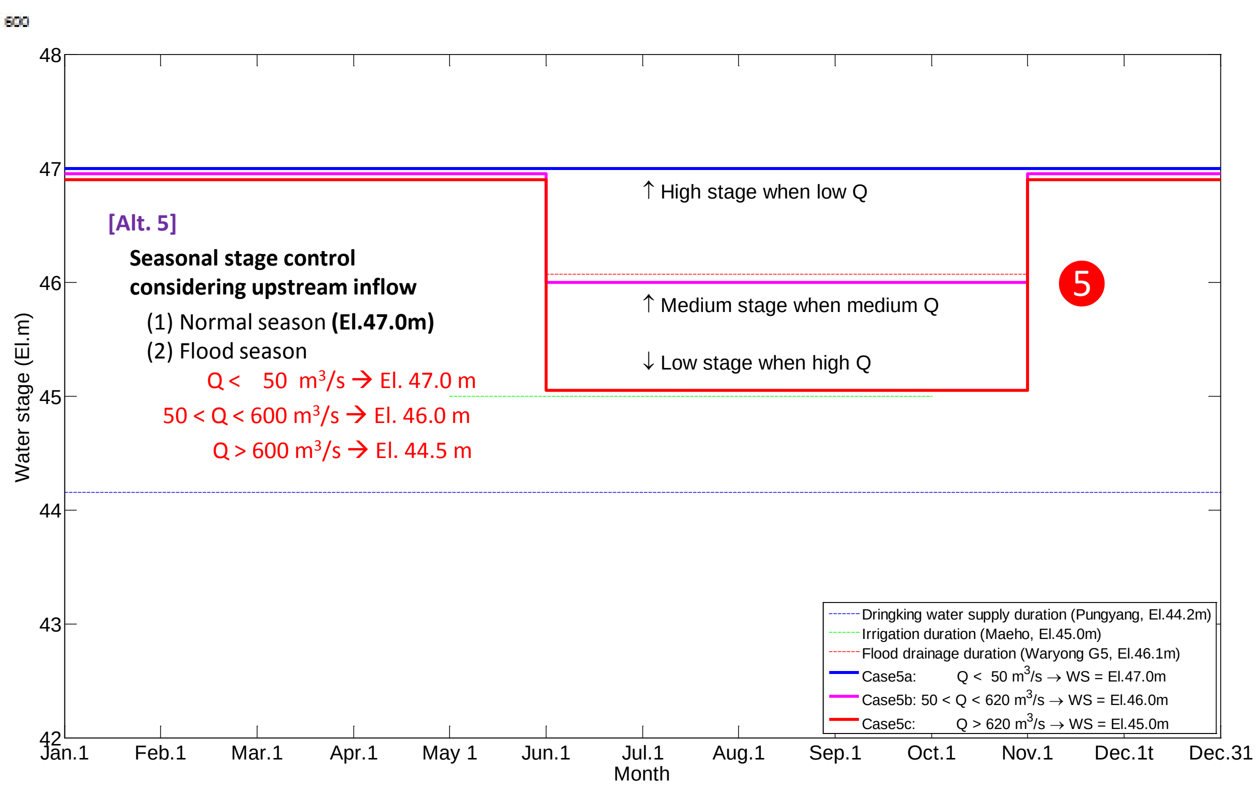


Figure 82: Alternatives developed for MCDA analysis

It is apparent with the sediment yield calculation using the FD/SRC method that the amount of sedimentation is affected by the magnitude of discharge. Accordingly, the stream flow was categorized as 3 groups: (1) low flow rate, (2) medium flow rate, and (3) high flow rate. Since the low flow rate during the flood season will not cause substantial sedimentation, the reservoir level remains high for the hydropower and water supply which is the same as the current operation rule. However, high flow rates, exceeding the break-even point, are very influential to the reservoir sedimentation. For this case, in order to reduce the trap efficiency and reservoir sedimentation, the reservoir stage remains low near the critical stage for water supply i.e., EL 44.5m. This will allow more sediment to pass through the Sangju Weir during the floods. For the medium stream flows during the flood season, the water stage is lowered to EL 46.0m to increase flood drainage ability. Figure 82 shows the proposed alternatives with seasonal stage difference according to discharges.

6.8 MCDA MODELING

Daily modeling was performed for every scenario over 20 years with respect to sediment and hydropower generation. The MCDA input variables were extracted based on daily modeling results. Next, numerical and word scaling standards were set up. Finally, the MCDA input variables were applied for the MCDA modeling.

6.8.1 Daily simulation

Daily simulations were performed over a 20 year simulation period (2015-2034) for hydropower generation, reservoir sedimentation, hydropower revenue, dredging cost, B/C ratio, trap efficiency, turbidity, and environmental constraints.

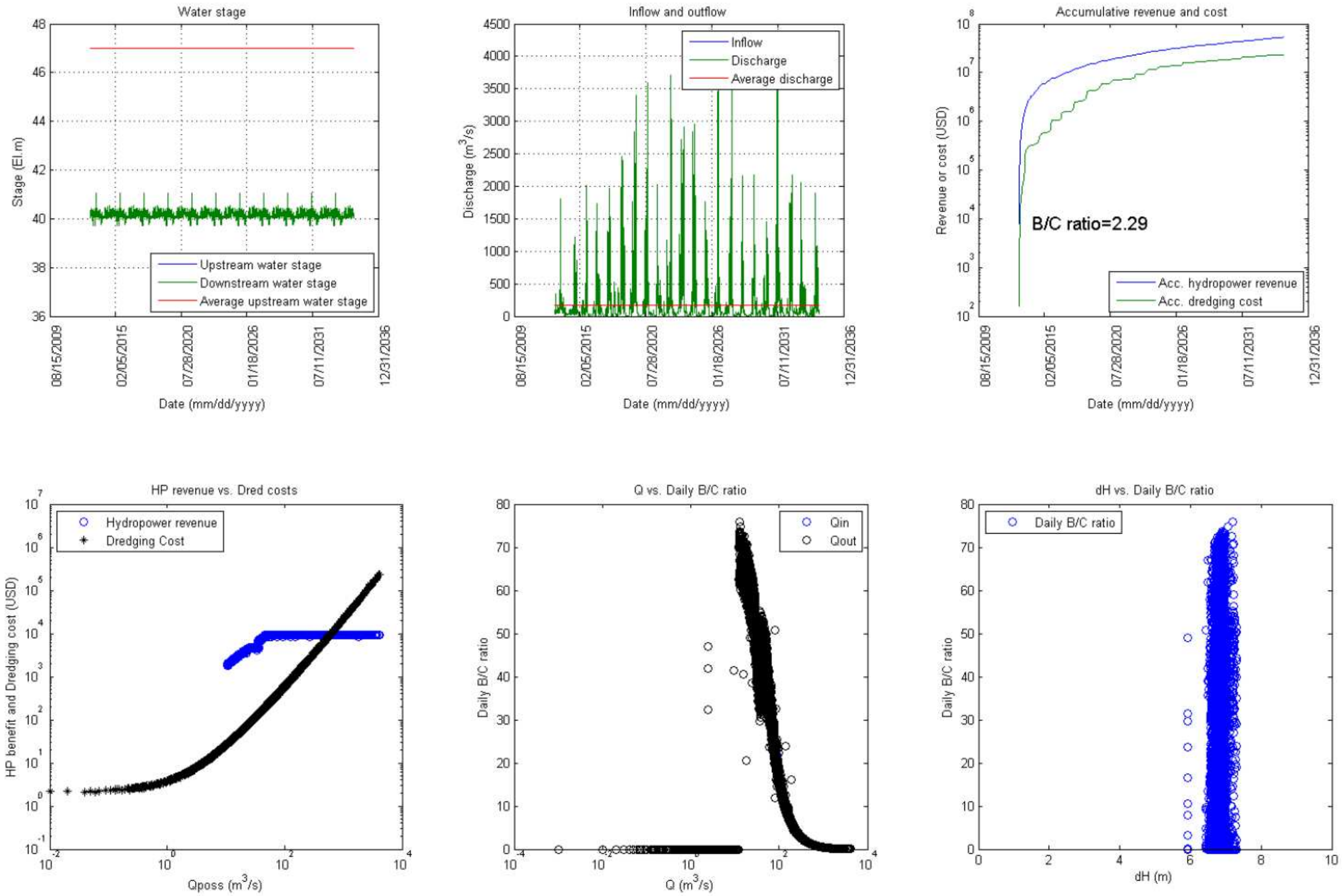


Figure 83: Simulation summary (Alt. 1)

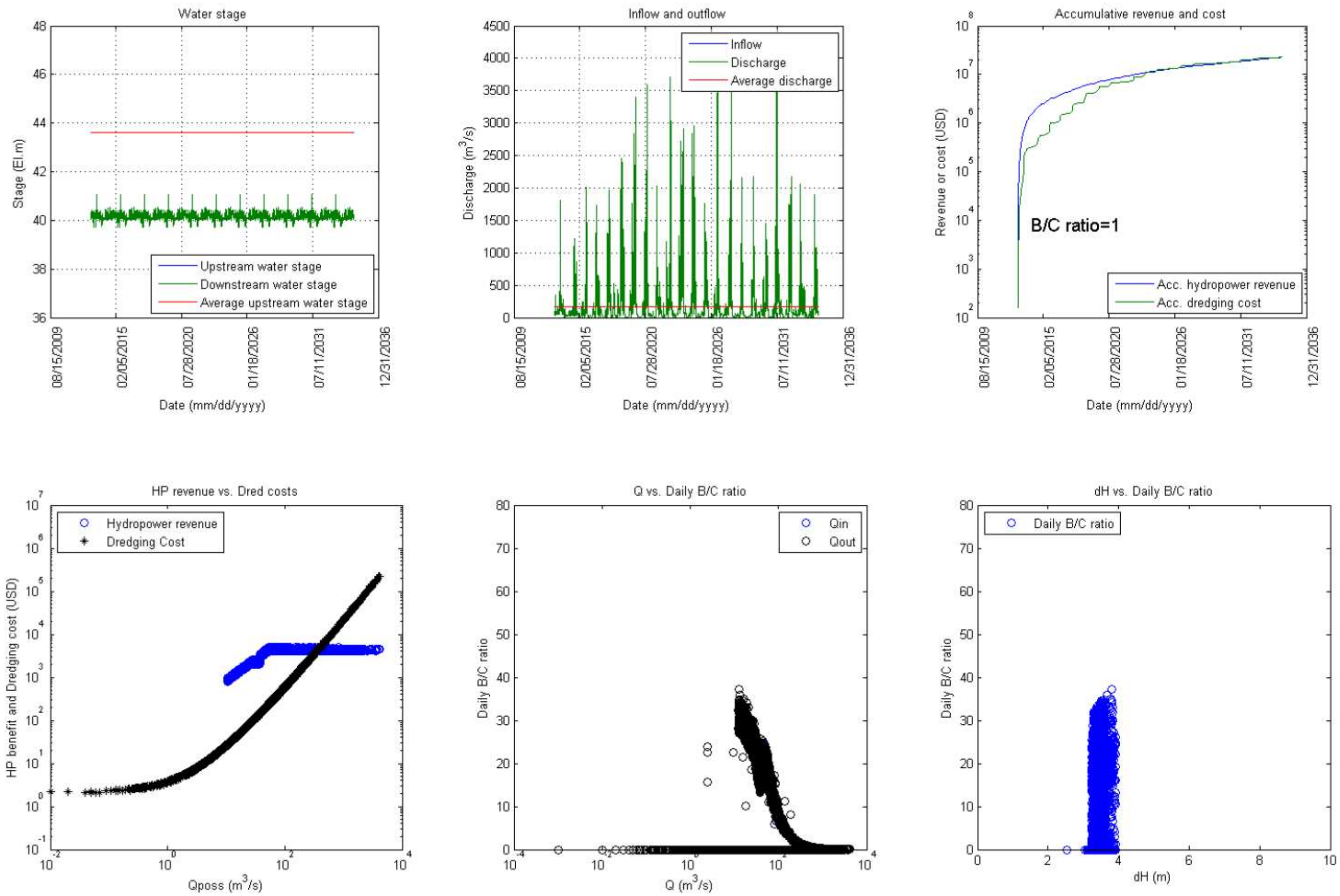


Figure 84: Simulation summary (Alt. 2)

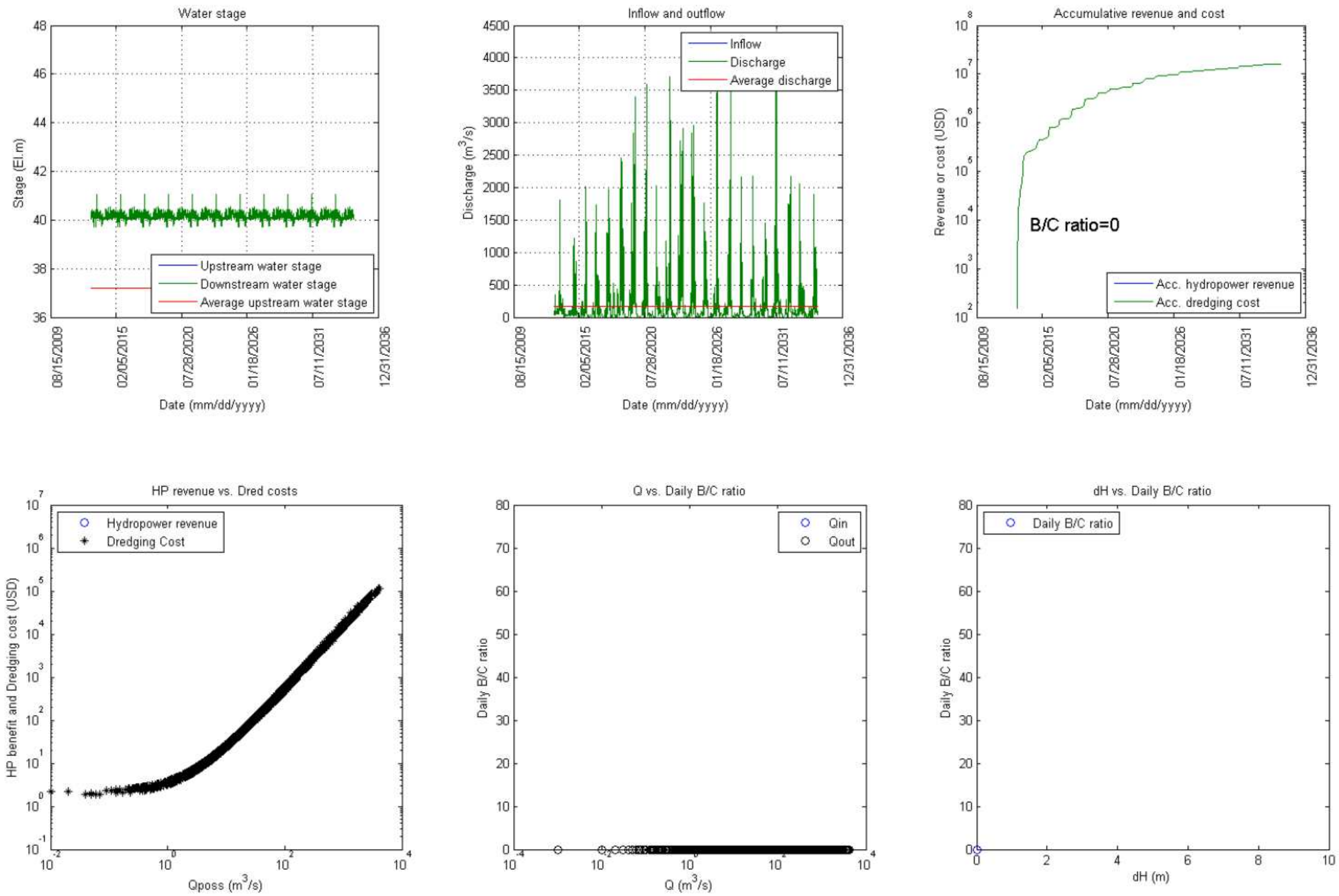


Figure 85: Simulation summary (Alt. 3)

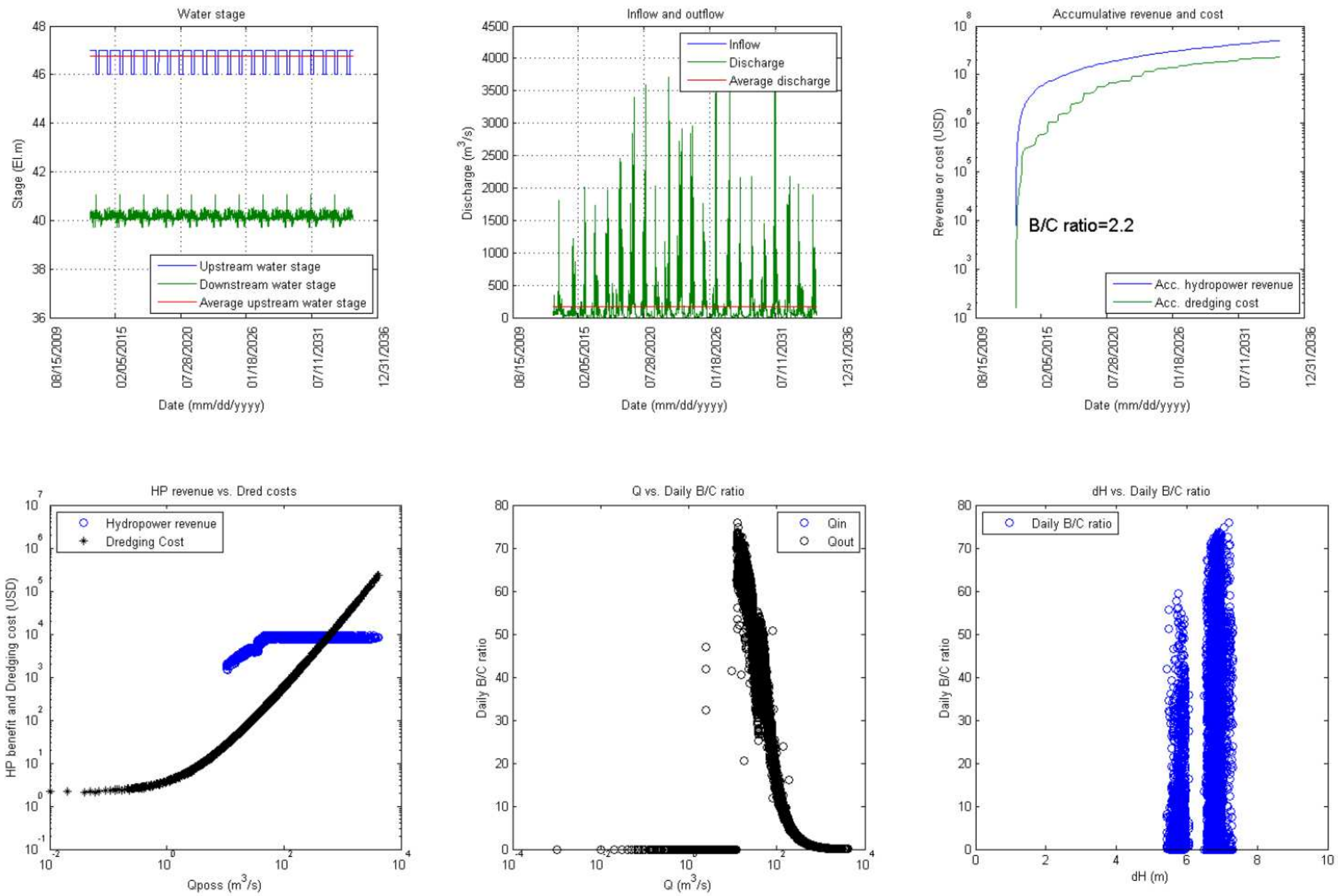


Figure 86: Simulation summary (Alt. 4)

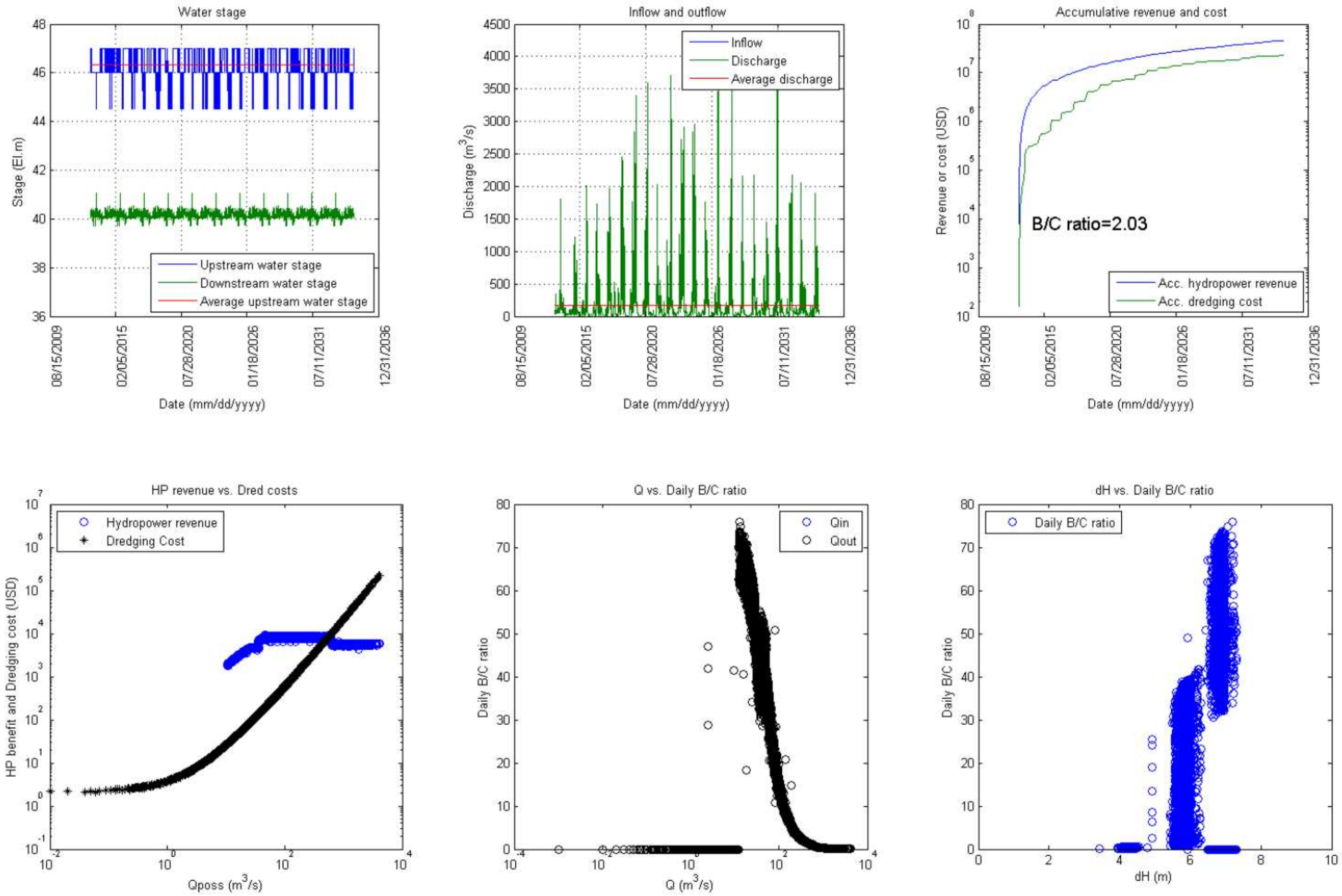


Figure 87: Simulation summary (Alt. 5)

6.8.2 MCDA input from simulation

From the daily modeling results, 14 MCDA variables were extracted (Table 27). Since there are 8,035 simulation days, a statistical method was used to decide the representative values. The most important sub-criteria, average trap efficiencies, were calculated by dividing the sum of daily reservoir sedimentation to the total sediment yield, which were different from medians of daily trap efficiencies.

Figure 88 shows the statistical trap efficiencies for every alternative. The median was selected as the representative value for MCDA input. Table 27 presents the summary of MCDA input variables calculated from daily modeling results.

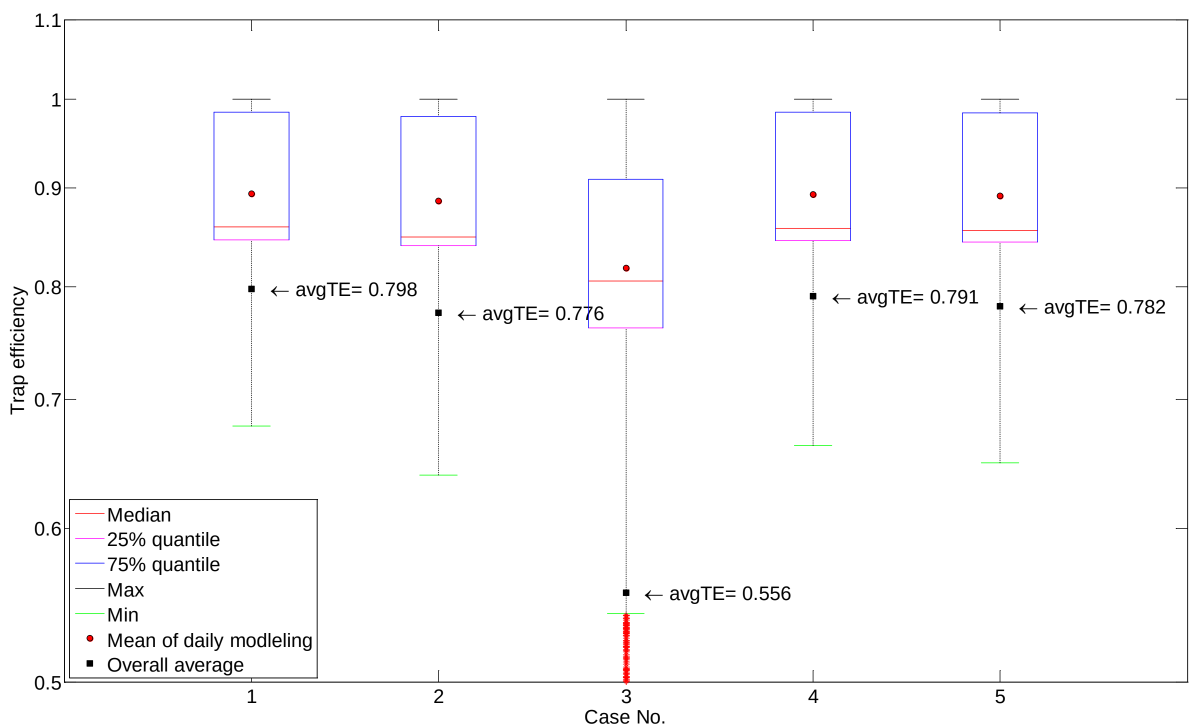


Figure 88: Trap efficiency for MCDA input

Table 27: Summary of MCDA input variables

Alternatives	T_E (%) (1)	avg_WS (El.m) (2)	avg_WSA (km^2) (3)	Dep_vol (10^6 m^3) (4)	Cost_dred (mil. USD) (5)	dH (m) (6)	Qa (m^3/s) (7)
Alt. 1	79.8	47.0	5.65	3.59	22.6	6.8	36.9
Alt. 2	77.6	43.6	3.94	3.49	22.0	3.4	38.6
Alt. 3	55.6	37.2	0.34	2.50	15.8	0.0	38.6
Alt. 4	79.1	46.7	5.45	3.55	22.4	6.6	37.6
Alt. 5	78.2	46.3	5.14	3.51	22.2	6.2	38.6

Alternatives	P_kWh (GWh) (8)	Bene_hp (mil. USD) (9)	V_{ws} (10^6 m^3) (10)	V_{empty} (10^6 m^3) (11)	A_{xs} (m^2) (12)	Turb (NTU) (13)	GVSR (%) (14)
Alt. 1	408.1	53.1	13.0	42.0	2,734	6.3	33.3
Alt. 2	171.4	22.3	-2.0	57.1	2,984	6.3	14.3
Alt. 3	0	0	-14.0	69.1	3,470	6.3	0.0
Alt. 4	389.2	50.6	11.7	47.4	2,807	6.3	28.6
Alt. 5	355.9	46.3	9.5	53.7	2,918	6.3	30.2

Note:

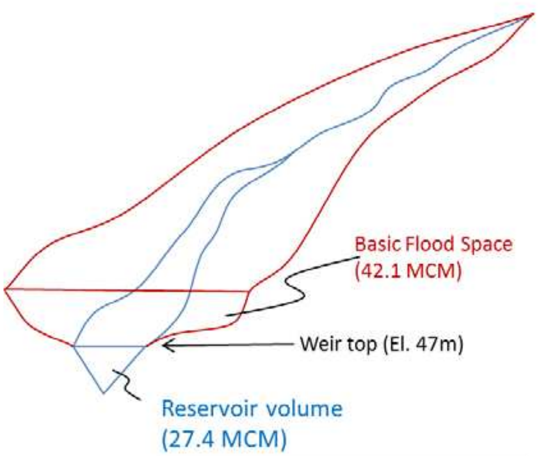
(1) T_E: overall trap efficiency (= Deposit volume / total sediment yield * 100) (%)
(2) avg_WS: average water stage during 20 years' daily simulation (El.m)
(3) avg_WSA: water surface area corresponding avg_WS (km^2)
(4) Dep_vol: the amount of reservoir sedimentation (10^6 m^3)
(5) Cost_dred: the excavation cost (million USD)
(6) avg_dH: average water stage differences between upstream and downstream (m)
(7) avg_Qa: average discharge through the hydropower turbine (m^3/s)
(8) PkWh: the amount of hydropower generation (GWh)
(9) Bene_hp: hydropower revenue (million USD)
(10) V_{ws}: the secured water volume for water supply (10^6 m^3)
(11) V_{empty}: the empty space reservoir volume for flood prevention (10^6 m^3)
(12) A_{xs}: the cross sectional area at the Sangju Weir location (m^2)
(13) Turb: average turbidity corresponding average discharge (NTU)
(14) GVSR: good view station ratio (%)

6.8.3 Scaling

All criteria were evaluated using rating scales that are the numerical scores given to the alternatives with respect to each criterion. The common scale, 0 to 1, or 1 to 5 was used. 12 of the sub-criteria can be expressed as numeric values. Thus, these variables were scaled between 1 and 5 based on their magnitude relative to good or poor conditions. For example, the highest score (5) is assigned for best values, and the lowest score (1) indicates the worst values (Figure 89).

Sub-Criteria	Best	Worst	Scale Upper	Scale Lower
Trap efficiency (%)	42.79	93.55	5	1
Water Stage (El.m)	37.20	47.00	5	1
Water surface area (m^2)	341,914	5,648,678	5	1
Sedimentation (m^3)	1,019,054	3,333,488	5	1
Dredging cost ($)	6,430,232	21,034,310	5	1

Figure 89: Numerical scale



Additional percentage (%)	Corresponding storage (m3)
25%	6,850,000
50%	13,700,000
75%	20,550,000
100%	27,400,000

Word scale

Empty space range (m^3)			Word scale	Scaling	Remarks
	~	42,100,000	Poor	1	Basic
42,100,000	~	48,950,000	Fair	2	Basic + 25% of Vres
48,950,000	~	55,800,000	Good	3	Basic + 50% of Vres
55,800,000	~	62,650,000	Very Good	4	Basic + 75% of Vres
62,650,000	~		Excellent	5	over (Basic + 75% of Vres)

Figure 90: Word scale development for flood control and drainage effect criterion

Capacity of facilities

Div.	Facilities	Constraints (El.m)	Distance (km)	Capacity (m^3/d)
Irrigation facility	Toegang	43.5	12.3	7,085
	Maeho	45.0	10.5	86,402
	Boelima	44.0	5.6	6,555
	Gamnamugol	44.0	5.6	2,298
	Hoesang	45.0	3.5	8,865
	Jugam	45.0	0.3	57,802
	Sub-total			169,006
Drinking water facility	Pungyang	44.2	10.0	1,000
	Saboel Maeho	41.5	11.0	18,900
	Sub-total			19,900
Total				188,906

Word Scale

Storage range (m^3)	Word scale	Scaling	Remarks
-1,889,000 ~ 0	Poor	1	Not available
0 ~ 1,889,000	Fair	2	0~10days
1,889,000 ~ 3,778,000	Good	3	10~20days
3,778,000 ~ 5,667,000	Very Good	4	20~30days
5,667,000 ~	Excellent	5	over 30days

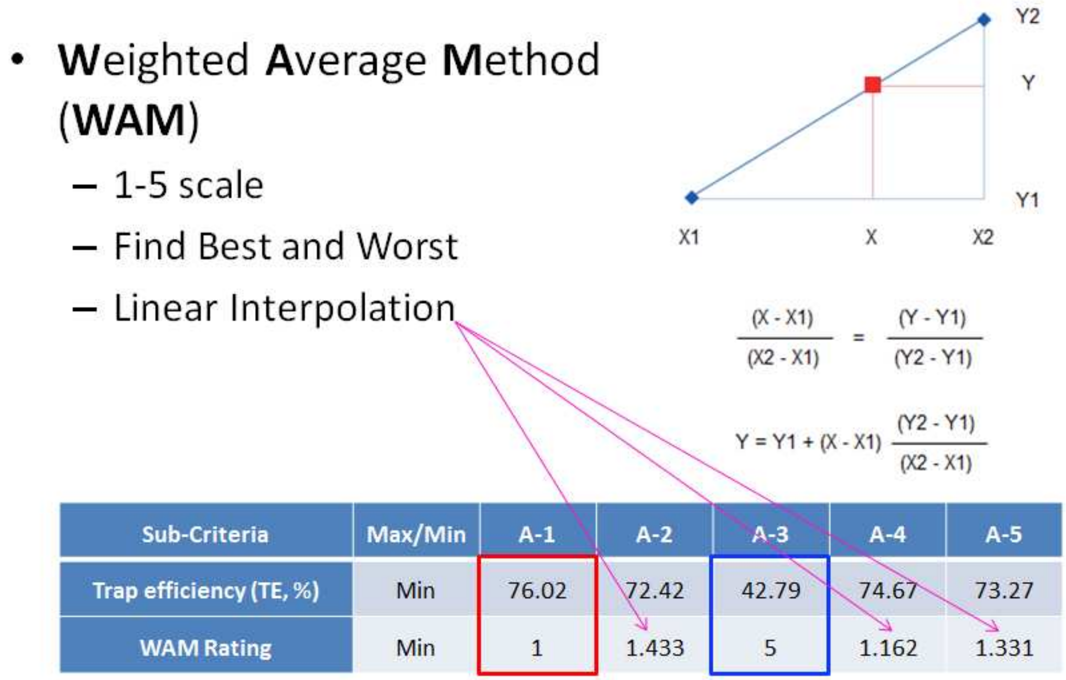
Possible water supply duration (days)	Corresponding storage (m^3)
-10	-1,889,000
0	0
10	1,889,000
20	3,778,000
30	5,667,000

Figure 91: Word scale for water supply criterion

However, two of the variables, water supply stability and flood control and drainage effect were not expressed numerically but using qualitative scores such as ‘Excellent, Very Good, Good, Poor, and Bad’. This word scale is converted into corresponding numerical scores as shown in Figure 89 and Figure 90.

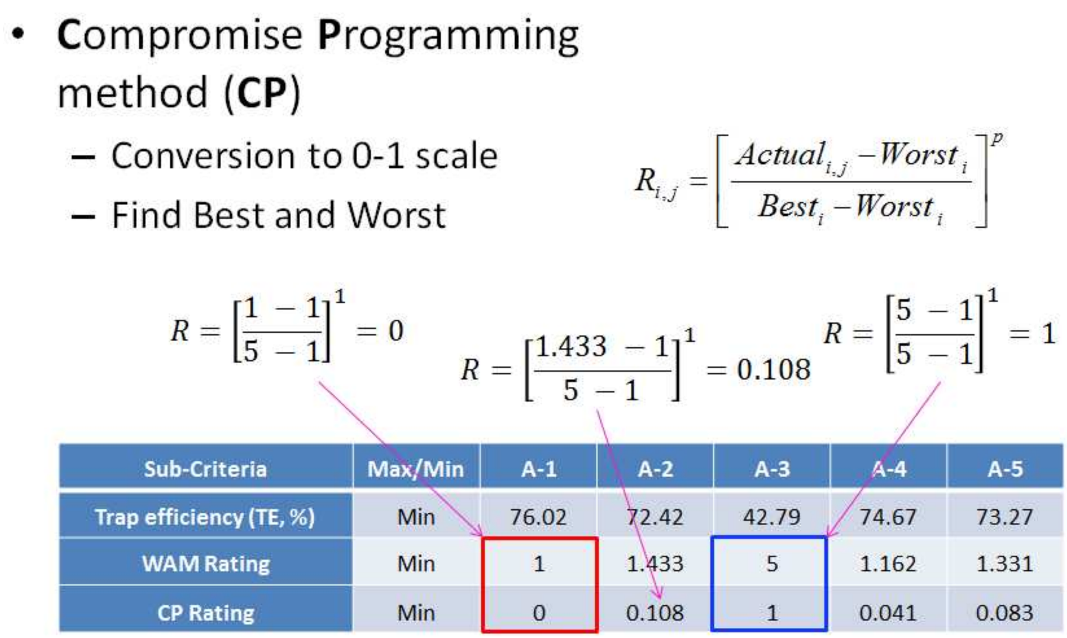
6.8.4 MCDA rating methods

Four MCDA rating methods were used to evaluate the five cases; (1) Weighted Average Method (WAM), (2) Compromise Programming Method (CP), (3) Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), and (4) a hybrid method (PROMETHEE-WAM). Table 28 shows the results for all cases given MCDA input data and modeling results. The calculation procedures are shown in Figure 92-Figure 97.



Sub-Criteria	Max/Min	A-1	A-2	A-3	A-4	A-5
Trap efficiency (TE, %)	Min	76.02	72.42	42.79	74.67	73.27
WAM Rating	Min	1	1.433	5	1.162	1.331

Figure 92: Weighted Average Method (WAM) scaling method

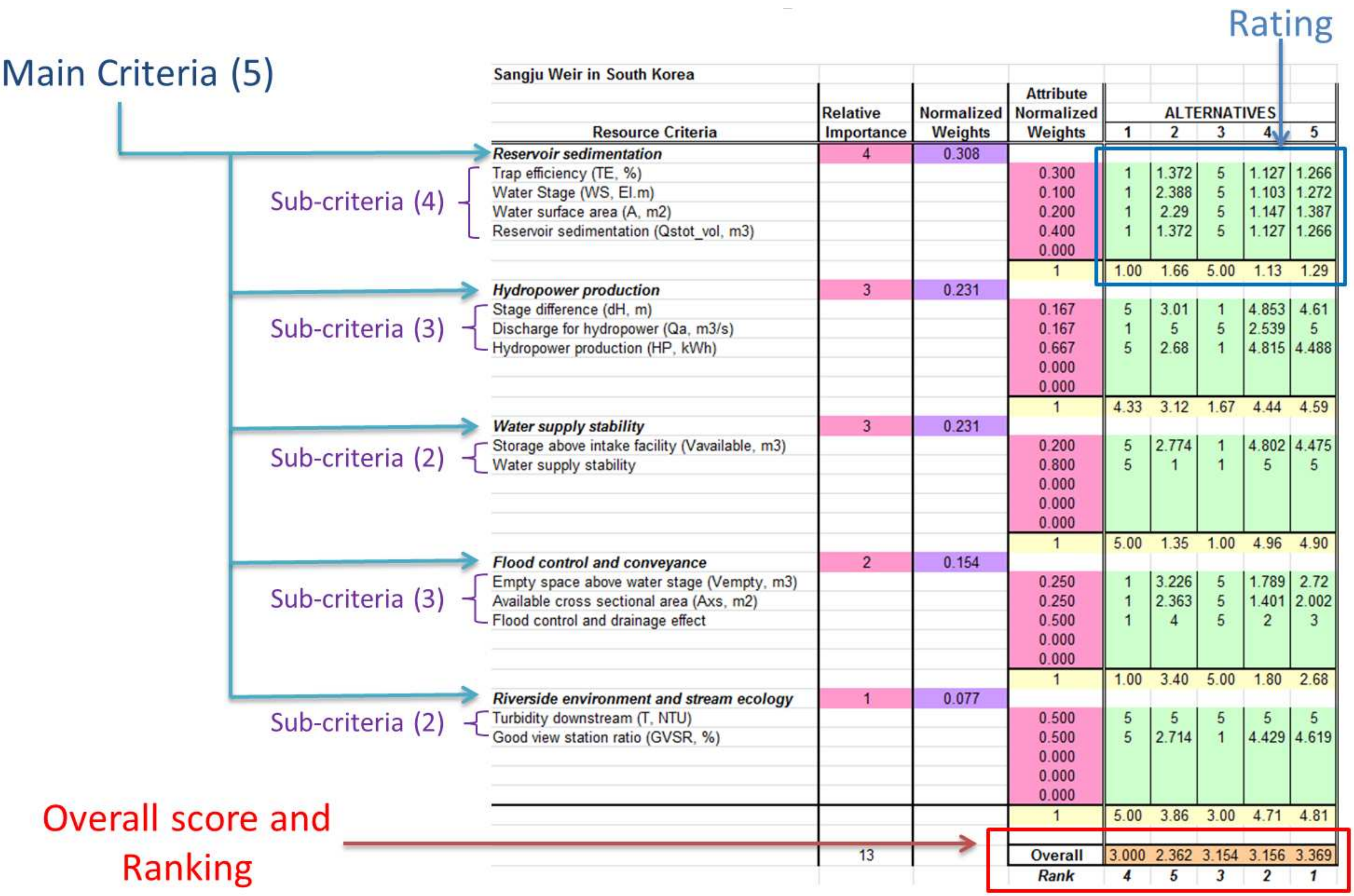


Sub-Criteria	Max/Min	A-1	A-2	A-3	A-4	A-5
Trap efficiency (TE, %)	Min	76.02	72.42	42.79	74.67	73.27
WAM Rating	Min	1	1.433	5	1.162	1.331
CP Rating	Min	0	0.108	1	0.041	0.083

Figure 93: Compromise Programming (CP) scaling method

Table 28: MCDA criteria, function, cases and inputs for MCDA simulation

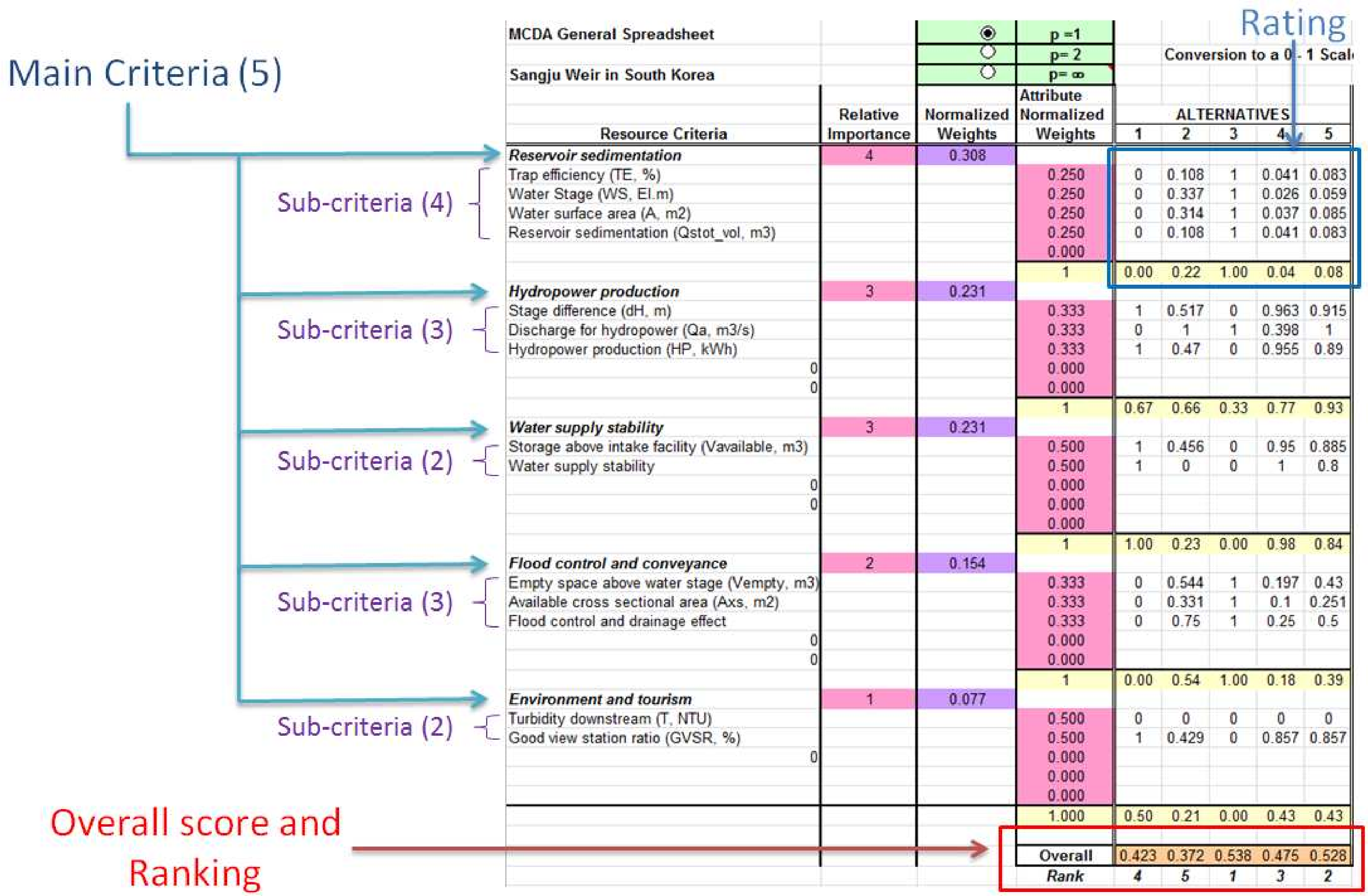
Criteria	Sub-Criteria	Max/Min	Alt. 1 (EL.47.0m)	Alt. 2 (EL.43.6m)	Alt. 3 (EL.37.2m)	Alt. 4 (flood season)	Alt. 5 (Q condition)
Reservoir sedimentation							
	Trap efficiency (TE, %)	Min	79.83	77.58	55.58	79.06	78.22
	Water Stage (WS, El.m)	Min	47.00	43.60	37.20	46.75	46.33
	Water surface area (A, km^2)	Min	5.64	3.93	0.34	5.45	5.13
	Reservoir sedimentation (Qs, 10^6 m^3)	Min	3.58	3.48	2.49	3.55	3.51
Hydropower production							
	Stage difference (dH, m)	Max	6.84	3.44	-	6.58	6.17
	Discharge for hydropower (Qa, m^3/s)	Max	36.94	38.64	38.64	37.59	38.64
	Hydropower production (HP, GWh)	Max	408.1	171.4	-	389.2	355.9
Water supply stability							
	Storage above intake facility (Vs, 10^6 m^3)	Max	13.0	(2.0)	(14.0)	11.7	9.5
	Water supply stability	Max	Excellent	Poor	Poor	Excellent	Excellent
Flood control and conveyance							
	Empty space above water stage (Vf, 10^6 m^3)	Max	42.0	57.0	69.1	47.4	53.7
	Available cross sectional area (Axs, m^2)	Max	2,734	2,984	3,470	2,807	2,918
	Flood control and drainage effect	Max	Poor	Very Good	Excellent	Fair	Good
Environment and riverside amenity							
	Turbidity downstream (T, NTU)	Min	6.32	6.32	6.32	6.32	6.32
	Good view station ratio (GVSR, %)	Max	33.3	14.2	-	28.6	30.2



Sangju Weir in South Korea

Resource Criteria	Relative Importance	Normalized Weights	Attribute Normalized Weights	ALTERNATIVES 1	2	3	4	5
Reservoir sedimentation	4	0.308						
Trap efficiency (TE, %)			0.300	1	1.372	5	1.127	1.266
Water Stage (WS, El.m)			0.100	1	2.388	5	1.103	1.272
Water surface area (A, m2)			0.200	1	2.29	5	1.147	1.387
Reservoir sedimentation (Qstot_vol, m3)			0.400	1	1.372	5	1.127	1.266
			0.000					
			1	1.00	1.66	5.00	1.13	1.29
Hydropower production	3	0.231						
Stage difference (dH, m)			0.167	5	3.01	1	4.853	4.61
Discharge for hydropower (Qa, m3/s)			0.167	1	5	5	2.539	5
Hydropower production (HP, kWh)			0.667	5	2.68	1	4.815	4.488
			0.000					
			0.000					
			1	4.33	3.12	1.67	4.44	4.59
Water supply stability	3	0.231						
Storage above intake facility (Vavailable, m3)			0.200	5	2.774	1	4.802	4.475
Water supply stability			0.800	5	1	1	5	5
			0.000					
			0.000					
			0.000					
			1	5.00	1.35	1.00	4.96	4.90
Flood control and conveyance	2	0.154						
Empty space above water stage (Vempty, m3)			0.250	1	3.226	5	1.789	2.72
Available cross sectional area (Axs, m2)			0.250	1	2.363	5	1.401	2.002
Flood control and drainage effect			0.500	1	4	5	2	3
			0.000					
			0.000					
			1	1.00	3.40	5.00	1.80	2.68
Riverside environment and stream ecology	1	0.077						
Turbidity downstream (T, NTU)			0.500	5	5	5	5	5
Good view station ratio (GVSR, %)			0.500	5	2.714	1	4.429	4.619
			0.000					
			0.000					
			0.000					
			1	5.00	3.86	3.00	4.71	4.81
	13		**Overall**	3.000	2.362	3.154	3.156	3.369
			Rank	**4**	**5**	**3**	**2**	**1**

Figure 94: WAM method



MCDA General Spreadsheet

Sangju Weir in South Korea

p =1 / p= 2 / p= ∞

Conversion to a 0 - 1 Scal

Resource Criteria	Relative Importance	Normalized Weights	Attribute Normalized Weights	1	2	3	4	5
Reservoir sedimentation	4	0.308						
Trap efficiency (TE, %)			0.250	0	0.108	1	0.041	0.083
Water Stage (WS, El.m)			0.250	0	0.337	1	0.026	0.059
Water surface area (A, m2)			0.250	0	0.314	1	0.037	0.085
Reservoir sedimentation (Qstot_vol, m3)			0.250	0	0.108	1	0.041	0.083
			0.000					
			1	0.00	0.22	1.00	0.04	0.08
Hydropower production	3	0.231						
Stage difference (dH, m)			0.333	1	0.517	0	0.963	0.915
Discharge for hydropower (Qa, m3/s)			0.333	0	1	1	0.398	1
Hydropower production (HP, kWh)			0.333	1	0.47	0	0.955	0.89
0			0.000					
0			0.000					
			1	0.67	0.66	0.33	0.77	0.93
Water supply stability	3	0.231						
Storage above intake facility (Vavailable, m3)			0.500	1	0.456	0	0.95	0.885
Water supply stability			0.500	1	0	0	1	0.8
0			0.000					
0			0.000					
			0.000					
			1	1.00	0.23	0.00	0.98	0.84
Flood control and conveyance	2	0.154						
Empty space above water stage (Vempty, m3)			0.333	0	0.544	1	0.197	0.43
Available cross sectional area (Axs, m2)			0.333	0	0.331	1	0.1	0.251
Flood control and drainage effect			0.333	0	0.75	1	0.25	0.5
0			0.000					
0			0.000					
			1	0.00	0.54	1.00	0.18	0.39
Environment and tourism	1	0.077						
Turbidity downstream (T, NTU)			0.500	0	0	0	0	0
Good view station ratio (GVSR, %)			0.500	1	0.429	0	0.857	0.857
0			0.000					
			0.000					
			0.000					
			1.000	0.50	0.21	0.00	0.43	0.43
			Overall	0.423	0.372	0.538	0.475	0.528
			Rank	4	5	1	3	2

Figure 95: Compromise Programming (CP) rating method

Preference Table for the Reservoir sedimentation criterion

Sub-Criteria	Indifference %	Normalized	A1-A1	A1-A2	A1-A3	A1-A4	A1-A5	A2-A1	A2-A2	A2-A3	A2-A4	A2-A5	A3-A1	A3-A2	A3-A3	A3-A4
Trap efficiency (TE, %)	0.0%	0.3	0	0	0	0	0	1	0	0	1	1	1	1	0	1
Water Stage (WS, El.m)	0.0%	0.1	0	0	0	0	0	1	0	0	1	1	1	1	0	1
Water surface area (A, m2)	0.0%	0.2	0	0	0	0	0	1	0	0	1	1	1	1	0	1
voir sedimentation (Qstot_v	0.0%	0.4	0	0	0	0	0	1	0	0	1	1	1	1	0	1
	0.0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Preference																
Preference Index			0	0	0	0	0	1	0	0	1	1	1	1	0	1

Outranking Table for the Reservoir sedimentatio criterion

	A-1	A-2	A-3	A-4	A-5	ϕ^{+}
A-1	0	0	0	0	0	0
A-2	1	0	0	1	1	0.75
A-3	1	1	0	1	1	1
A-4	1	0	0	0	0	0.25
A-5	1	0	0	1	0	0.5
ϕ^{-}	1	0.25	0	0.75	0.5	
$\phi = \phi^{+} - \phi^{-}$	-1.000	0.500	1.000	-0.500	0.000	
Ranking	5	2	1	4	3	

Figure 96: PROMETHEE rating method

SANGJU WEIR operations to mitigate sedimentation problems (MCDA spreadsheet)

Table Continues to the Right

Sangju Weir in South Korea

Outranking Comparison Using the PROMETHEE Method with Indifference Ranges for the Main Criteria combined with the Weighted Average Method for the Sub-criteria

Preference Table for the Main Criteria

Criteria	Indifference %	Normalized	A1-A1	A1-A2	A1-A3	A1-A4	A1-A5	A2-A1	A2-A2	A2-A3	A2-A4	A2-A5	A3-A1
Reservoir sedimentation	0.0%	0.307692308	0	0	0	0	0	1	0	0	1	1	1
Hydropower production	0.0%	0.230769231	0	1	1	0	0	0	0	1	0	0	0
Water supply stability	0.0%	0.230769231	0	1	1	1	1	0	0	1	0	0	0
Flood control and conveyance	0.0%	0.153846154	0	0	0	0	0	1	0	0	1	1	1
Environment and tourism	0.0%	0.076923077	0	1	1	1	1	0	0	1	0	0	0
Preference													
Preference Index			0	0.538462	0.538462	0.307692	0.307692	0.461538	0	0.538462	0.461538	0.461538	0.46153

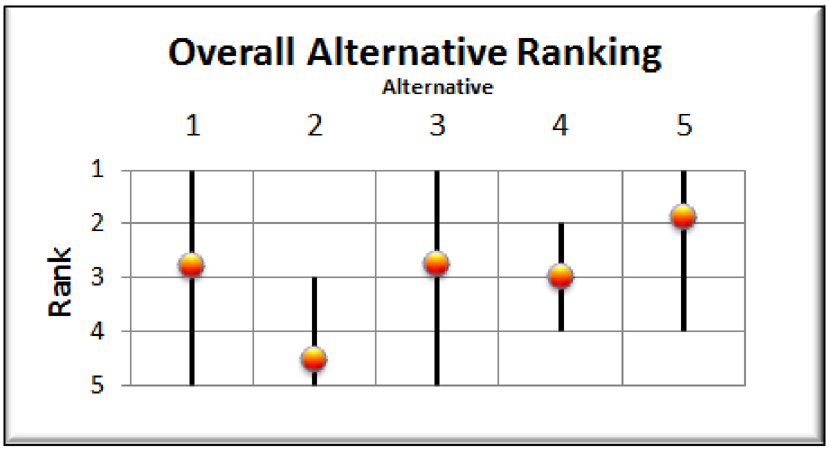
Outranking Table

	A-1	A-2	A-3	A-4	A-5	ϕ^+
A-1	0	0.538462	0.538462	0.307692	0.307692	0.423077
A-2	0.461538462	0	0.538462	0.461538	0.461538	0.480769
A-3	0.461538462	0.461538	0	0.461538	0.461538	0.461538
A-4	0.692307692	0.538462	0.538462	0	0.230769	0.5
A-5	0.692307692	0.538462	0.538462	0.692308	0	0.615385
ϕ^-	0.576923077	0.519231	0.538462	0.480769	0.365385	
$\phi = \phi^+ - \phi^-$	-0.154	-0.038	-0.077	0.019	0.250	
Ranking	5	3	4	2	1	

Figure 97: PROMETHEE-WAM rating method

6.9 MODELING RESULTS

According to the simulation results, Alt. 5 has the first position in overall simulations, which has 84 times simulations by rating methods and RIF. The four MCDA methods to determine ratings and decision makers' groups were considered. The overall ranking in Figure 98 shows that Alt. 5 has the priority. The detail results are in Appendix C.



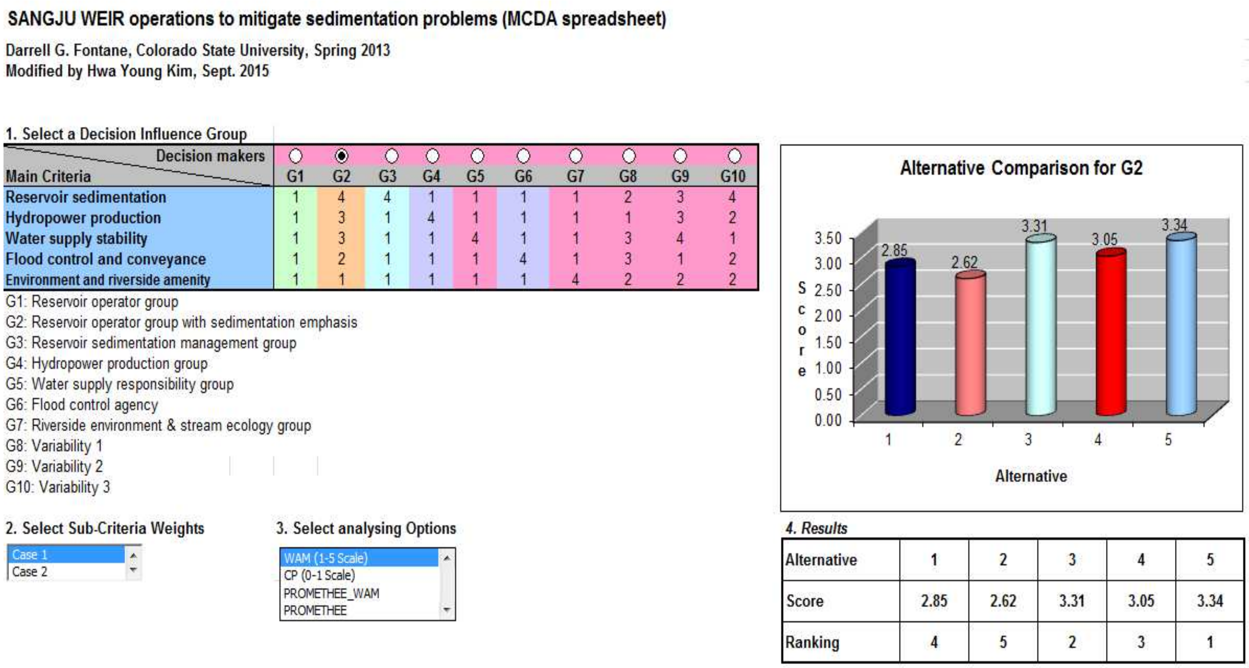
Comprehensive Results

Alternative	1	2	3	4	5
Average ranking	2.80	4.53	2.75	3.00	1.90
Ranking	3	5	2	4	1

Figure 98: Comprehensive MCDA result of overall alternative ranking

The results vary according to the rating methods and the decision makers group which feature different relative importance factors (RIF). The rankings also fluctuated depending on the sub-criteria's RIF which were modeled with equal RIF and different RIF.

In this study, the most important issue is the reservoir sedimentation at the Sangju Weir. Figure 99-Figure 100 present the modeling results. For the case with the highest RIF for reservoir sedimentation (Group 2) and same relative importance factor for all criteria (Group 1), Alt. 5 has a superior score.



SANGJU WEIR operations to mitigate sedimentation problems (MCDA spreadsheet)

Darrell G. Fontane, Colorado State University, Spring 2013
Modified by Hwa Young Kim, Sept. 2015

1. Select a Decision Influence Group

Main Criteria \ Decision makers	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
Reservoir sedimentation	1	4	4	1	1	1	1	2	3	4
Hydropower production	1	3	1	4	1	1	1	1	3	2
Water supply stability	1	3	1	1	4	1	1	3	4	1
Flood control and conveyance	1	2	1	1	1	4	1	3	1	2
Environment and riverside amenity	1	1	1	1	1	1	4	2	2	2

G1: Reservoir operator group
G2: Reservoir operator group with sedimentation emphasis
G3: Reservoir sedimentation management group
G4: Hydropower production group
G5: Water supply responsibility group
G6: Flood control agency
G7: Riverside environment & stream ecology group
G8: Variability 1
G9: Variability 2
G10: Variability 3

2. Select Sub-Criteria Weights

Case 1
Case 2

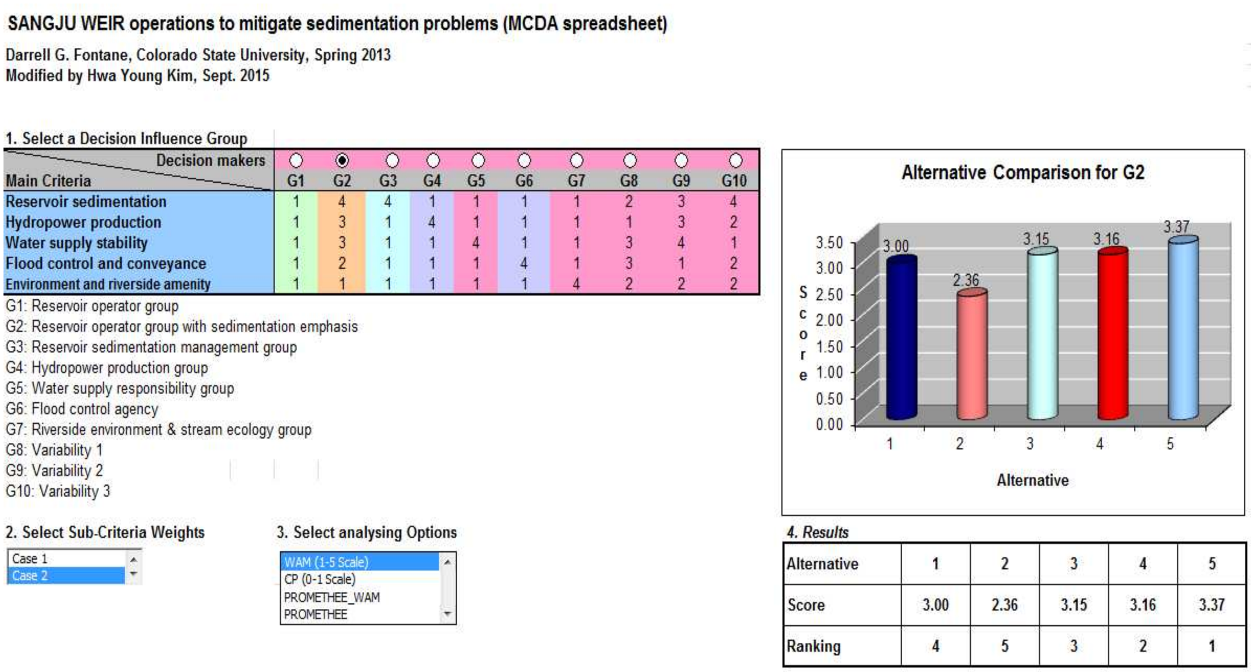
3. Select analysing Options

WAM (1-5 Scale)
CP (0-1 Scale)
PROMETHEE_WAM
PROMETHEE

4. Results

Alternative	1	2	3	4	5
Score	2.85	2.62	3.31	3.05	3.34
Ranking	4	5	2	3	1

Figure 99: MCDA simulation result for decision making group 1 (Reservoir operator group) using WAM method with same RIF for sub-criteria



SANGJU WEIR operations to mitigate sedimentation problems (MCDA spreadsheet)

Darrell G. Fontane, Colorado State University, Spring 2013
Modified by Hwa Young Kim, Sept. 2015

1. Select a Decision Influence Group

Main Criteria \ Decision makers	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
Reservoir sedimentation	1	4	4	1	1	1	1	2	3	4
Hydropower production	1	3	1	4	1	1	1	1	3	2
Water supply stability	1	3	1	1	4	1	1	3	4	1
Flood control and conveyance	1	2	1	1	1	4	1	3	1	2
Environment and riverside amenity	1	1	1	1	1	1	4	2	2	2

G1: Reservoir operator group
G2: Reservoir operator group with sedimentation emphasis
G3: Reservoir sedimentation management group
G4: Hydropower production group
G5: Water supply responsibility group
G6: Flood control agency
G7: Riverside environment & stream ecology group
G8: Variability 1
G9: Variability 2
G10: Variability 3

2. Select Sub-Criteria Weights

Case 1
Case 2

3. Select analysing Options

WAM (1-5 Scale)
CP (0-1 Scale)
PROMETHEE_WAM
PROMETHEE

4. Results

Alternative	1	2	3	4	5
Score	3.00	2.36	3.15	3.16	3.37
Ranking	4	5	3	2	1

Figure 100: MCDA simulation result for decision making group 2 (Reservoir operator group with relative important factor) using WAM method with different RIF for sub-criteria

Hence, Alt. 5 is the most appropriate alternative with regard to many stakeholders' interests. In conclusion, Alt. 5: Seasonal stage control considering upstream inflow, is proposed as the new Sangju Weir operation rule.

Season	Inflow (m^3/s)	Stage (EL. m)
Non-flood season (October-May)	Any	47.0
Flood Season (June-September)	below 50	47.0
	50 ~ 600	46.0
	above 600	44.5

Figure 101: Proposed Sangju Weir operation rules

The systematic analysis procedure, the combination of the Flow-Duration and Sediment Rating Curve (FD/SRC) method, the Series Expansion of the Modified Einstein Point Procedure (SEMEPP), and the Multi-Criterion Decision Analysis (MCDA) method, are deemed useful to find an optimum operation rule which can mediate the disputes among various decision makers related to reservoir operation.

7 CHAPTER VII – SUMMARY AND CONCLUSIONS

Three purposes of this study were fulfilled according to their individual procedures as follows.

First, the Integrated Reservoir Sedimentation Estimation Procedure (IRSEP) was proposed to estimate the reservoir sedimentation at weirs and low-head dams in this studay. IRSEP integrates all conventional methods related to reservoir sedimentation: (1) Flow-Duration (FD), (2) Sediment-Rating Curve (SRC), (3) Series Expansion of the Modified Einstein Point Procedure (SEMEPP), and (4) Trap efficiency (T_E), in order to estimate reservoir sedimentation rate. Through stream flow runoff modeling and channel geometry analysis, the trap efficiencies in accordance with certain stages were defined. The trap efficiency of Sangju Weir was calculated for each sediment size fraction as a function of two variables, sediment load at daily discharges and particle size distribution of the sediment transported by the Nakdong River. The trap efficiency is also dependent on channel geometry, inflow discharge and reservoir stage determined by the operation rules at Sangju Weir. Then, the amount of reservoir sedimentation was calculated by multiplying the annual sediment load with trap efficiencies, which vary with discharge and water stage. As a result, the reservoir filling rates were examined.

Second, the B/C ratio and break-even point between hydropower production revenues and sediment excavation costs were estimated using a Benefit and Cost Analysis (BCA) method based on daily-modeling.

Since the operation rules of Sangju Weir significantly affect the trap efficiency and the volume of dredging, it is essential to determine the effects of the reservoir operation rules using the Multi-Criterion Decision Analysis (MCDA) technique in order to seek improvement in the operation rules to mitigate sedimentation costs, simultaneously considering the other decision makers' interests. Finally, a new operational rule for Sangju Weir was proposed.

The conclusions of this research with respect to the sediment problems and reservoir operation rule are summarized as follows:

(1) Using the Integrated Reservoir Sedimentation Estimation Procedure (IRSEP) which integrates all conventional methods related to reservoir sedimentation: (1) Flow-Duration (FD), (2) Sediment-Rating Curve (SRC), (3) Series Expansion of the Modified Einstein Point Procedure (SEMEPP), and (4) Trap efficiency (T_E), the total sediment yield (Q_T) and trap efficiency (T_E) were calculated. The total incoming sediment load and the average trap efficiency (T_E) at the lowest (EL 37.2m) and highest (EL47.0m) stages were estimated as 425,000 tons/year, 50.1 % and 78.1%, respectively; and the maximum annual amount of reservoir sedimentation at Sangju Weir was estimated as 332,000 tons/year (207,000 m^3/year) which corresponds to 0.76 %/year of the total reservoir storage of Sangju Weir. In contrast, the minimum reservoir sedimentation rate was 0.49 %/year, which occurs when the water stage was the lowest (EL 37.2m). According to this result, reservoir operation rules incorporating management of water stage considerably affect reservoir sedimentation.

(2) Since the operation rules of Sangju Weir affects significantly the trap efficiency, a Benefit and Cost Analysis (BCA) based on daily-modeling was performed in order to find the break-even point between hydropower production revenues and sediment excavation

costs. For daily sediment transport modeling, historical and predicted reservoir stream flow data (2015-2034) were generated by the Tank model using seventy-six daily precipitation data. The B/C ratio obtained 20 years of daily simulation was calculated as 2.28. Also, the discharge and stage thresholds, balancing both hydropower production revenues and sediment excavation costs, are found as 600 m^3/s and EL 43.6 m, respectively.

(3) Based on the daily Multi-Criterion Decision Analysis (MCDA) modeling, the most favorable Sangju Weir operation rules to mitigate reservoir sedimentation were found in Alt. 5 after including seasonal management of water stage according to the magnitude of the upstream inflow. Proposed seasonal management stage and operation rules are shown below:

Season	Inflow (m^3/s)	Stage (EL. m)
Non-flood season (October-May)	Any	47.0
Flood Season (June-September)	below 50	47.0
	50 ~ 600	46.0
	above 600	44.5

The systematic analysis procedure, the combination of the Integrated Reservoir Sedimentation Estimation Procedure (IRSEP) and the Multi-Criterion Decision Analysis (MCDA) method, are deemed useful to find optimum operation rules of weirs and low-head dams, which can mediate the disputes among various decision makers who have different interests related to reservoir operation. The proposed methodology could be applied to the other weirs of the Four River Restoration Project, and elsewhere.

BIBLIOGRAPHY

Ackoff, R. L. (1978). *The Art of Problem Solving.* John Wiley & Sons, Inc., New York, NY.

An, S. D., & Julien, P. Y. (2014). "Three-dimensional Modeling of Turbid Density Currents in Imha Reservoir, South Korea". *Journal of Hydraulic Engineering, ASCE*, Vol. 140, No. 5, pp. 05014004-1-15.

Andritz Hydro. (2010). *4-Rivers K (Sangju) Expected Prototype Turbine Performance Hill Chart.* Andritz Hydro, Ravensburg, Germany.

Annandale, G. W. (2001). *Reservoir Conservation and Sediment Management.* Water Bank Group, Washington, D.C.

Aufdenkampe, A. K., Mayorga, E., Raymond, P. A., Mclack, J. M., Doney, S. C., Alin, S. R., et al. (2011). "Riverine coupling of biogeochemical cycles between land, oceans, and atmosphere". *The Ecological Society of America*, Vol. 9, No. 1, pp.53-60.

Bonghwa-gun, Yeongju-si, & Yecheon-gun. (2013). Public letters for gravel and sand mining location and amount from Naesung Stream. Yeongju Multi-purpose Dam Construction Office, K-water, Yeongju-si, South Korea.

Borland, W. M. (1971). *Reservoir sedimentation, Chapter 29. In H. W. Shen (Editor), River Mechanics Volume 2.* Fort Collins, CO.

Borland, W. M. (1975). *Sedimentation Engineering, American Society of Civil Engineering Manual No. 54.* American Society of Civil Engineers (ASCE).

Brabben, T. E. (1988). *Reservoir Desilting Methods.* Wallingford.

Brandt, S. A. (2000). "Classification of geomorphological effects downstream of dams". *Catena*, Vol. 40, pp. 375-401.

Brown, C. B. (1943). *The Control of Reservoir Silting* (Vol. Miscellaneous Publication No. 521). U.S. Department of Agriculture, Washington, D.C.

Brown, C. B. (1944). "Discussion of 'Sediment in Reservoirs' by B.J. Witzig." Trans. ASCE, Vol. 109.

Brune, G. M. (1953). "Trap Efficiency of Reservoirs". *American Geophysical Union Trans.*, Vol. 34, No. 3, pp. 407-418.

Burkham, D. E., & Dawdy, D. R. (1980). *General study of the Modified Einstein Method of Computing Total Sediment Discharge (Geological Survey Water-Supply Paper 2066).* U.S. Government Printing Office, Washington, D.C.

Churchill, M. A. (1948). Discussion of "Analysis and Use of Reservoir Sedimentation Data" by L. C. Gottschalk: Federal Inter-Agency Sedimentation Conference, Denver, CO, 1947, Proceeding, pp. 139-140.

Cohon, J. L., & Marks, D. H. (1975). "A review and evaluation of multi objective programming techniques". *Water Resources Research*, Vol. 11, No. 2, pp. 208-220.

Cohon, J. L., Church, R. L., & Sheer, D. P. (1979). "Generating Multiobjective Trade-Offs: An Algorithm for Bicriterion Problems". *Water Resources Research*, Vol. 15, No. 5, pp. 1001-1010.

Colby, B. R., & Hembree, C. H. (1955). "*Computations of Total Sediment Discharge Niobrara River Near Cody, Nebraska (Geological Survey Water-Supply Paper 1357).*" U.S. Government Printing Office, Washington, D.C.

Colby, B. R., & Hubbell, D. W. (1961). *Simplified Method for Computing Total Sediment Discharge with the Modified Einstein Procedure (Geological survey Water-Supply Paper 1593).* U.S. Government Printing Office, Washington, D.C.

Einstein, H. A. (1942). Formulas of the transportation of bed load. *American Society of Civil Engineers (ASCE)*, pp. 561-597.

Einstein, H. A. (1950). *The bed-load function for sediment transportation in open channel flows (Technical Bulletin No. 1026).* U.S. Department of Agriculture Soil Conservation Service, Washington, D.C.

Einstein, H. A. (1965). *Spawning Grounds: Final Report.* Universtiy of California, Hydraulic Engineering laboratory, CA.

Fan, J. (1985a). Methods of preserving reservoir capacity. Methods of Computing Sedimentation in Lake and Reservoir, A contribution to the International Hydrological Programme, IHP-II Project A. 2.6.1 Panel, Paris, pp. 65-164. UNESCO.

Fan, J. (1985b). Methods of preserving reservoir capacity. Lecture Notes of the Training Course on Reservoir Sedimentation, Seriese of Publication IRTCES, pp. II.1-II.96, Beijing, China.

Fan, J., & Morris, G. L. (1992). "Reservoir Sedimentation. II: Reservoir Desiltation and Long-term Storage Capacity". *Journal of Hydraulic Engineering, ASCE*, pp. 370-384.

Feather, T. D., Harrington, K. W., & Capan, D. T. (1995). *Trade-off analysis for environmentatl projects: An annotated bibliography.* Army Engineering inst for water resources, Fort Belvoir, VA.

Flug, M., Seitz, H. L., & Scott, J. F. (2000). "Multicriteria Decision Analysis Applied to Glen Canyon Dam". *Journal of Water Resources Planning and Management*, Vol. 126, No.5, pp. 270-276.

Fontane, D. G. (2014). Water Resources Systems Analysis (CIVE 546, 2014 Spring) lecture note, Department of Civil and Environmental Engineering, CSU, Fort Collins, CO.

Frenette, M., & Julien, P. Y. (1986). Advances in Predicting Reservoir Sedimentation. *3rd International Symposium on River Sedimentation*, *ISRS-111, pp. 26-46.* Oxford, UK.

Gershon, M., Duckstein, L., & McAniff, R. (1982). "Multiobjective river basin planning with qualitative criteria". *Water Resources Research*, Vol. 18, No. 2, pp. 193-202.

Goicoechea, A., Duckstein, L., & Fogel, M. M. (1976). "Multiobjective Programing in Watershed Management: A Studay of the Charleston Watershed". *Water Resources Research*, Vol. 12, No. 6, pp. 1085-1092.

Graf, W. H. (1984). *Hydrulics of Sediment Transport.* Water Resources Publications, Highlands Ranch, CO.

Guo, J., & Julien, P. Y. (2004). "Efficient algorithm for computing Einstein integrals". *Journal of Hydraulic Engineering*, Vol. 130, No. 12, pp. 1198-1201.

Han River Flood Control Office. (2015). *WAMIS*. Retrieved 11 1, 2015, from Water Resources Management Information System: http://www.wamis.go.kr

Isan Corp. & Dongho Corp. (2009). *A Report of master plan for the Nakdong River Implimentation Project (revised).* Busan Regional Office of Costruction Management, Busan, South Korea.

Ji, U., Julien, P. Y., & Park, S. K. (2011). "Sediment Flushing at the Nakdong River Esturary Barrage". *Journal of Hydarulic Engineering, ASCE*, Vol. 137, No. 11, pp. 1522-1535.

Ji, U., Velleux, M., Julien, P. Y., & Hwang, M. H. (2014). "Risk assessment of watershed erosion at Naesung Stream, South Korea". *Journal of Environmental Management*, Vol. 138, pp.16-26.

Julien, P. Y. (1998). *Erosion and Sedimentation (1st paperback ed.).* Cambridge University Press, Cambridge, UK.

Julien, P. Y. (2002). *River Mechanics*. Cambridge University Press, New York, NY.

Julien, P. Y. (2010). *Erosion and Sedimentation* (2nd ed.). Cambridge University Press, New York, NY.

Keulegan, G. H. (1938). "Laws of turbulent flow in open channels". *Journal of Research of the United States National Bureau of Standards, Vol. 21*, pp. 707-741.

Kim, H. S., & Julien, P. Y. (2006). "Soil erosion modeling using RUSLE and GIS on the Imha watershed". *Water Engineering Research*, Vol. 7, No. 1, pp. 29-41.

Ko, S. G., Fontane, D. G., & Labadie, J. W. (1992). "Multiobjective optimization of reservoir systems operation". *Water Resources Bulletin*, *American Water Resources Association*, Vol. 28, No. 1, pp. 111-127.

Kondolf, G. M. (1997). "Hungry Water: Effects of Dams and Gravel Mining on River Channels". *Environmental Management*, Vol. 21, No. 4, pp. 533-551.

Korea Engineering Consultants Corp. (2009). *Nakdong River Restoration Project 33 unit (Sangju) detailed design.* Ministry of Land, Transport and Maritime Affair (MLTM), South Korea.

K-water. (2012). *Four Major Rivers Restoration Project Technical Note.* K-water, Daejon, South Korea.

K-water. (2012). *The instruction for weir operation rule.* K-water, Daejon, South Korea.

K-water. (2013). *The Sediment Management Plan Establishment Research for channel stabilization.* Ministry of Land, Transport and Maritime Affair (MLTM), South Korea.

K-water. (2014). *Dam Operation Mannual.* South Korea: K-water, Daejon, South Korea.

K-water. (2014). *Hydropower generation management system.* K-water, Daejon, South Korea.

K-water. (2014). *Nakdong River Estuary Barrage Excavation Amount and Costs.* Nakdong River

Dams and Weirs Operation Center, K-water, Busan, South Korea.

Lai, J. S., & Shen, H. W. (1996). "Flushing Sediment Through Reservoirs". *Journal of Hydraulic Research*, Vol. 34, No. 2, pp. 237-255.

Lara, J. M. (1966). *Computation of 'Z's' for use in the modified Einstein procedure.* U.S. Department of the Interior, Bureau of Reclamation, Office of Chief Engineer.

Lopez, J. L. (1978). Mathematical Modeling of Sediment Deposition in Reservoir. *Ph.D. dissertation, Colorado State University*. Fort Collins, CO.

Mahmood, K. (1987). *Reservoir sedimentation: IMPACT, Extent, and Mitigation (World Bank Technical Paper; no. 71).* Washington, D.C.

McCUEN, R. H. (1989). *Hydrologic analysis and design.* New Jersey: Prentice Hall, Englewood Cliffs, NJ.

MCT. (2001). *Water Vision 2020.* Ministry of Construction and Transportation (MCT), South Korea.

Miller, C. R., & Borland, W. M. (1963). "Stabilization of Fivemile and Muddy Creeks". *Jouranal of the Hydraulics Division*, Vol. 89, No. 1, pp. 67-98.

MLTM. (2011). *Hydrologic annual report in 2010: Sediment measurement.* Ministry of Land, Transport, and Maritime Affair (MLTM), South Korea.

MLTM. (2012). *Hydrological Annual Report in 2011: Sediment measurement.* Ministry of Land, Transport, and Maritime Affair, South Korea.

Morgan, R. P. (1995). *Soil Erosion and Conservation.* Longman Group, Essex.

Morris, G. L., & Fan, J. (1997). *Reservoir Sedimentation Handbook: Design and Management of Dams, Reservoir, and Watershed for Sustainable Use.* McGraw Hill, New York, NY.

Rice, T. L. (1981). Reservoir Sedimentation Modeling. *Ph.D. Dissertation*. Fort Collins, CO.

Rouse, H. (1937). "Modern conceptions of the mechanics of turbulence". *Transactions of the American Society of Civil Engineers*, Vol. 102, pp. 463-505.

Saman Corp. & Isan Corp. (2012). *A Report of master plan for the Naesung Stream (National River) Improvement Project.* Busan Regional Office of Costruction Management, Busan, South Korea.

Saman Corp. & Isan Corp. (2013). *A Report of master plan for the Naesung Stream (Locall River) Improvement Project.* Busan Regional Office of Construction Mangement, Busan, South Korea.

Saman Corp. & Isan Corp. (2013). *A report of master plan for the Nakdong River Improvement Project (revised).* Busan Regional Office of Costruction Management, Busan, South Korea.

Saman Corp. (1991). *A Report of master plan forthe Yeong Stream Improvement Project.* Gyeongsangbuk-do, South Korea.

Samsung Inc. (2009). *Yeongju multi-purpose dam detail design.* Samsung Inc., Seoul, South Korea.

Sangju Weir Operation Office, K-water. (2014). Sangju Weir operation constraints survey. K-water, Daejon, South Korea.

Shah-Fairbank, S. C. (2009). Seriese expansion of the Modified Einstein Method. *Ph.D. dissertation*. Colorado State University, Fort Collins, CO.

Shah-Fairbank, S. C., & Julien, P. Y. (2015). "Sediment load calculations from point measurements in sand-bed rivers". *International Journal of Sediment Research*, Vol. 30, No. 1, pp. 1-12.

Shah-Fairbank, S. C., Julien, P. Y., & Baird, D. C. (2011). "Total Sediment Load from SEMEP

Using Depth-Integrated Concentration Measurements". *Journal of Hydraulic Engineering, ASCE*, Vol. 137, No. 12, pp. 1606-1614.

Shen, H. E., & Hung, C. S. (1983). "Remodified Einstein Procedure for Sediment Load". *Journal of Hydraulic Engineering*, Vol. 109, No.4, pp. 565-578.

Simons, D. B., & Senturk, F. (1992). *Sediment Transport Technology: Water and Sediment Dynamics.* Water Resources Publications, Littleton, CO.

Simons, Li, & Ass. (1982). Engineering Analysis of Fluvial Systems. Fort Collins, CO.

Sugawara, M., Watanabe, E., Ozaki, E., & Katsuyama, Y. (1984). "Tank model with snow component". *The National Research Center for Disaster Prevention*.

Tauxe, G. W., Inman, R. R., & Mades, D. M. (1979). "Multiobjective Dynamic Programing With Application to a Reservoir". *Water Resources Research*, Vol. 15, No. 6, pp. 1403-1408.

U.S. Bureau of Reclamation. (2006). *Erosion and Sedimentation Manual* (Vols. 20402-0001). U.S. Government Printing Office, Washington D.C.

USDA. (2005). *SWAT*. Retrieved 12 1, 2015, from Soil Water Assessment Tool: http://swat.tamu.edu/software/avswat/

Williams, G. P., & Wolman, M. G. (1984). *Downstream Effects of Dams on Alluvial Rivers (Geological Survey Professional Paper; 1286).* U.S. Government Printing Office, Washington, D.C.

Wohl, E. (2014). Fluvial Geopmorphology (GEOL652, 2014 Spring) lecture note, Department of GeoScience, Colorado State University, Fort Collins, CO.

Wohl, E. (2014). *Rivers in the Landscape: Science and Management.* Wiley Blackwell, Hoboken, NJ.

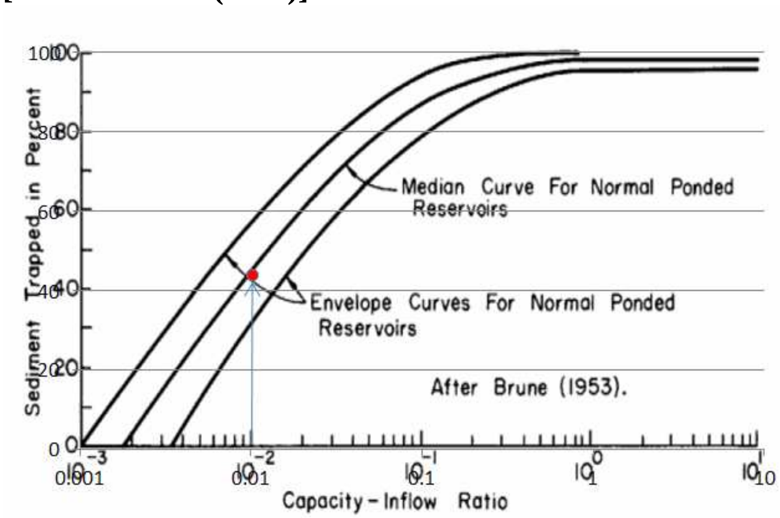
Woo, H. S., Kim, W., & Ji, U. (2015). *River hydraulics.* Chungmoongak, Paju-si, Gyeonggi-do, South Korea.

Yoon, Y. N. (2009). *Hydrology Basic and Application.* Chungmungak, Paju-si, Gyeonggi-do, South Korea.

Yucel, O., & Graf, W. H. (1973). Bed Load Deposition in Reservoir. Istanbul, Turkey.

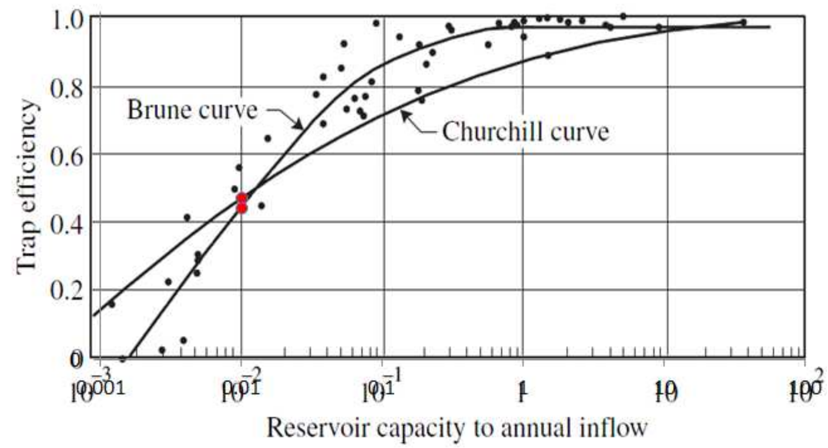
APPENDIX A: TRAP EFFICIENCY CALCULATION BY BRUNE AND CHURCHILL METHODS

[Brune's curve (1953)]



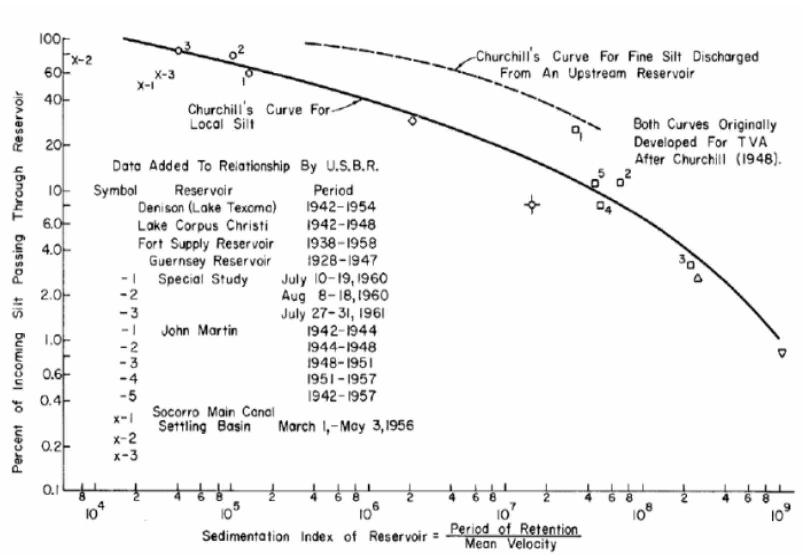
Reservoir storage =	27.4	MCM
Mean annual inflow (Qin)=	95	cms
	2,996	MCM
Capacity-Inflow ratio =	0.01	
Trap efficiency =	44	%

[USBR method (2006)]



Reservoir storage =	27.4	MCM
Mean annual inflow (Qin)=	95	cms
	2,996	MCM
Capacity-Inflow ratio =	0.01	
Trap efficiency in Brune curve =	0.44	
Trap efficiency in Churchill curve =	0.47	

[Churchill curve (1948)]



Mean annual inflow (Qin)=	95	cms
	2,996	MCM
Reservoir storage =	27.4	MCM
Period of retention =	0.01	
Length of reservoir =	15,517	m
Mean XS area =	1,766	m2
Mean velocity (V) =	0.054	m/s
Sedimentation index of reservoir =	0.17	

APPENDIX B: SEDIMENT YIELD CALCULATION

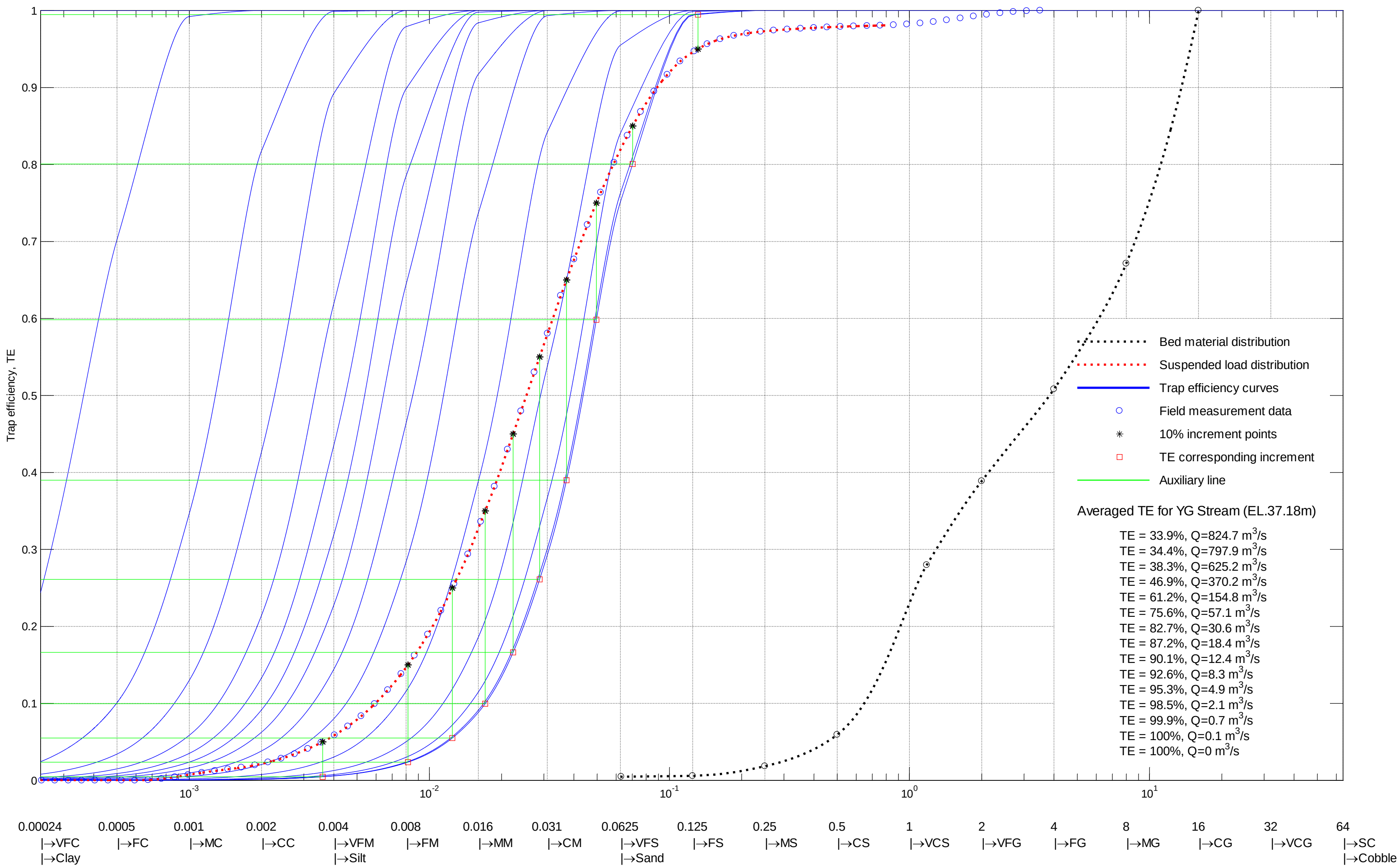


Figure 102: Trap efficiency curve with respect to various discharges when EL37.2m, suspended load, and bed-material distribution curves for Yeong Stream

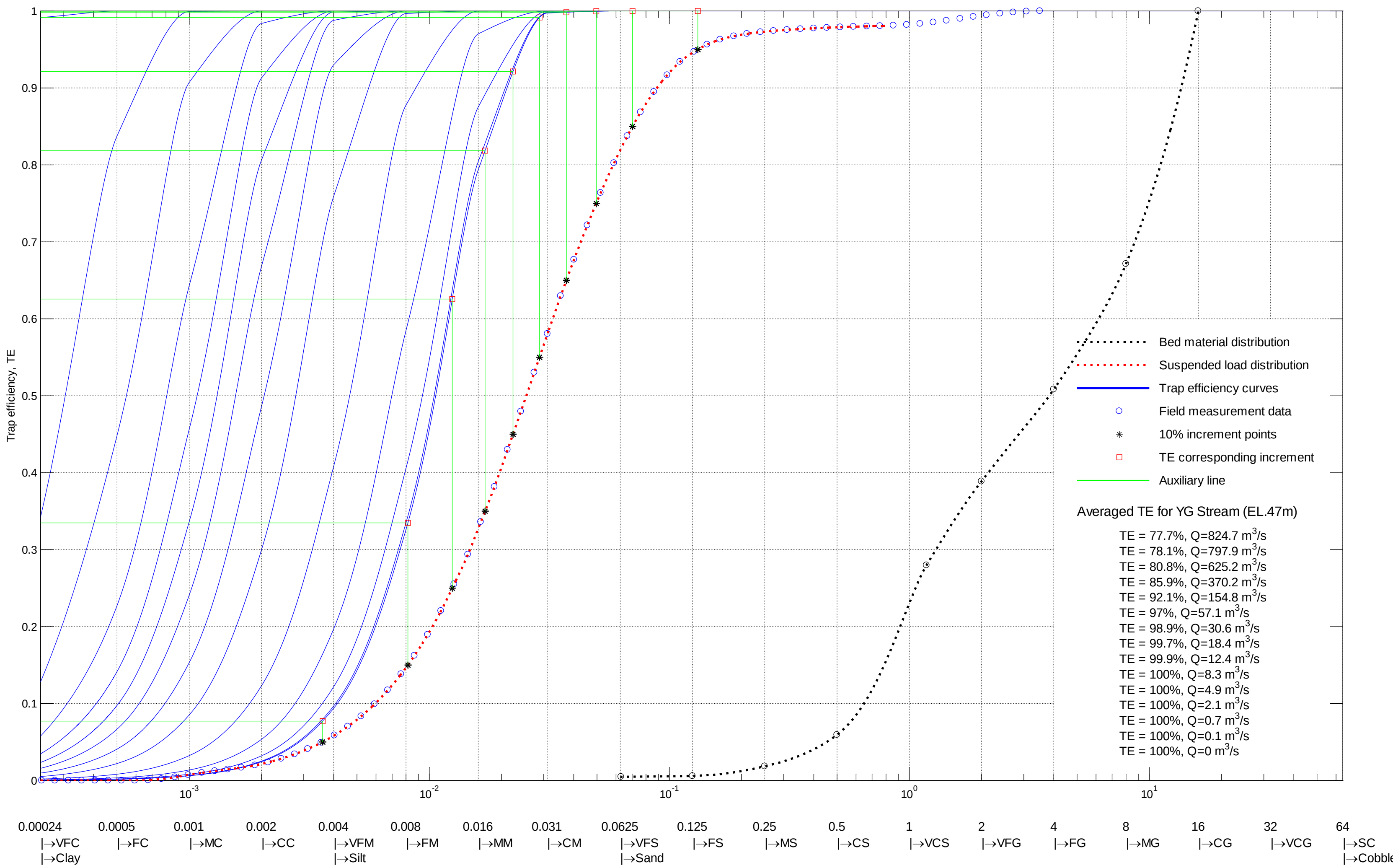


Figure 103: Trap efficiency curve with respect to various discharges when EL47 m, suspended load, and bed-material distribution curves for Yeong Stream

Table 29: Long-term sediment yield for Yeong Stream using Flow-Duration and Sediment-Rating Curve method when the stage is EL. 37.2 m

Time intervals (%) (1)			Interval mid-point (%) (2)	Interval ΔP(%) (3)	Discharge Q (m^3/s) (4)	Concentration C (mg/L) (5)	Q × ΔP (6)	Sediment Load Qs× ΔP (tons/yr) (7)		q_p/q_t ratio (%) (8)	Sediment Load Qs × ΔP (tons/yr) (9)		Average T_E (%) (10)	Qs×T_E (tons/yr) (11)=(9)*(10)	
0	~	0.02	0.01	0.02	825	230	0.2	1,452	3%	95.8%	1516	3%	33.9	514	2%
0.02	~	0.1	0.06	0.08	798	222	0.6	4,204	10%	95.5%	4402	9%	34.4	1,514	6%
0.1	~	0.5	0.3	0.4	625	176	2.5	13,886	31%	93.4%	14867	29%	38.3	5,694	22%
0.5	~	1.5	1	1	370	106	3.7	12,378	28%	88.7%	13955	27%	46.9	6,545	26%
1.5	~	5	3.25	3.5	155	46	5.4	7,840	18%	81.0%	9679	19%	61.2	5,924	23%
5	~	15	10	10	57	17	5.7	3,058	7%	72.2%	4235	8%	75.6	3,202	13%
15	~	25	20	10	31	10	3.1	978	2%	66.8%	1464	3%	82.7	1,211	5%
25	~	35	30	10	18	6	1.8	341	1%	62.0%	550	1%	87.2	480	2%
35	~	45	40	10	12	4	1.2	151	0%	58.4%	259	1%	90.1	233	1%
45	~	55	50	10	8	3	0.8	76	0%	54.8%	139	0%	92.6	129	0%
55	~	65	60	10	5	2	0.5	32	0%	50.6%	63	0%	95.3	60	0%
65	~	75	70	10	2	1	0.2	6	0%	42.5%	14	0%	98.5	14	0%
75	~	85	80	10	1	0	0.1	0	0%	36.4%	0	0%	99.9	0	0%
85	~	95	90	10	0	0	0	0	0%	16.0%	0	0%	100.0	0	0%
95	~	100	97.5	5	0	0	0	0	0%	16.0%	0	0%	100.0	0	0%
Total								44,402	100%	86.8%	51,143	100%	49.9%	25,520	100 %

Table 30: Long-term sediment yield for Yeong Stream using flow-duration and sediment-rating curve method when the stage is EL. 47.0 m

Time intervals % (1)	Interval midpoint (%) (2)	Interval delta P(%) (3)	Discharge Q (m3/s) (4)	Concentration C (mg/L) (5)	Q × ΔP (6)	Sediment Load Qs× ΔP (tons/yr) (7)		q_p/q_t ratio (%) (8)	Sediment Load Qs × ΔP (tons/yr) (9)		Average Te (%) (10)	Qs*Te (tons/yr) (11)=(9)*(10)	
0 ~ 0.02	0.01	0.02	825	230	0.2	1,452	3%	95.8%	1516	3%	77.7	1,178	3%
0.02 ~ 0.1	0.06	0.08	798	222	0.6	4,204	10%	95.5%	4402	9%	78.1	3,438	8%
0.1 ~ 0.5	0.3	0.4	625	176	2.5	13,886	31%	93.4%	14867	29%	80.8	12,013	27%
0.5 ~ 1.5	1	1	370	106	3.7	12,378	28%	88.7%	13955	27%	85.9	11,987	27%
1.5 ~ 5	3.25	3.5	155	46	5.4	7,840	18%	81.0%	9679	19%	92.1	8,914	20%
5 ~ 15	10	10	57	17	5.7	3,058	7%	72.2%	4235	8%	97.0	4,108	9%
15 ~ 25	20	10	31	10	3.1	978	2%	66.8%	1464	3%	98.9	1,448	3%
25 ~ 35	30	10	18	6	1.8	341	1%	62.0%	550	1%	99.7	548	1%
35 ~ 45	40	10	12	4	1.2	151	0%	58.4%	259	1%	99.9	259	1%
45 ~ 55	50	10	8	3	0.8	76	0%	54.8%	139	0%	100.0	139	0%
55 ~ 65	60	10	5	2	0.5	32	0%	50.6%	63	0%	100.0	63	0%
65 ~ 75	70	10	2	1	0.2	6	0%	42.5%	14	0%	100.0	14	0%
75 ~ 85	80	10	1	0	0.1	0	0%	36.4%	0	0%	100.0	0	0%
85 ~ 95	90	10	0	0	0	0	0%	16.0%	0	0%	100.0	0	0%
95 ~ 100	97.5	5	0	0	0	0	0%	16.0%	0	0%	100.0	0	0%
Total						44,402	100%	86.8%	51,143	100%	86.2%	44,109	100%

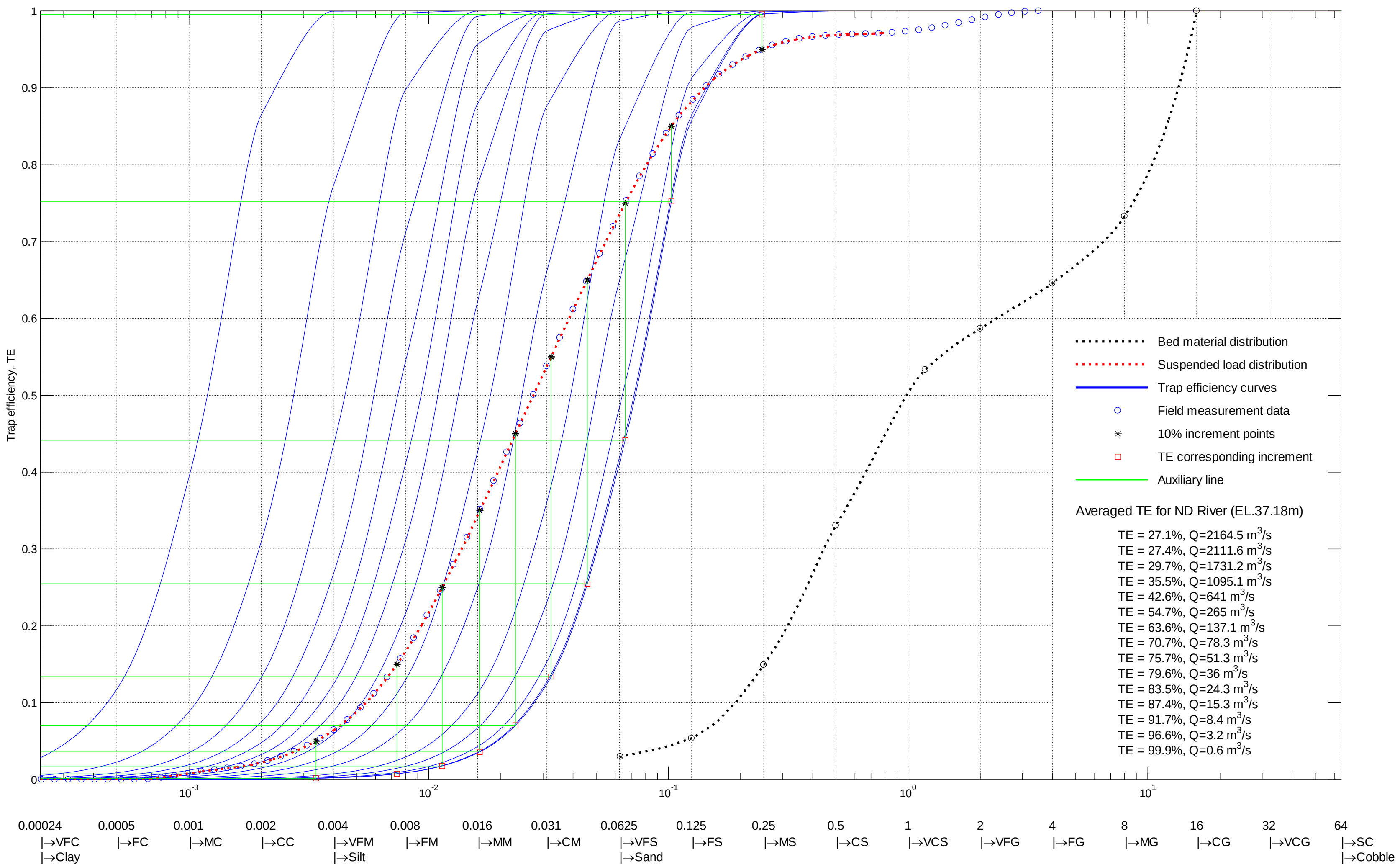


Figure 104: Trap efficiency curve with respect to various discharges when EL. 37.2m, suspended load, and bed-material distribution curves for Nakdong River

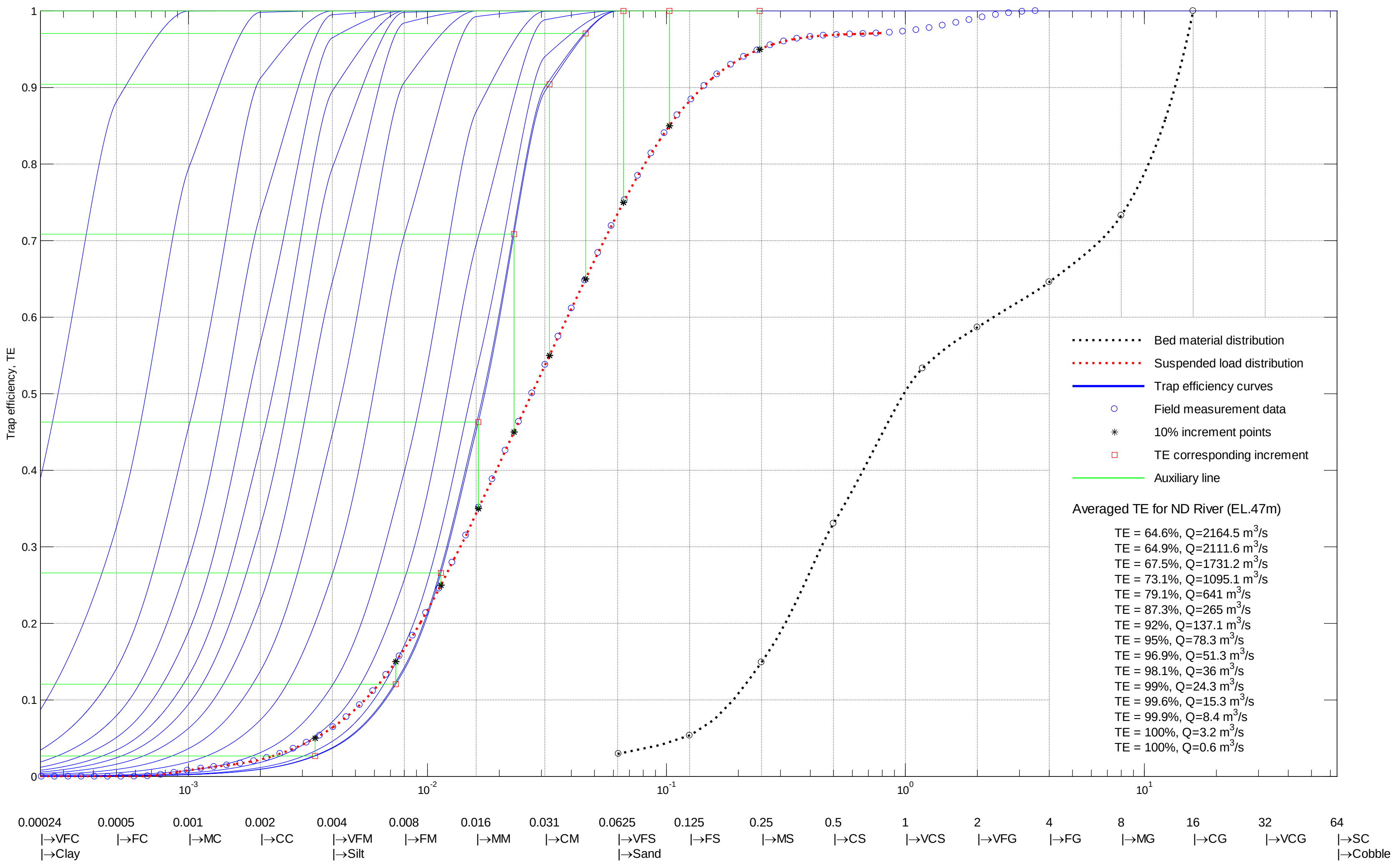


Figure 105: Trap efficiency curve with respect to various discharges when EL. 47 m, suspended load, and bed-material distribution curves for Nakdong River

Table 31: Long-term sediment yield for Nakdong River using flow-duration and sediment-rating curve method when the stage is EL. 37.2 m

Time intervals (%) (1)			Interval mid-point (%) (2)	Interval ΔP(%) (3)	Discharge Q (m^3/s) (4)	Concentration C (mg/L) (5)	Q × ΔP (6)	Sediment Load Qs× ΔP (tons/yr) (7)		q_p/q_t ratio (%) (8)	Sediment Load Qs × ΔP (tons/yr) (9)		Average T_E (%) (10)	Qs×T_E (tons/yr) (11)=(9)*(10)	
0	~	0.02	0.01	0.02	2,165	184	0.4	2,323	2%	96.1%	2,417	2%	27.1	655	1%
0.02	~	0.1	0.06	0.08	2,112	179	1.7	9,604	7%	96.1%	9,994	7%	27.4	2,738	5%
0.1	~	0.5	0.3	0.4	1,731	144	6.9	31,358	25%	95.7%	32,767	24%	29.7	9,732	18%
0.5	~	1.5	1	1	1,095	87	10.9	29,928	23%	94.7%	31,603	23%	35.5	11,219	21%
1.5	~	5	3.25	3.5	641	48	22.4	33,933	27%	93.5%	36,292	27%	42.6	15,460	29%
5	~	15	10	10	265	18	26.5	15,054	12%	91.6%	16,434	12%	54.7	8,989	17%
15	~	25	20	10	137	9	13.7	3,891	3%	90.2%	4,314	3%	63.6	2,744	5%
25	~	35	30	10	78	5	7.8	1,231	1%	89.0%	1,383	1%	70.7	978	2%
35	~	45	40	10	51	3	5.1	483	0%	88.1%	548	1%	75.7	415	1%
45	~	55	50	10	36	2	3.6	227	0%	87.3%	260	0%	79.6	207	1%
55	~	65	60	10	24	1	2.4	76	0%	86.4%	88	0%	83.5	73	0%
65	~	75	70	10	15	1	1.5	47	0%	85.4%	55	0%	87.4	48	0%
75	~	85	80	10	8	0	0.8	0	0%	84.1%	0	0%	91.7	0	0%
85	~	95	90	10	3	0	0.3	0	0%	81.9%	0	0%	96.6	0	0%
95	~	100	97.5	5	1	0	0.1	0	0%	79.6%	0	0%	99.9	0	0%
Total								128,155	100%	94.1%	136,155	100%	39.1%	53,258	100%

Table 32: Long-term sediment yield for Nakdong River using flow-duration and sediment-rating curve method when the stage is EL. 47.0 m

Time intervals (%) (1)			Interval mid-point (%) (2)	Interval ΔP(%) (3)	Discharge Q (m^3/s) (4)	Concentration C (mg/L) (5)	Q × ΔP (6)	Sediment Load Qs× ΔP (tons/yr) (7)		q_p/q_t ratio (%) (8)	Sediment Load Qs × ΔP (tons/yr) (9)		Average T_E (%) (10)	Qs×T_E (tons/yr) (11)=(9)*(10)	
0	~	0.02	0.01	0.02	2,165	184	0.4	2,323	2%	96.1%	2,417	2%	64.6	1,561	1%
0.02	~	0.1	0.06	0.08	2,112	179	1.7	9,604	7%	96.1%	9,994	7%	64.9	6,486	6%
0.1	~	0.5	0.3	0.4	1,731	144	6.9	31,358	25%	95.7%	32,767	24%	67.5	22,118	22%
0.5	~	1.5	1	1	1,095	87	10.9	29,928	23%	94.7%	31,603	23%	73.1	23,102	23%
1.5	~	5	3.25	3.5	641	48	22.4	33,933	27%	93.5%	36,292	27%	79.1	28,707	28%
5	~	15	10	10	265	18	26.5	15,054	12%	91.6%	16,434	12%	87.3	14,347	14%
15	~	25	20	10	137	9	13.7	3,891	3%	90.2%	4,314	3%	92.0	3,969	4%
25	~	35	30	10	78	5	7.8	1,231	1%	89.0%	1,383	1%	95.0	1,314	1%
35	~	45	40	10	51	3	5.1	483	0%	88.1%	548	1%	96.9	531	1%
45	~	55	50	10	36	2	3.6	227	0%	87.3%	260	0%	98.1	255	0%
55	~	65	60	10	24	1	2.4	76	0%	86.4%	88	0%	99.0	87	0%
65	~	75	70	10	15	1	1.5	47	0%	85.4%	55	0%	99.6	55	0%
75	~	85	80	10	8	0	0.8	0	0%	84.1%	0	0%	99.9	0	0%
85	~	95	90	10	3	0	0.3	0	0%	81.9%	0	0%	100.0	0	0%
95	~	100	97.5	5	1	0	0.1	0	0%	79.6%	0	0%	100.0	0	0%
Total								128,155	100%	94.1%	136,155	100%	75.3%	102,532	100%

APPENDIX C: DAILY SEDIMENT TRANSPORT MODELING RESULTS

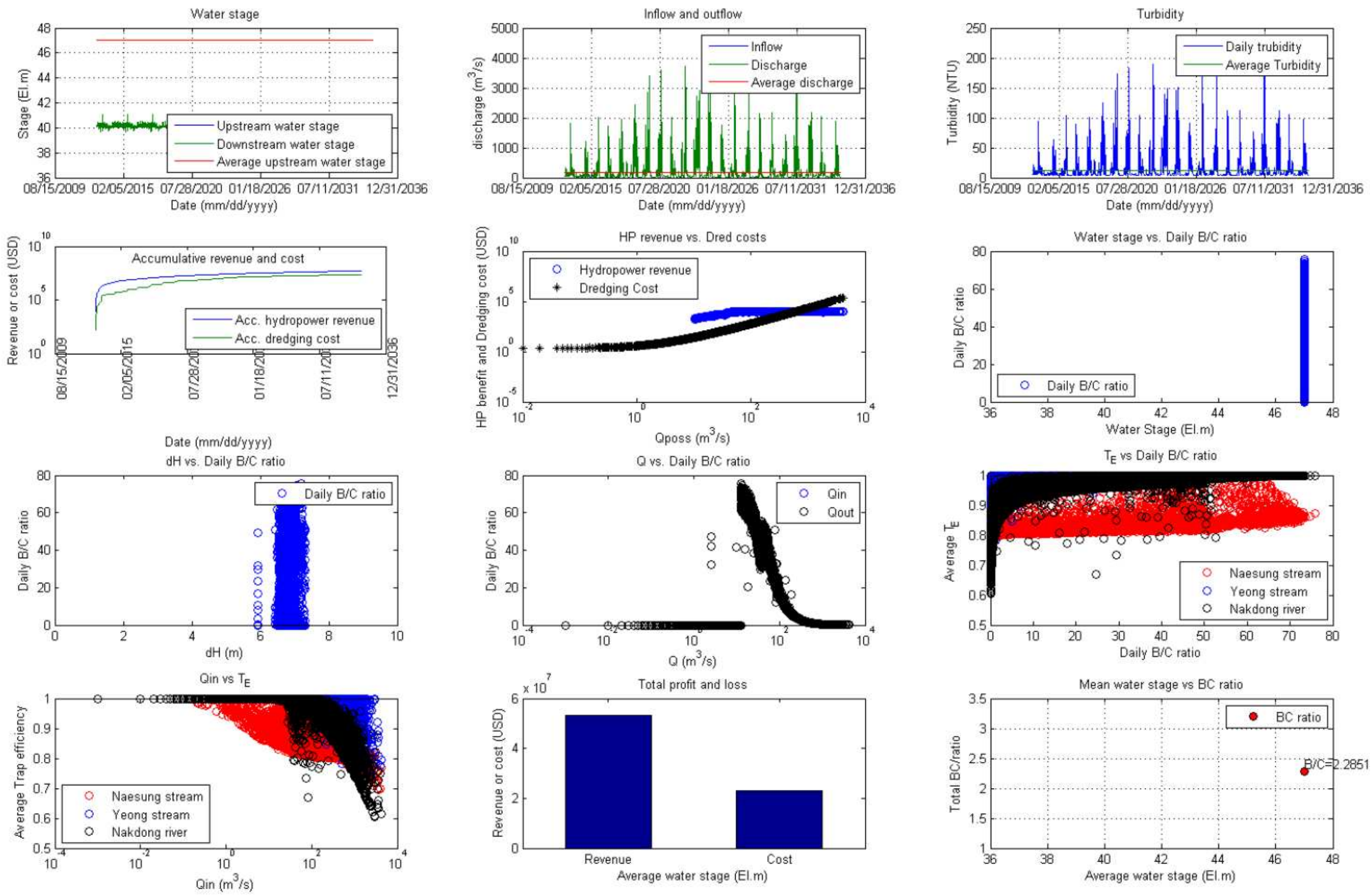


Figure 106: Simulation result (Alt. 1)

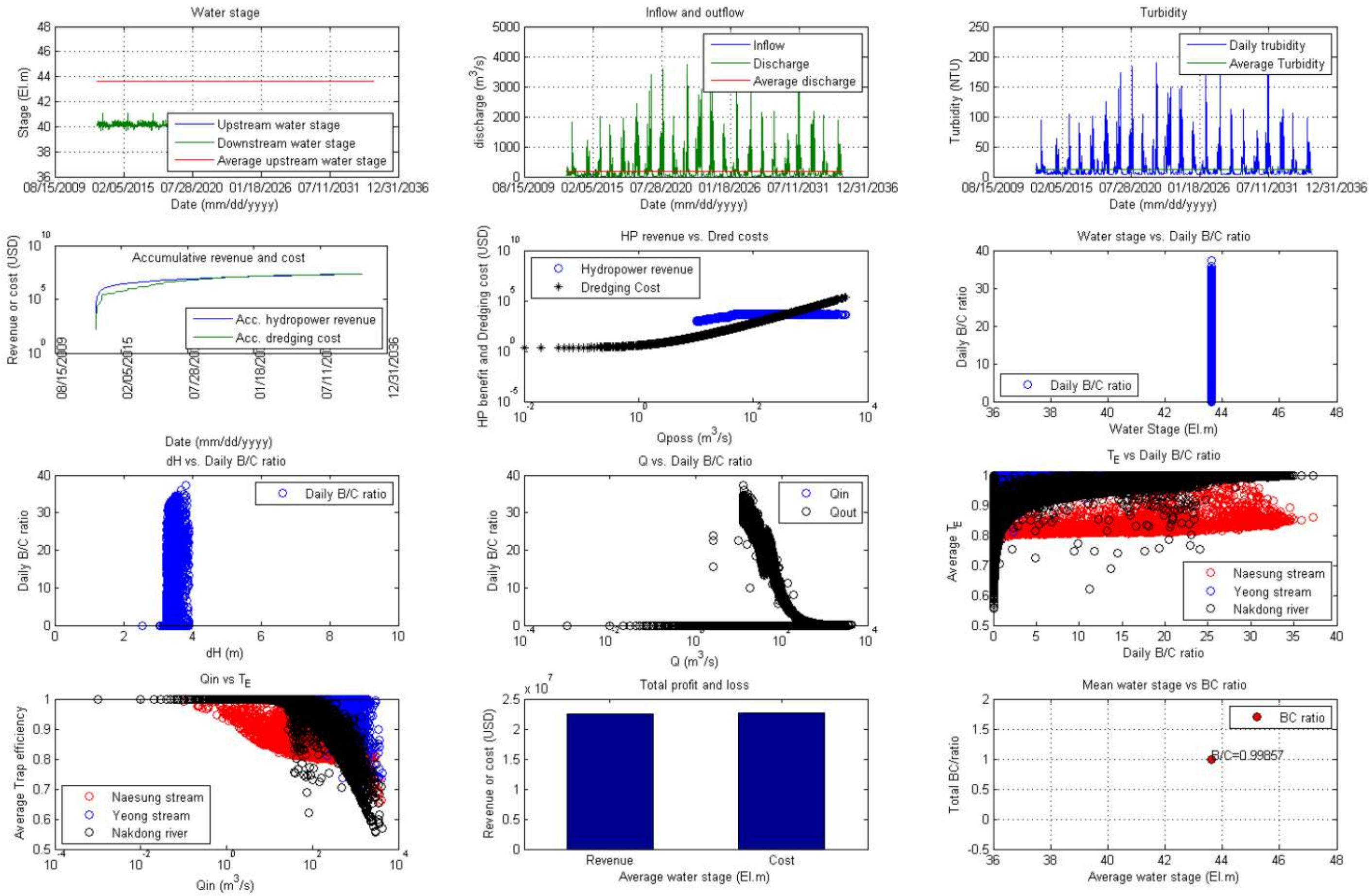


Figure 107: Simulation result (Alt. 2)

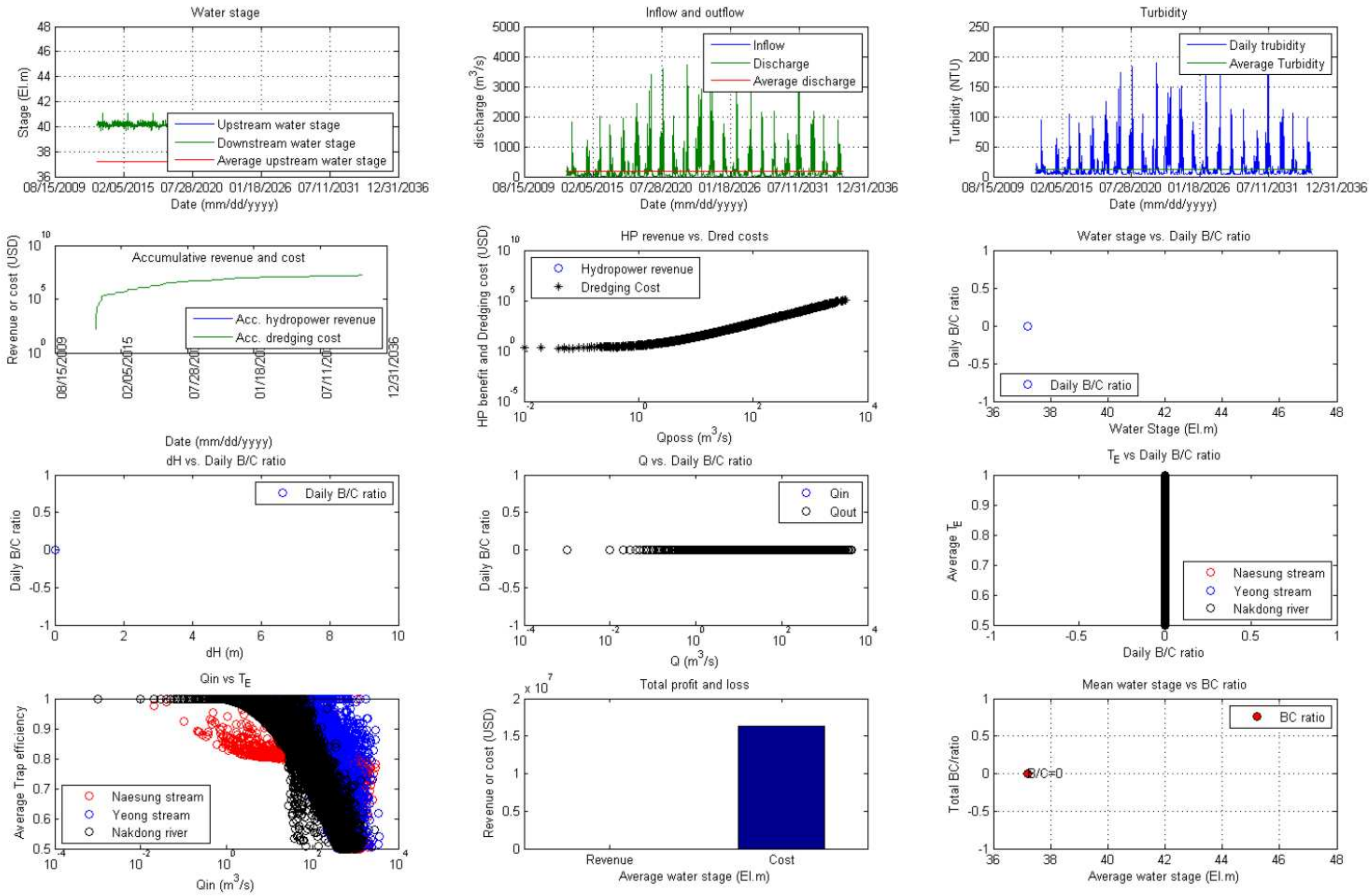


Figure 108: Simulation result (Alt. 3)

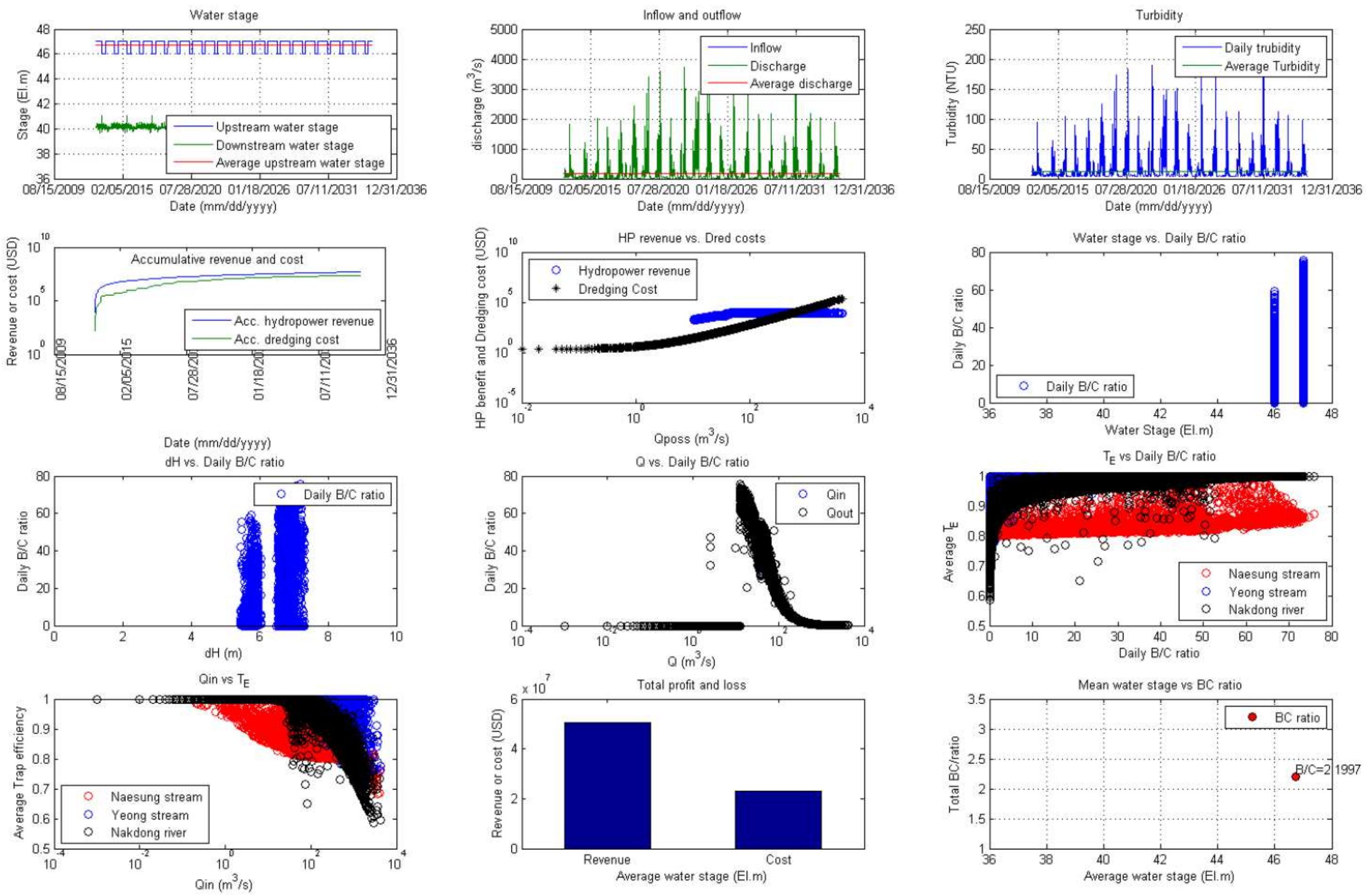


Figure 109: Simulation result (Alt. 4)

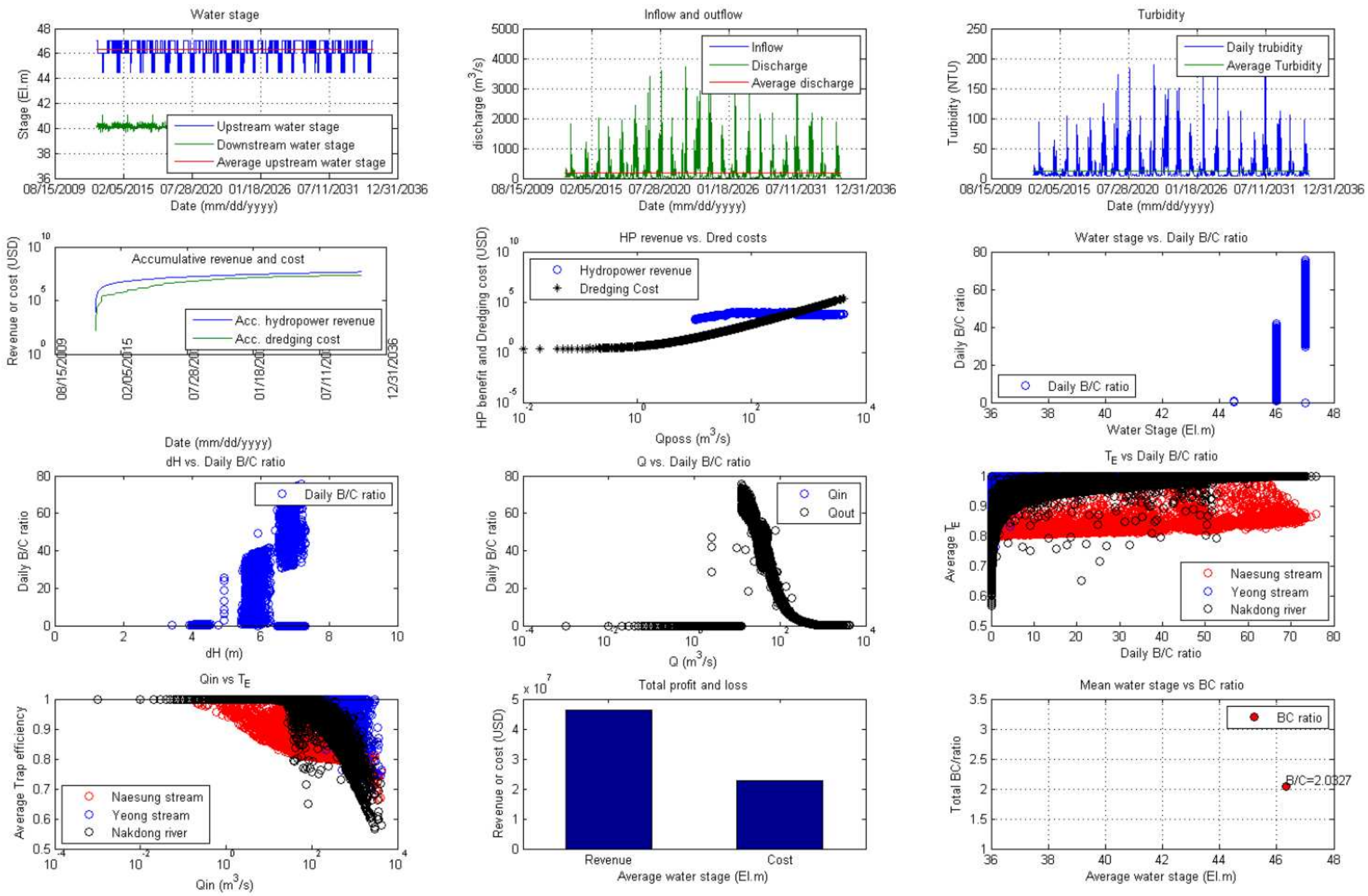


Figure 110: Simulation result (Alt. 5)

APPENDIX D: FACILITY DESCRIPTION FOR THE STUDY AREA

YEONGJU MULTI-PURPOSE DAM

Yeongu multi-purpose dam is located in the northeastern part of the Nakdong River watershed and will be completed in 2016. It is one of the major sources of base flow for entire Nakdong River, with various water supply purposes, as shown in Figure 19. The capacity of the volume reaches 181 million cubic meters and flood control with 75 million cubic meters among the total storage of 181 million cubic meters. It also contributes to the annual power generation of 5,000 kW. The catchment area of Yeongju dam is about 500 square kilometers, drained by Naesung Stream. It has a steep, narrow and meandering river with a 0.2 bottom slope and with ranging from 300 meter to 1,000 meter. Maximum water depth is about 58 meters near the dam site.

Figure 111: Bird's-eye view of Yeongju multi-purpose dam.

In particular, sediment trap reservoir was installed 13 kilometer upstream from the main dam, which is the first introduction in dam construction history (Samsung Inc., 2009).

Mean annual rainfall was measured at 1,247 mm, 1,089 mm, and 1,029 mm, respectively, at three stations located near Yeongju Dam, based on hydrological observation over 20 years.

1. Facilities

Yeongju dam has five spillways, intake and outlet, and hydropower generators like other dams. Intake tower was constructed with combined with main dam and 5,000 kW of hydro power plant was connected at the end of water supply pipeline.

The sediment detention weir was constructed 13 km upstream, which is the first case in Korea. Since this facility will be exposed about two month in a year, the sediments accumulated in this facility will be excavated by backhoe or other excavation equipment. The detailed design report says that almost all of the sediments have relatively coarser particles will be trapped at this facility.

In addition, washout facility was installed on main dam. This facility will release finer particles that would be accumulated near main dam after passing through upstream sediment detention facility. These two facilities are unique in Korea: (1) sediment detention utility; and (2) washout structure. Table 33 gives detailed information about the dam. Figure 113 show the designs and real photos of facilities, left column presents the planning pictures and right column shows real photos of facilities already have completed or on constructing, respectively.

Table 33: Detailed information about Yeongju multi-purpose dam

[Basin]	
• Stream name	Naesung Stream
• Catchment area	500 ㎢
• Annual rainfall	1,137mm
• Annual inflow	316.6 MCM/year
[Reservoir]	
• Total storage	181.1 MCM
• Flood control	75.0 MCM
• Effective storage	160.4 MCM
• Dead storage	8.8 MCM
• Submerged area	10.4 ㎢
[Main dam]	
• Location	Kyeongbuk Yeongju-si Pyeongun-myeon Geumgwang- li (Left bank) Kyeongbuk Yeongju-si Pyeongun-myeon Yonghyeol- li (Right bank)
• Type	Complex(CGD+CFRD)
• Length	400m (CGD:193.0m, CFRD:207.0m)
• Height	55.5m
[Spillway]	
• Maximum capacity	4,692 ㎥/s (PMF)
• Gate	Radial Gate (B10.4m × H13.67m × 5 ea.)
• Gate dimension	66m (5@10.4m + 4@3.5m)
• Elevation of overflow section	EL.153.0m
• Energy dissipator	Stilling basin (B66.0m × L71.8m)
[Intake and release facility]	
• Type	sidewall circular multistage type
• Intake method	Depth-selective and surface intake
• Range	N.H.W.L(EL.163.0m) ~ L.W.L(EL.135.0m)
• Dimension	2.1 ~ 3.6 × 36.65m × 6 step
• Outlet pipe	Normal (2.2m × L110.7m) Emergency (1.35 ~ 1.70m × L32.0m)
• Outlet gate	Jet Flow gate(1.35m)
[Washout valve]	
• Location	Main dam No. 12 block
• Dimension	B5.0m × H5.0m × 1EA
• Longitudinal slope	1/25(inlet elevation: EL.125.0m)
• Dimension	Main gate (B5.0m×H5.0m×1EA) Auxiliary(B5.0m×H8.0m×1EA)

Continued from Table 33:

[Sediment detention reservoir]	
• Location	Kyeongbuk Yeongju-si Pyeongun-myeon Cheonbon-li (Left bank) Kyeongbuk Yeongju-si Isan-myeon Sincheon-li (Right bank) (13km upstream from main dam confluence of Toil Stream)
• Type	Concrete fixed type
• Elevation of overflow section	EL.156.7m
• Elevation of non-overflow section	EL.165.0m
• Height×Length	18.3m × 246.0m
[Hydropower plant]	
• Capacity	5,000kW(500kW, 1,500kW, 3,000kW)
• Type	Francis, Horizontal shaft
• Efficiency	Over 82.72%
• Annual power amount	15.78GWh
• Utility factor of facility	47.31%

[In Plan, 2009] [On construction, 2014]

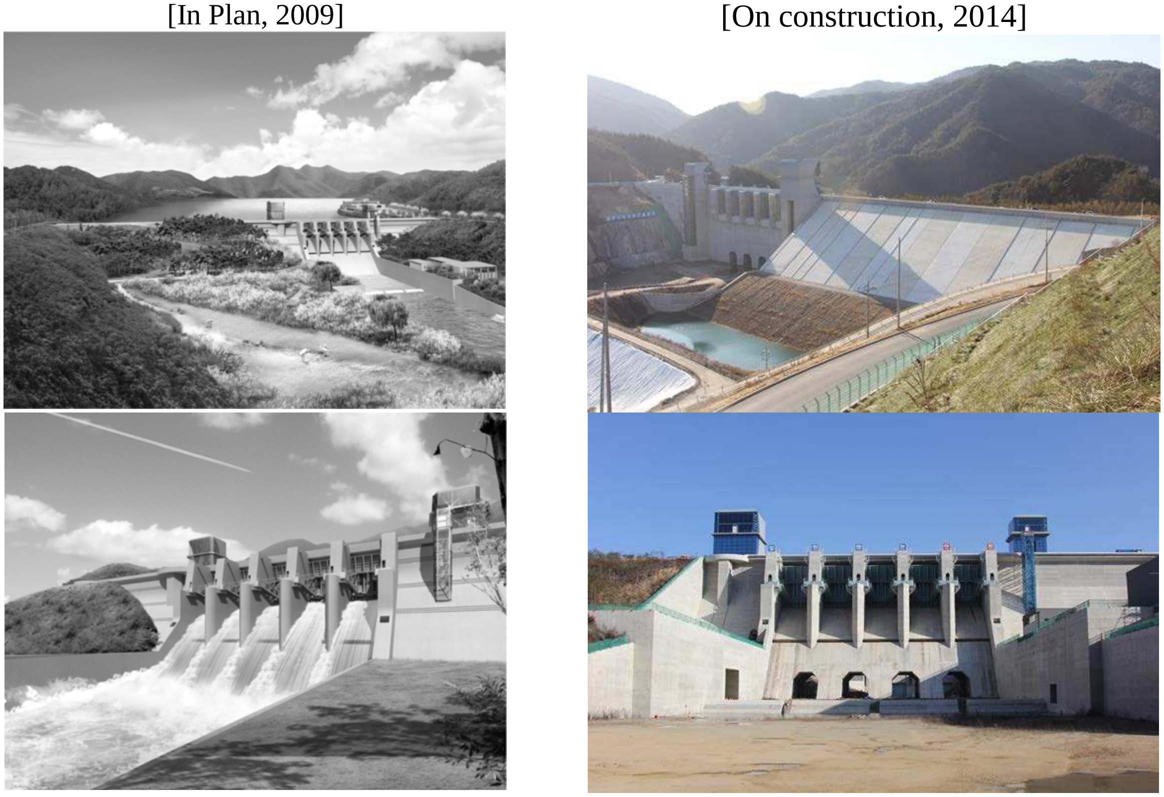


Figure 112: Photos of Yeongju multi-purpose dam facilities: main dam (up) and spillway (down) (photo by K-water, May 2014)

[In Plan, 2009] [On construction, 2014]

Figure 113: Photos of Yeongju multi-purpose dam facilities: intake tower (up), sediment detention reservoir constructed 13 km upstream from the main dam (middle), and sediment through installed on main dam (down)

2. Operation rule

The main purpose of Yeongju multi-purpose dam is supplying environmental flow downstream. Considering flow reduction and water quality deterioration period at Namji station located on downstream in Nakdong River, the water supply plan was designed primarily to supply the environmental flow in the March to June (Figure 114 and Table 34).

Table 34: Monthly water supply plan of Yeongju multi-purpose dam

(Unit: m^3/s)

Div.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Total	5.13	5.13	9.15	15.13	13.61	11.7	2.02	2.05	1.84	1.48	5.14	5.13	6.45 (203.3)
Municipal and industrial	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34 (10.7)
Irrigation	-	-	-	0.12	0.22	0.42	0.55	0.58	0.37	0.01	0.01	-	0.19 (6.0)
Base flow for stream	4.79	4.79	8.81	14.67	13.05	10.94	1.13	1.13	1.13	1.13	4.79	4.79	5.92 (186.6)

Note: ( ) MCM/year

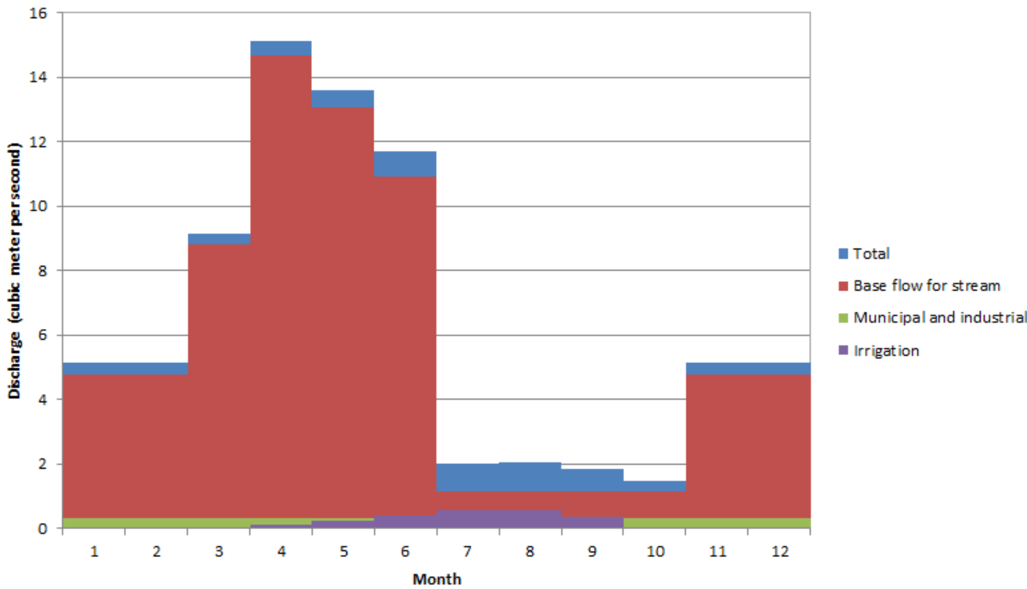


Figure 114: Monthly water supply plan on Yeongju multi-purpose dam

SANGJU WEIR

Sangju Weir is located in Sangju city, Kyeongbuk province. The catchment area is 7,407 square kilometers and total storage is 28.7 million cubic meter when water stage of the reservoir is 47 El.m (management water stage). The length of the weir is 355 meter, of which 230 meter is fixed weir and the rest (105 m) is movable gates with 2 gates of 45 meter-long and 10 meter-high. Also it has hydropower plant with 3,000 kilo watts of facility capacity.

Figure 115: Picture of Sangju Weir.

1. Facilities

The two shell type roller gates were installed on Sangju Weir. They have 45 m of width and 10 m of height. These two gates put on the concrete of which elevation from mean sea level is EL. 37.18 m.

The one auxiliary gate, flap gate, was installed right next to the main gates. This gate adjusts upstream water stage to management status with change the amount of discharge with small range because using main gate can cause sudden drop or rise of upstream water stage.

The natural type of fish path was constructed at the right bank side. The 2.5 cubic meters per second of water flow through this path, which is the first priority at normal operation season.

[Plan, 2009]

[Completion, 2012]

Figure 116: Photos of Sangju Weir facilities: shell type roller gates and flap gate (up) and hydropower plant (down)

Table 35: Basic information of Sangju Weir

Div.		Unit	Sangju Weir
Catchment Area		㎢	7,407
Management water stage		EL.m	47
Storage		MCM	27.4
Low limit water stage		EL.m	43.6
Storage		MCM	12.4
Upper limit water stage		EL.m	47.5
Design flood discharge		㎥/s	11,100 (100 yr)
Design flood water level		EL.m	49.6
Height of levee		EL.m	52.61
Weir Structure	Type	-	Shell type roller gate /Flap gate
	Scale (B×H×Ea.)	m, Ea	45×10×2 (Roller) 45×1.8×1 (Flap)
	Elevation of overflow section (movable/fixed)	EL.m	37.18 (Movable gate bottom) 47.00 (Fixed weir crest)
Hydropower	Type		Horizontal shaft, Kaplan turbine synchronous generator
	Facility capacity	㎾	3,000
	water discharge	㎥/s	54
Fish passage	Type	-	Natural type (Right bank)
	Water discharge	㎥/s	2.5
Foundation	Type	-	Spread foundation
	Length	m	335

2. Operation rules

Since Sangju Weir has several functions, there are order in releasing stream flow; (1) Fish path, (2) hydropower generation, (3) fixed weir, and (4) movable weir. The operation rules must be followed this order.

The main gate(s) control water flow by opening or closing according to inflow discharge from upstream. However, there are some ambiguous standard for operation rule in flood season. The gate opening range is too big to decide time for operation. Table 36 shows Sangju Weir operation rules.

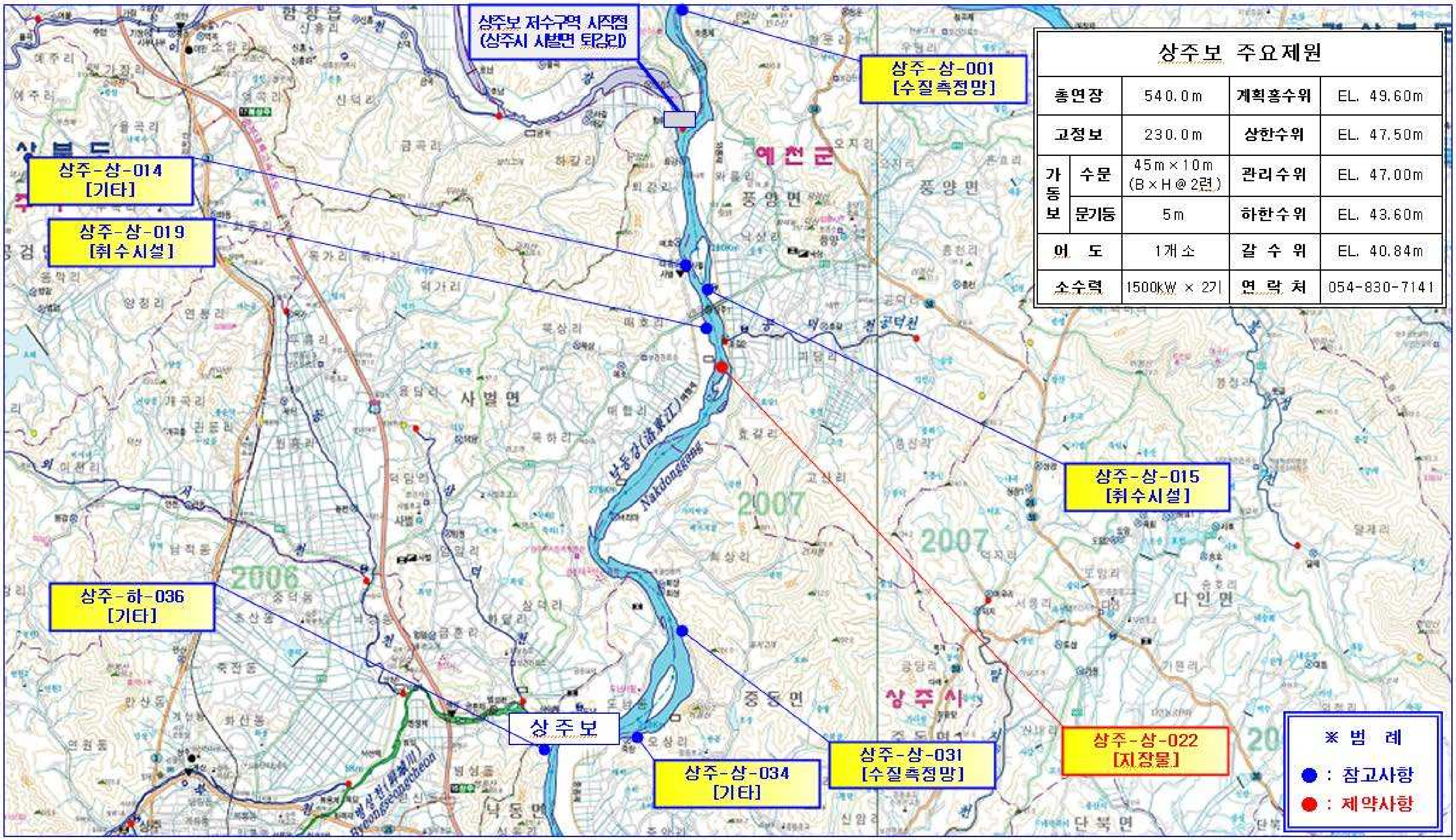
Table 36: Sangju Weir operation rule (K-water, 2012).

Div.		Stage (EL. m)	discharge (m^3/sec)	Operation
Drought		lower 47.0	below 25	· Releasing through fish passage and hydropower plant · Changing generating power according to inflow to the weir
Normal		47.0 ~ 47.5	25 ~ 4,491	· Keeping management water stage (El. 47 m), · Open the gate if it is needed to keep management stage.
Flood	Ascending	47.0 ~ 47.5	25 ~ 4,491	· Fully open the gate if it is needed
		47.5 ~ 49.6	4,491 ~ 8,808	· Fully open the gate if it is needed
		above 49.6	above 8,808	· Fully open the gate
	Descending	47.5 ~ 47.0	below 4,491	· Gradually close the gates * lower limit (Pungyang intake EL.44.20m)

The current operation rules of Sangju Weir do not provide any specific directions such as when the gates are opened fully. The instruction is ambiguous and has big ranges for reference discharge.

APPENDIX E: SANGJU WEIR CONSTRAINTS SURVEY

상 주 보 제 약 사 항 총 괄 위 치 도



상주보 주요제원				
총연장		540.0m	계획홍수위	EL. 49.60m
고정보		230.0m	상한수위	EL. 47.50m
가동보	수문	45m×10m (B×H@2련)	관리수위	EL. 47.00m
	문기둥	5m	하한수위	EL. 43.60m
어 도		1개소	갈 수 위	EL. 40.84m
소수력		1500kW × 2기	연 락 처	054-830-7141

○ 취수시설

시설 명	번호		이수가능수위 (EL.m)	위 치	내 용	비상연락망	조 치 계 획
풍양취수장	취수 시설	상주-상-015	44.155	예천군 풍양면 효갈리 1346-1번지 상주보 상류 10.0km(좌안)	하한수위 운영시 취수 제약	K-water 예천수도관리단	운영단계에서 안정적인 양수기능 가능토록 조치필요
사벌 매호 취수장	취수 시설	상주-상-019	41.50	상주시 사벌면 매호리 상주보 상류 11.0km(우안)	하한수위 운영시 취수 제약	상주시 054-537-8787	운영단계에서 안정적인 양수기능 가능토록 조치필요

○ 양수시설

시설 명	번호		이수가능수위 (EL.m)	위 치	내 용	비상연락망	조 치 계 획
매호양수장	양수 시설	상주-상-012	45.00	상주시 사벌면 매호리 762 상주보 상류 10.50km(우안)	하한수위 운영시 양수 제약	한국농어촌공사 (상주지사) 054-531-3610	운영단계에서 안정적인 양수기능 가능토록 조치필요
퇴강양수장	양수 시설	상주-상-004	43.50	상주시 사벌면 퇴강리 764 상주보 상류 12.26km(우안)	하한수위 운영시 양수 제약	상주시 054-537-7560	운영단계에서 안정적인 양수기능 가능토록 조치필요
버리미양수장	양수 시설	상주-상-028	44.00	상주시 중동면 회상리 1436번지 상주보 상류 5.64km(좌안)	하한수위 운영시 양수 제약	상주시 054-537-7560	운영단계에서 안정적인 양수기능 가능토록 조치필요
감나무골양수장	양수 시설	상주-상-029	44.00	상주시 중동면 회상리 1436번지 상주보 상류 5.62km(좌안)	하한수위 운영시 양수 제약	상주시 054-537-7560	운영단계에서 안정적인 양수기능 가능토록 조치필요
회상양수장	양수 시설	상주-상-030	45.00	상주시 중동면 회상리 819-1 상주보 상류 3.50km(좌안)	하한수위 운영시 양수 제약	한국농어촌공사 (상주지사) 054-531-3610	운영단계에서 안정적인 양수기능 가능토록 조치필요
죽암양수장	양수 시설	상주-상-035	45.00	상주시 중동면 오상리 92 상주보 상류 0.3km(좌안)	하한수위 운영시 양수 제약	한국농어촌공사 (상주지사) 054-531-3610	운영단계에서 안정적인 양수기능 가능토록 조치필요

○ 배수시설

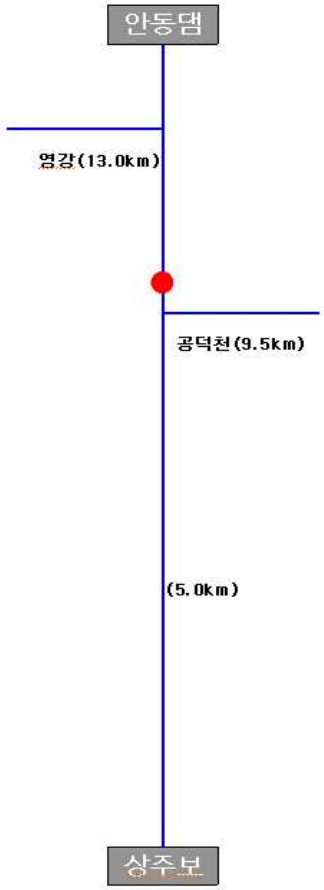
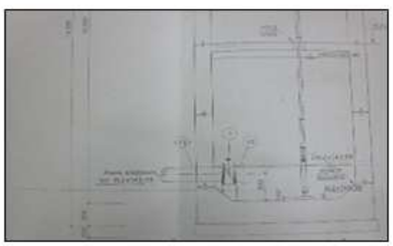
시설 명	배수시설 표고 (EL.m)		배수가능수위 (EL.m)	위치	보 수위(EL.m)		조 사 의 견	향후 조치계획	비 고
	시설물	유출구 관저고			상한수위 (관리수위)	갈수위			
와룡제 1배수통관	D=1000 ㎜	49.73	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 상주시 · 현 황 : 유출구 관저고가 관리수위보다 높음 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
와룡배수장	1@3.0×1.5	49.78	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 한국농어촌공사(예천지사) · 현 황 : 유출구 관저고가 관리수위보다 높음 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
와룡제2 배수문	2@2.0×2.0	43.50	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 상주시 · 현 황 : 관리수위시 배수원활 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
와룡제 2배수통관	D=1000 ㎜	48.35	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 상주시 · 현 황 : 유출구 관저고가 관리수위보다 높음 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
와룡제 3배수통관	D=1000 ㎜	48.90	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 상주시 · 현 황 : 유출구 관저고가 관리수위보다 높음 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
와룡제 4배수통관	D=1200 ㎜	49.58	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 상주시 · 현 황 : 유출구 관저고가 관리수위보다 높음 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
와룡 제5배수통관	D=1000 ㎜	49.58	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 상주시 · 현 황 : 유출구 관저고가 관리수위보다 높음 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
와룡 제6배수통관	D=1000 ㎜	49.58	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 상주시 · 현 황 : 유출구 관저고가 관리수위보다 높음 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
와룡 제2배수문	2@2.0×2.0	49.199	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 한국농어촌공사(예천지사) · 현 황 : 유출구 관저고가 관리수위보다 높음 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
와룡 제7배수통관	D=1000 ㎜	49.92	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 상주시 · 현 황 : 유출구 관저고가 관리수위보다 높음 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
와룡제3 배수문	2@2.0×2.0	47.50	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 한국농어촌공사(예천지사) · 현 황 : 관리수위시 배수원활 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
와룡제5 배수문	2@2.0×2.0	46.07	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 한국농어촌공사(예천지사) · 현 황 : 유출구 관저고가 관리수위보다 낮음	· 없 음	

시설 명	배수시설 표고 (EL.m)		배수가능수위 (EL.m)	위치	보 수위(EL.m)		조 사 의 견	향후 조치계획	비 고
	시설물	유출구 관저고			상한수위 (관리수위)	갈수위			
							· 배수가능수위 : 부산청 T/F 합동점검 세부측량성과		
퇴강 제1배수문	2@1.2×1.2	47.57	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 상주시 · 현 황 : 유출구 관저고가 관리수위보다 높음 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
매협배수문	1@2.0×2.0	47.52	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 한국농어촌공사(상주지사) · 현 황 : 유출구 관저고가 관리수위보다 높음 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
매협배수장	2@D700㎜	47.69	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 한국농어촌공사(상주지사) · 현 황 : 유출구 관저고가 관리수위보다 높음 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
매호1 배수문	1@2.0×2.0	47.60	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 한국농어촌공사(의성군위지사) · 현 황 : 유출구 관저고가 관리수위보다 높음 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
매호2 배수문	2@2.0×2.0	46.60	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 한국농어촌공사(의성군위지사) · 현 황 : 유관리수위시 배수원활 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
매호3 배수문	2@2.0×2.0	46.50	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 한국농어촌공사(의성군위지사) · 현 황 : 관리수위시 배수원활 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	
매호4 배수문	2@2.5×2.5	46.10	-	상주보 상류	47.5 (47.0)	40.84	· 운영주체 : 한국농어촌공사(의성군위지사) · 현 황 : 관리수위시 배수원활 · 배수가능수위 : 부산청 T/F 합동점검 세부측량성과	· 없 음	

CRITICAL WATER SUPPLY CONTRAINT -YEAR BASE

“**Pungyang**” drinking water intaking station, Sangju Weir water stage has to be above El.44.2m all the time

ㅇ 상주-상-015 [취수시설, 풍양취수장] (참고)

현 장 사 진	하 천 모 식 도
	
위 치 도	
	
도 면	
	
취수장 단면도	상주보 상류 10.0km지점

조 사 내 용

상주보 주요제원

계획홍수위	EL. 49.60 m	관리수위	EL. 47.00 m
관리수위	EL. 47.00 m	하한수위	EL. 43.60 m

세 부 조 사 결 과

제약(참고)사항(요약)

☐ 일반현황

시 설 명	풍양취수장	주 소	예천군 풍양면 효갈리 1346-1번지
설치일자	1979.12.31	관리기관	K-water 예천수도관리단
담당자명	K-water 예천수도관리단	연 락 처	504-220

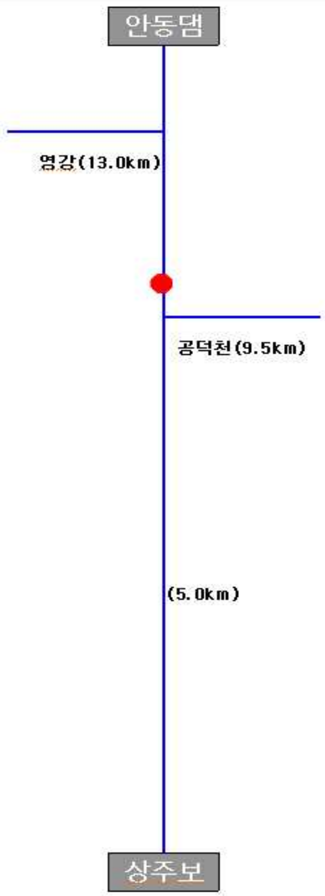
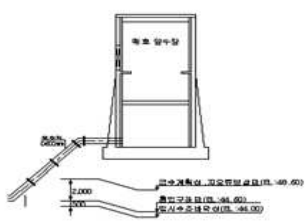
☐ 제원 및 제약사항

시설형식		집수매거	시설용량(㎥/일)	1,000
			취수량(㎥/일)	1,000
수원종류		복류수	용수공급지역	예천읍 외 5개소
시설 표고 (EL.m)	상단	43.65	좌표 경도	128-16-38
	하단	43.05	좌표 위도	36-29-08
	기타	-	위 치	상주보 상류 10.0km(좌안)
운영매뉴얼 비치 유무		-	취수가능수위(EL.m)	44.155
실시간 자료 취득여부		유 (2006년 부터)	연중 운영시기	상시가동
취수가능수위 산정근거		2005년 취수장 준공이후 2009년 08월에 취수펌프 고장 및 성능저하로 펌프모터를 긴급으로 교체하였음, 현재 설치된 심정용 수중펌프의 제원(L:1.705m)을 고려하여 LWL값(EL.44.155m)으로 설정 LWL EL.44.155m : EL42.45(취수펌프바닥) + 1.705m(취수펌프 제원) ※심정용 수중펌프는 유체(물)에 의해 냉각되기 때문에 유체에 담겨져 있어야 함(유체에 완전히 잠길수 있도록 설계)		
세부 제약내용		완경사제방 및 고수부지 조성공사로 인한 접합점 상승(2개소) 완료		
조치방안 및 향후계획		보 준설구간 조정을 통한 집수매거 유지 관리수위 유지시 취수제약 없을 전망		

CRITICAL WATER SUPPLY CONTRAINT - IRRIGATION SEASON

"**Maeho**" pumping station for irrigation, Sangju Weir water stage has to be above El.45.0m during irrigation season (Apr.-Sep.)

ㅇ 상주-상-012 [양수시설, 매호양수장] (참고)

현 장 사 진	하 천 모 식 도
	
위 치 도	
	
도 면	
	
양수장 단면도	상주보 상류 10.50km지점

조 사 내 용

상주보 주요제원

계획홍수위	EL. 49.60 m	상한수위	EL. 47.50 m
관리수위	EL. 47.00 m	하한수위	EL. 43.60 m

세 부 조 사 결 과

제약사항(요약) : 수위저하시 취수 지장

☐ 일반현황

시 설 명	매호양수장	주 소	상주시 사벌면 매호리 762
설치일자	1975.12.31	관리기관	한국농어촌공사(상주지사)
담당자명	한국농어촌공사(상주지사)	연 락 처	054-531-3610

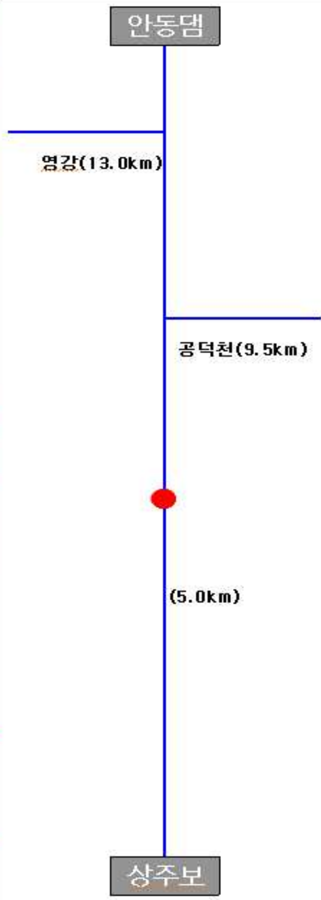
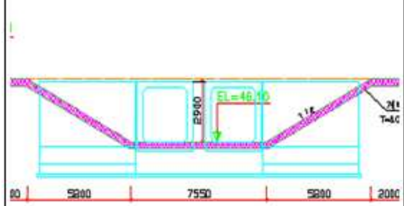
☐ 제원 및 제약사항

최대양수량(m³/초)		1.58	원동기 대수		3
펌프구경		550×1, 500×2	원동기 마력(HP)		400×2, 250×1
시설 제원	취수구 하단고	EL 45.00m	좌표	경도	128-15-57
	기계실	-		위도	36-30-15
	기 타	-	위 치		상주보 상류 10.50km(우안)
운영매뉴얼 비치 유무		-	취수가능수위(EL.m)		45.00 이상
실시간 자료 취득여부		무	연중 운영시기		4월~9월
취수가능수위 산정근거		부산청 T/F 합동점검 세부측량성과			
세부 제약내용		상주보 수위(EL. 45.00m 이상) 유지 필요			
조치방안 및 향후계획					

CRITICAL DRAINAGE CONTRAINT -FLOOD SEASON

“**Maeho 4**” drainage facility, Sangju Weir water stage has to be below El.46.1m during flood season (Jun.-Sep.)

ㅇ 상주-상-027 [배수시설, 매호4배수문] (참고)

현 장 사 진	하 천 모 식 도
	
위 치 도	
	
도 면	
	
배수문 단면도	상주보 상류 6.34km지점

조 사 내 용

상주보 주요제원

계획홍수위	EL. 49.60 m	상한수위	EL. 47.50 m
관리수위	EL. 47.00 m	하한수위	EL. 43.60 m

세 부 조 사 결 과

제약사항(요약) : 유출구 관저고 관리수위 이하

□ 일반현황

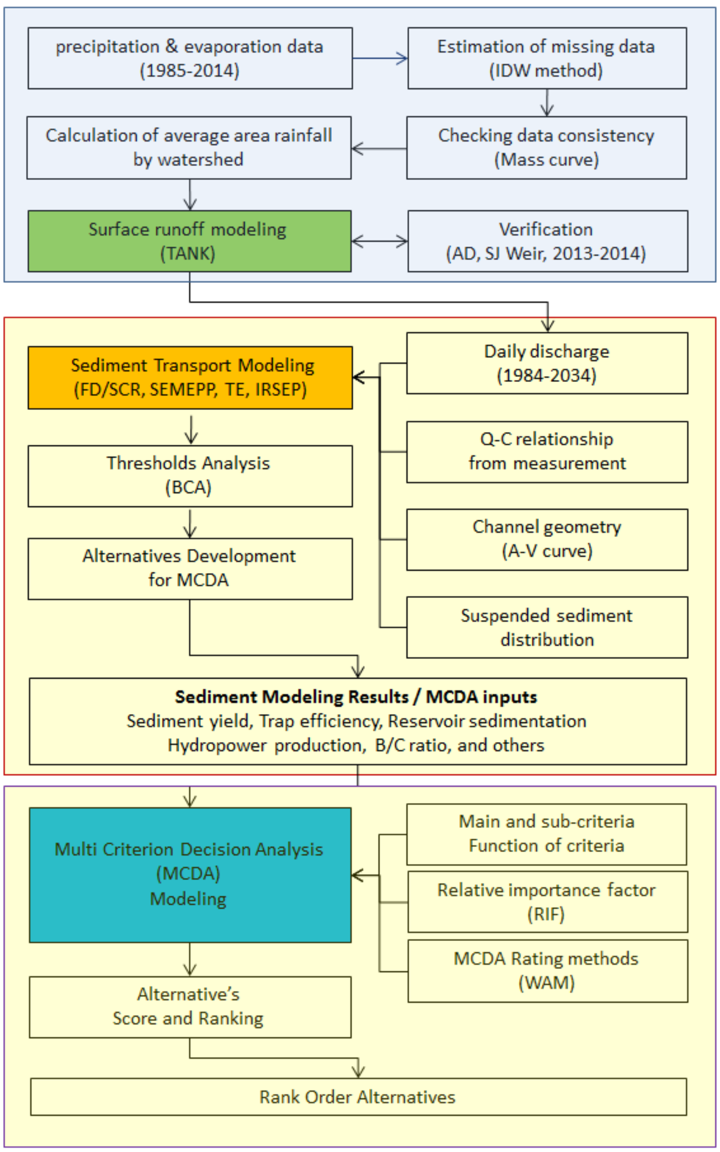
시 설 명	매호 4배수문	주 소	상주시 사벌면 매호리
설치일자	-	관리기관	한국농어촌공사(의성군위지사)
담당자명	한국농어촌공사(의성군위지사)	연 락 처	054-862-8700

□ 제원 및 제약사항

시설형식	배수문	문 비(B×H, m)		2.5×2.5
유출구 관저고 (EL.m)	46.10	배수자동화 시설		없 음
배수펌프장 연결여부	묵하배수장	좌표	경도	128-14-37
배수가능수위(EL.m)	-		위도	36-28-15
운영매뉴얼 비치 유무	-	위 치		상주보 상류 6.34km(우안)
배수가능수위 산정근거	부산청 T/F 합동점검 세부측량성과			
세부 제약내용	유출구 관저고 관리수위 이하			
조치방안 및 향후계획	주변 농경지 최저답 표고 EL. 51.80m 배수에 문제 없음			

APPENDIX F: PROGRAM SOURCE CODE

The program source code was composed of three parts: (1) surface runoff modeling, (2) sediment transport modeling, and (3) MCDA modeling. Figure 117 shows the basic structure of the program codes for this study. Part 1 and 2 were written with Matlab2013a and Part 3 was written with Excel Visual Basic, which was originally written by Dr. Fontane and modified by Hwa Young. Kim for this research. The main codes have several sub-routines.



[Part 1]

Surface runoff modeling

[Part 2]

Sediment Transport Modeling

[Part 3]

MCDA Modeling

Figure 117: Program source code structure

Loading daily precipitation data from excel and text files

Oct01st2015_Getdata_kma_only.m

```
clear all, close all, clc
% Hwa Y. Kim (Oct. 8th, 2015, ERC315)
% need functions of Func_arrange_rf_from_kmadata / Func_vlookup
% This code load rainfall data from kma pervious and kma reatime (wamis)
% data, which code must be supported by Func_arrange_rf_from_kmadata and


fname4prev = 'raw_Taebaek(kma)_previous.xlsx';
ini_yr = 1986;
fns_yr = 2009;
fname4realtime = 'raw_Taebaek(kma)_realtime.xlsx';
fname4write = 'arranged_rawdata_with_missingdata.xlsx';
sheetnm = 'Taebaek(kma)';
[ new_mat ] = Func_arrange_rf_from_kmadata( fname4prev, ini_yr, fns_yr,
fname4realtime, fname4write, sheetnm )

fname4prev = 'raw_Bonghwa(kma)_previous.xlsx';
ini_yr = 1988;
fns_yr = 2009;
fname4realtime = 'raw_Bonghwa(kma)_realtime.xlsx';
fname4write = 'arranged_rawdata_with_missingdata.xlsx';
sheetnm = 'Bonghwa(kma)';
[ new_mat ] = Func_arrange_rf_from_kmadata( fname4prev, ini_yr, fns_yr,
fname4realtime, fname4write, sheetnm )

fname4prev = 'raw_Andong(kma)_previous.xlsx';
ini_yr = 1985;
fns_yr = 2009;
fname4realtime = 'raw_Andong(kma)_realtime.xlsx';
%fname4write = 'arranged_rawdata_with_missingdata.xlsx';
sheetnm = 'Andong(kma)';
[ new_mat ] = Func_arrange_rf_from_kmadata( fname4prev, ini_yr, fns_yr,
fname4realtime, fname4write, sheetnm )

fname4prev = 'raw_Munkyeong(kma)_previous.xlsx';
ini_yr = 1985;
fns_yr = 2009;
fname4realtime = 'raw_Munkyeong(kma)_realtime.xlsx';
%fname4write = 'arranged_rawdata_with_missingdata.xlsx';
sheetnm = 'Munkyeong(kma)';
[ new_mat ] = Func_arrange_rf_from_kmadata( fname4prev, ini_yr, fns_yr,
fname4realtime, fname4write, sheetnm )

fname4prev = 'raw_Uiseong(kma)_previous.xlsx';
ini_yr = 1985;
fns_yr = 2009;
fname4realtime = 'raw_Uiseong(kma)_realtime.xlsx';
```

```
%fname4write = 'arranged_rawdata_with_missingdata.xlsx';
sheetnm = 'Uiseong(kma)';
[ new_mat ] = Func_arrange_rf_from_kmadata( fname4prev, ini_yr, fns_yr,
fname4realtime, fname4write, sheetnm )

fname4prev = 'raw_Yeongju(kma)_previous.xlsx';
ini_yr = 1985;
fns_yr = 2009;
fname4realtime = 'raw_Yeongju(kma)_realtime.xlsx';
%fname4write = 'arranged_rawdata_with_missingdata.xlsx';
sheetnm = 'Yeongju(kma)';
[ new_mat ] = Func_arrange_rf_from_kmadata( fname4prev, ini_yr, fns_yr,
fname4realtime, fname4write, sheetnm )
```

Oct01st2015_Getdata_kwater_only.m

```
clear all, close all, clc
% Hwa Y. Kim (Oct. 8th, 2015, ERC315)
% need functions of Func_arrange_rf_from_text / Func_vlookup
% load raw data from Kwater DB (txtfile)
% save arranged excel file by date with missing data (-9999)

station_name = {'Ilweol(kwater)' 'Subi2(kwater)' 'Yeongyang(kwater)'
'Seokbo(kwater)'...
                'Jinbo2(kwater)' 'Cheongsong(kwater)' 'Budong(kwater)'
'Bunam(kwater)' 'Gasa(kwater)_new' 'Hyeonnae(kwater)_new'...% for bsn2002
                'Taebaek(kwater)' 'Baekcheon(kwater)' 'Chunyang(kwater)'
'Goseon2(kwater)'...
                'Seomyeon(kwater)' 'Galsan(kwater)' 'Myeongho(kwater)'
'Yuicheon(kwater)' 'Yean(kwater)'...% for bsn2001
                'Boeun2(kwater)'...
                'Andong(mltm)' 'Seoksan(mltm)_new'}% for special case
fname4write = 'arranged_rawdata_with_missingdata.xlsx';

for k=1:length(station_name)
 station_name{k}
[ new_mat ] = Func_arrange_rf_from_text( station_name{k}, fname4write )
end
```

Oct01st2015_Getdata_mltm_only.m

```
clear all, close all, clc
% Hwa Y. Kim (Oct. 8th, 2015, ERC315)
% need functions of Func_arrange_rf_from_excel / Func_vlookup

fname4read = 'raw_kwater_mltm.xlsx';
fname4write = 'arranged_rawdata_with_missingdata.xlsx'

sheetnm = {'Hwangji(mltm)' 'Taebaeksan(mltm)' 'Seokpo(mltm)'
'Seokhyeon(mltm)' 'Namhoeryong(mltm)' 'Docheon(mltm)'...
           'Jaesan(mltm)' 'Yean2(mltm)' 'Mijil(mltm)' 'Seokdong(mltm)'...%
bsn 2001
```

```
            'Subi(mltm)' 'Imdong(mltm)' 'Giran(mltm)' 'Hyeonseo(mltm)'
'Dopyeong(mltm)' 'Hwabuk2(mltm)'... % bsn2002
            'Uiseong(mltm)' 'Andong(mltm)' 'Iljik2(mltm)' 'Iljik1(mltm)'
'Angye(mltm)' 'Pungsan(mltm)' 'Jibo(mltm)'...% bsn2003
            'Wolpo(mltm)' 'Dongno2(mltm)' 'Dongno1(mltm)' 'Sihang(mltm)'
'Yeongju(mltm)' 'Bonghwa(mltm)' 'Punggi(mltm)'...
            'Buseok(mltm)' 'Huibang(mltm)' 'Olsan(mltm)'...% bsn 2004
            'Jeomchon(mltm)' 'Ian(mltm)' 'Sabeol(mltm)' 'Hwaseo(mltm)'
'Hwabuk1(mltm)' 'Nongam2(mltm)' 'Nongam1(mltm)' 'Donghwawon(mltm)'...
            'Deokjusa(mltm)' 'Yeonpung(mltm)' 'Songmyeon(mltm)' 'Ipseok(mltm)'
'Bokcheonam(mltm)' 'Samga(mltm)' 'Pyeongon(mltm)' 'Eoeseo(mltm)'}% for bsn
2005 & 2007

%% using function
for k=1:length(sheetnm)
[ new_mat ] = Func_arrange_rf_from_excel( fname4read, sheetnm{k},
fname4write );
end
```

Estimating missing records with Inverse Distance Weighting (IDW) method

```
%clear all; close all; clc;
% Hwa Y. Kim (Oct. 1st, 2015, ERC315)
% Filling missing data record using IDW method
% Inverse Distance Weight method (Func_idw_3~6pnts.m)
% Distance calculaton (Func_distcalc.m)

% Arranged rainfall rawdata which are collected from WAMIS.
%filename = 'bsn2001_before_interpolation.xlsx';
filename = 'arranged_rawdata_with_missingdata.xlsx';

%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% for basin 2001 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Group-1

[Taebaek_kma_, ~, ~] = xlsread(filename, 'Taebaek(kma)');
[Hwangji_mltm_, ~, ~] = xlsread(filename, 'Hwangji(mltm)');
[Taebaeksan_mltm_, ~, ~] = xlsread(filename, 'Taebaeksan(mltm)');
[Taebaek_kwater_, ~, ~] = xlsread(filename, 'Taebaek(kwater)');
[Baekcheon_kwater_, ~, ~] = xlsread(filename, 'Baekcheon(Kwater)');
[Seokpo_mltm_, ~, ~] = xlsread(filename, 'Seokpo(mltm)');

dnum = Taebaek_kma_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, Taebaek_kma_(:,2)), title('TBkma'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, Hwangji_mltm_(:,2)), title('HJmltm'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, Taebaeksan_mltm_(:,2)), title('TBSmltm'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
```

```
subplot(6,1,4), bar(dnum, Taebaek_kwater_(:,2)), title('TBkwater'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, Baekcheon_kwater_(:,2)), title('BCkwater'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, Seokpo_mltm_(:,2)), title('SPmltm'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])

% 1st run
% rainfall
r2=Taebaek_kma_(:,2);
r1=Hwangji_mltm_(:,2);
r3=Taebaeksan_mltm_(:,2);
r4=Taebaek_kwater_(:,2);
r5=Baekcheon_kwater_(:,2);
r6=Seokpo_mltm_(:,2);

stnm2 ='Taebaek(kma)';
stnm1 ='Hwangji(mltm)';
stnm3 ='Taebaeksan(mltm)';
stnm4 ='Taebaek(kwater)';
stnm5 ='Baekcheon(kwater)';
stnm6 ='Seokpo(mltm)';

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ r1 ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14, d15, d16 );
cor_Hwangji_mltm_= r1;

size(cor_Hwangji_mltm_)
size(dnum)

figure()
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, Taebaek_kma_(:,2)), title('TBkma'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Hwangji_mltm_), title('HJmltm'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, Taebaeksan_mltm_(:,2)), title('TBSmltm'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, Taebaek_kwater_(:,2)), title('TBkwater'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, Baekcheon_kwater_(:,2)), title('BCkwater'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, Seokpo_mltm_(:,2)), title('SPmltm'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])


% 2nd run
```

```
r1=Seokpo_mltm_(:,2);
r2=cor_Hwangji_mltm_;
r3=Taebaeksan_mltm_(:,2);
r4=Taebaek_kwater_(:,2);
r5=Baekcheon_kwater_(:,2);
r6=Taebaek_kma_(:,2);

stnm6 ='Taebaek(kma)';
stnm2 ='Hwangji(mltm)';
stnm3 ='Taebaeksan(mltm)';
stnm4 ='Taebaek(kwater)';
stnm5 ='Baekcheon(kwater)';
stnm1 ='Seokpo(mltm)';

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ r1 ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14, d15, d16 );
cor_Seokpo_mltm_= r1;

figure()
k=725008:365:735964;, set(gca,'XTick',[k])
subplot(6,1,1), bar(dnum, Taebaek_kma_(:,2)), title('TBkma'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Hwangji_mltm_), title('HJmltm'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, Taebaeksan_mltm_(:,2)), title('TBSmltm'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, Taebaek_kwater_(:,2)), title('TBkwater'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, Baekcheon_kwater_(:,2)), title('BCkwater'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, cor_Seokpo_mltm_), title('SPmltm'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])

% 3rd run
r5=Taebaek_kma_(:,2);
r2=cor_Hwangji_mltm_;
r3=Taebaeksan_mltm_(:,2);
r4=Taebaek_kwater_(:,2);
r1=Baekcheon_kwater_(:,2);
r6=cor_Seokpo_mltm_;

stnm5 ='Taebaek(kma)';
stnm2 ='Hwangji(mltm)';
stnm3 ='Taebaeksan(mltm)';
stnm4 ='Taebaek(kwater)';
stnm1 ='Baekcheon(kwater)';
stnm6 ='Seokpo(mltm)';
```

```
% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ r1 ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14, d15, d16 );
cor_Baekcheon_kwater_= r1;

figure()
k=725008:365:735964;, set(gca,'XTick',[k])
subplot(6,1,1), bar(dnum, Taebaek_kma_(:,2)), title('TBkma'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Hwangji_mltm_), title('HJmltm'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, Taebaeksan_mltm_(:,2)), title('TBSmltm'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, Taebaek_kwater_(:,2)), title('TBkwater'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, cor_Baekcheon_kwater_), title('BCkwater'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, cor_Seokpo_mltm_), title('SPmltm'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])

% 4th run
r1=Taebaek_kma_(:,2);
r2=cor_Hwangji_mltm_;
r3=Taebaeksan_mltm_(:,2);
r4=Taebaek_kwater_(:,2);
r5=cor_Baekcheon_kwater_;
r6=cor_Seokpo_mltm_;

stnm1 ='Taebaek(kma)';
stnm2 ='Hwangji(mltm)';
stnm3 ='Taebaeksan(mltm)';
stnm4 ='Taebaek(kwater)';
stnm5 ='Baekcheon(kwater)';
stnm6 ='Seokpo(mltm)';

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ r1 ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14, d15, d16 );
cor_Taebaek_kma_= r1;
```

```
figure()
k=725008:365:735964;, set(gca,'XTick',[k])
subplot(6,1,1), bar(dnum, cor_Taebaek_kma_), title('TBkma'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Hwangji_mltm_), title('HJmltm'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, Taebaeksan_mltm_(:,2)), title('TBSmltm'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, Taebaek_kwater_(:,2)), title('TBkwater'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, cor_Baekcheon_kwater_), title('BCkwater'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, cor_Seokpo_mltm_), title('SPmltm'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])

% 5th run
r3=cor_Taebaek_kma_;
r2=cor_Hwangji_mltm_;
r1=Taebaeksan_mltm_(:,2);
r4=Taebaek_kwater_(:,2);
r5=cor_Baekcheon_kwater_;
r6=cor_Seokpo_mltm_;

stnm3 ='Taebaek(kma)';
stnm2 ='Hwangji(mltm)';
stnm1 ='Taebaeksan(mltm)';
stnm4 ='Taebaek(kwater)';
stnm5 ='Baekcheon(kwater)';
stnm6 ='Seokpo(mltm)';

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ r1 ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14, d15, d16 );
cor_Taebaeksan_mltm_= r1;

figure();
k=725008:365:735964;, set(gca,'XTick',[k])
subplot(6,1,1), bar(dnum, cor_Taebaek_kma_), title('TBkma'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Hwangji_mltm_), title('HJmltm'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Taebaeksan_mltm_), title('TBSmltm'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, Taebaek_kwater_(:,2)), title('TBkwater'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, cor_Baekcheon_kwater_), title('BCkwater'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, cor_Seokpo_mltm_), title('SPmltm'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
```

```
% 6th run
r4=cor_Taebaek_kma_;
r2=cor_Hwangji_mltm_;
r3=cor_Taebaeksan_mltm_;
r1=Taebaek_kwater_(:,2);
r5=cor_Baekcheon_kwater_;
r6=cor_Seokpo_mltm_;

stnm4 ='Taebaek(kma)';
stnm2 ='Hwangji(mltm)';
stnm3 ='Taebaeksan(mltm)';
stnm1 ='Taebaek(kwater)';
stnm5 ='Baekcheon(kwater)';
stnm6 ='Seokpo(mltm)';

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ r1 ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14, d15, d16 );
cor_Taebaek_kwater_= r1;

figure()
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Taebaek_kma_), title('TBkma'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Hwangji_mltm_), title('HJmltm'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Taebaeksan_mltm_), title('TBSmltm'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Taebaek_kwater_), title('TBkwater'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, cor_Baekcheon_kwater_), title('BCkwater'),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, cor_Seokpo_mltm_), title('SPmltm'), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])



%% Group-2

stnm1 ='Seokhyeon(mltm)';
stnm2 ='Chunyang(kwater)';
stnm3 ='Bonghwa(kma)';
stnm4 ='Goseon2(kwater)';
stnm5 ='Baekcheon(kwater)'; % already corrected
stnm6 ='Seokpo(mltm)';  % already corrected

[Seokhyeon_mltm_, ~, ~] = xlsread(filename,stnm1 );
[Yean2_mltm_, ~, ~] = xlsread(filename,stnm2 );
[Bonghwa_kma_, ~, ~] = xlsread(filename,stnm3 );
```

```
[Goseon2_kwater_, ~, ~] = xlsread(filename,stnm4 );

or1=Seokhyeon_mltm_(:,2);
or2=Yean2_mltm_(:,2);
or3=Bonghwa_kma_(:,2);
or4=Goseon2_kwater_(:,2);
or5=cor_Baekcheon_kwater_;
or6=cor_Seokpo_mltm_;

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(stnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(stnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(stnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
r1=Seokhyeon_mltm_(:,2);
r2=Yean2_mltm_(:,2);
r3=Bonghwa_kma_(:,2);
r4=Goseon2_kwater_(:,2);
r5=cor_Baekcheon_kwater_;
r6=cor_Seokpo_mltm_;

stnm1 ='Seokhyeon(mltm)';
stnm2 ='Chunyang(kwater)';
stnm3 ='Bonghwa(kma)';
stnm4 ='Goseon2(kwater)';
stnm5 ='Baekcheon(kwater)';
stnm6 ='Seokpo(mltm)';

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Seokhyeon_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13,
d14, d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
```

```
subplot(6,1,1), bar(dnum, cor_Seokhyeon_mltm_), title(stnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(stnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(stnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
r3=Seokhyeon_mltm_(:,2);
r2=Yean2_mltm_(:,2);
r1=Bonghwa_kma_(:,2);
r4=Goseon2_kwater_(:,2);
r5=cor_Baekcheon_kwater_;
r6=cor_Seokpo_mltm_;

stnm3 ='Seokhyeon(mltm)';
stnm2 ='Chunyang(kwater)';
stnm1 ='Bonghwa(kma)';
stnm4 ='Goseon2(kwater)';
stnm5 ='Baekcheon(kwater)';
stnm6 ='Seokpo(mltm)';

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Bonghwa_kma_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Seokhyeon_mltm_), title(stnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(stnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Bonghwa_kma_), title(stnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
```

```
% 3rd run
r3=Seokhyeon_mltm_(:,2);
r1=Yean2_mltm_(:,2);
r2=Bonghwa_kma_(:,2);
r4=Goseon2_kwater_(:,2);
r5=cor_Baekcheon_kwater_;
r6=cor_Seokpo_mltm_;

stnm3 ='Seokhyeon(mltm)';
stnm1 ='Chunyang(kwater)';
stnm2 ='Bonghwa(kma)';
stnm4 ='Goseon2(kwater)';
stnm5 ='Baekcheon(kwater)';
stnm6 ='Seokpo(mltm)';

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Chunyang_kwater_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13,
d14, d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Seokhyeon_mltm_), title(stnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Chunyang_kwater_), title(stnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Bonghwa_kma_), title(stnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 4th run
r3=Seokhyeon_mltm_(:,2);
r4=Yean2_mltm_(:,2);
r2=Bonghwa_kma_(:,2);
r1=Goseon2_kwater_(:,2);
r5=cor_Baekcheon_kwater_;
r6=cor_Seokpo_mltm_;

stnm3 ='Seokhyeon(mltm)';
stnm4 ='Chunyang(kwater)';
stnm2 ='Bonghwa(kma)';
stnm1 ='Goseon2(kwater)';
stnm5 ='Baekcheon(kwater)';
```

```
stnm6 ='Seokpo(mltm)';

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Goseon2_kwater_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13,
d14, d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Seokhyeon_mltm_), title(stnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Chunyang_kwater_), title(stnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Bonghwa_kma_), title(stnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Goseon2_kwater_), title(stnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

%% Group-3

stnm1 ='Seomyeon(kwater)';
stnm2 ='Namhoeryong(mltm)';
stnm3 ='Seokhyeon(mltm)';
stnm4 ='Chunyang(kwater)';
stnm5 ='Bonghwa(kma)';
stnm6 ='Goseon2(kwater)';

% for figure
ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;
ostnm5=stnm5;
ostnm6=stnm6;

[Seomyeon_kwater_, ~, ~] = xlsread(filename,stnm1 );
[Namhoeryong_mltm_, ~, ~] = xlsread(filename,stnm2 );

or1=Seomyeon_kwater_(:,2);
or2=Namhoeryong_mltm_(:,2);
or3=cor_Seokhyeon_mltm_;
or4=cor_Chunyang_kwater_;
or5=cor_Bonghwa_kma_;
```

```
or6=cor_Goseon2_kwater_;

dnum = Seomyeon_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm1 ='Seomyeon(kwater)';
stnm2 ='Namhoeryong(mltm)';
stnm3 ='Seokhyeon(mltm)';
stnm4 ='Chunyang(kwater)';
stnm5 ='Bonghwa(kma)';
stnm6 ='Goseon2(kwater)';

r1=Seomyeon_kwater_(:,2);
r2=Namhoeryong_mltm_(:,2);
r3=cor_Seokhyeon_mltm_;
r4=cor_Chunyang_kwater_;
r5=cor_Bonghwa_kma_;
r6=cor_Goseon2_kwater_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Seomyeon_kwater_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13,
d14, d15, d16 );

dnum = Seomyeon_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Seomyeon_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
```

```
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm2 ='Seomyeon(kwater)';
stnm1 ='Namhoeryong(mltm)';
stnm3 ='Seokhyeon(mltm)';
stnm4 ='Chunyang(kwater)';
stnm5 ='Bonghwa(kma)';
stnm6 ='Goseon2(kwater)';

r2=cor_Seomyeon_kwater_;
r1=Namhoeryong_mltm_(:,2);
r3=cor_Seokhyeon_mltm_;
r4=cor_Chunyang_kwater_;
r5=cor_Bonghwa_kma_;
r6=cor_Goseon2_kwater_;



% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Namhoeryong_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13,
d14, d15, d16 );

dnum = Seomyeon_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Seomyeon_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Namhoeryong_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

%% Group-4

stnm1 ='Docheon(mltm)';
stnm2 ='Myeongho(kwater)';
```

```
stnm3 ='Jaesan(mltm)';
stnm4 ='Galsan(kwater)';
stnm5 ='Bonghwa(kma)';

% for figure
ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;
ostnm5=stnm5;


[Docheon_mltm_, ~, ~] = xlsread(filename,stnm1 );
[Myeongho_kwater_, ~, ~] = xlsread(filename,stnm2 );
[Jaesan_mltm_, ~, ~] = xlsread(filename,stnm3 );
[Galsan_kwater_, ~, ~] = xlsread(filename,stnm4 );

or1=Docheon_mltm_(:,2);
or2=Myeongho_kwater_(:,2);
or3=Jaesan_mltm_(:,2);
or4=Galsan_kwater_(:,2);
or5=cor_Bonghwa_kma_;

dnum = Docheon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(5,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm1 ='Docheon(mltm)';
stnm2 ='Myeongho(kwater)';
stnm3 ='Jaesan(mltm)';
stnm4 ='Galsan(kwater)';
stnm5 ='Bonghwa(kma)';

r1=Docheon_mltm_(:,2);
r2=Myeongho_kwater_(:,2);
r3=Jaesan_mltm_(:,2);
r4=Galsan_kwater_(:,2);
r5=cor_Bonghwa_kma_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
```

```
[ d15 ] = Func_distcalc( stnm1, stnm5 );
%[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Docheon_mltm_ ] = Func_idw_5pnts( r1, r2, r3, r4, r5, d12, d13, d14,
d15);

dnum = Docheon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(5,1,1), bar(dnum, cor_Docheon_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(5,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,5), bar(dnum, or5), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run

stnm3 ='Docheon(mltm)';
stnm2 ='Myeongho(kwater)';
stnm1 ='Jaesan(mltm)';
stnm4 ='Galsan(kwater)';
stnm5 ='Bonghwa(kma)';

r3=Docheon_mltm_(:,2);
r2=Myeongho_kwater_(:,2);
r1=Jaesan_mltm_(:,2);
r4=Galsan_kwater_(:,2);
r5=cor_Bonghwa_kma_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
%[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Jaesan_mltm_ ] = Func_idw_5pnts( r1, r2, r3, r4, r5, d12, d13, d14,
d15);

dnum = Docheon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(5,1,1), bar(dnum, cor_Docheon_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(5,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
```

```
subplot(5,1,3), bar(dnum, cor_Jaesan_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(5,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm3 ='Docheon(mltm)';
stnm2 ='Myeongho(kwater)';
stnm4 ='Jaesan(mltm)';
stnm1 ='Galsan(kwater)';
stnm5 ='Bonghwa(kma)';

r3=Docheon_mltm_(:,2);
r2=Myeongho_kwater_(:,2);
r4=Jaesan_mltm_(:,2);
r1=Galsan_kwater_(:,2);
r5=cor_Bonghwa_kma_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
%[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Galsan_kwater_ ] = Func_idw_5pnts( r1, r2, r3, r4, r5, d12, d13, d14,
d15);

dnum = Docheon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(5,1,1), bar(dnum, cor_Docheon_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(5,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,3), bar(dnum, cor_Jaesan_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(5,1,4), bar(dnum, cor_Galsan_kwater_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(5,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 4th run
stnm3 ='Docheon(mltm)';
stnm1 ='Myeongho(kwater)';
stnm4 ='Jaesan(mltm)';
stnm2 ='Galsan(kwater)';
stnm5 ='Bonghwa(kma)';

r3=Docheon_mltm_(:,2);
r1=Myeongho_kwater_(:,2);
```

```
r4=Jaesan_mltm_(:,2);
r2=Galsan_kwater_(:,2);
r5=cor_Bonghwa_kma_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
%[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Myeongho_kwater_ ] = Func_idw_5pnts( r1, r2, r3, r4, r5, d12, d13, d14,
d15);

%figure(), plot(dnum, cor_MHkwater)

dnum = Docheon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(5,1,1), bar(dnum, cor_Docheon_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(5,1,2), bar(dnum, cor_Myeongho_kwater_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(5,1,3), bar(dnum, cor_Jaesan_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(5,1,4), bar(dnum, cor_Galsan_kwater_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(5,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

%% Group-5

stnm1 ='Yuicheon(kwater)';
stnm2 ='Yean2(mltm)';
stnm3 ='Mijil(mltm)';
stnm4 ='Yean(kwater)';
stnm5 ='Seokdong(mltm)';
stnm6 ='Docheon(mltm)'; % for compensation

% for figure
ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;
ostnm5=stnm5;
ostnm6=stnm6;

[Yuicheon_kwater_, ~, ~] = xlsread(filename,stnm1 );
[Yean2_mltm_, ~, ~] = xlsread(filename,stnm2 );
[Mijil_mltm_, ~, ~] = xlsread(filename,stnm3 );
[Yean_kwater_, ~, ~] = xlsread(filename,stnm4 );
[Seokdong_mltm_, ~, ~] = xlsread(filename,stnm5 );
```

```
or1=Yuicheon_kwater_(:,2);
or2=Yean2_mltm_(:,2);
or3=Mijil_mltm_(:,2);
or4=Yean_kwater_(:,2);
or5=Seokdong_mltm_(:,2);
or6=cor_Docheon_mltm_;

dnum = Yuicheon_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])


% 1st run
stnm1 ='Yuicheon(kwater)';
stnm2 ='Yean2(mltm)';
stnm3 ='Mijil(mltm)';
stnm4 ='Yean(kwater)';
stnm5 ='Seokdong(mltm)';
stnm6 ='Docheon(mltm)';

r1=Yuicheon_kwater_(:,2);
r2=Yean2_mltm_(:,2);
r3=Mijil_mltm_(:,2);
r4=Yean_kwater_(:,2);
r5=Seokdong_mltm_(:,2);
r6=cor_Docheon_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Yuicheon_kwater_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13,
d14, d15, d16);

dnum = Yuicheon_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
```

```
subplot(6,1,1), bar(dnum, cor_Yuicheon_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm3 ='Yuicheon(kwater)';
stnm2 ='Yean2(mltm)';
stnm1 ='Mijil(mltm)';
stnm4 ='Yean(kwater)';
stnm5 ='Seokdong(mltm)';
stnm6 ='Docheon(mltm)';

r3=Yuicheon_kwater_(:,2);
r2=Yean2_mltm_(:,2);
r1=Mijil_mltm_(:,2);
r4=Yean_kwater_(:,2);
r5=Seokdong_mltm_(:,2);
r6=cor_Docheon_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Mijil_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16);

dnum = Yuicheon_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Yuicheon_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Mijil_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
```

```
% 3rd run
stnm3 ='Yuicheon(kwater)';
stnm1 ='Yean2(mltm)';
stnm2 ='Mijil(mltm)';
stnm4 ='Yean(kwater)';
stnm5 ='Seokdong(mltm)';
stnm6 ='Docheon(mltm)';

r3=Yuicheon_kwater_(:,2);
r1=Yean2_mltm_(:,2);
r2=Mijil_mltm_(:,2);
r4=Yean_kwater_(:,2);
r5=Seokdong_mltm_(:,2);
r6=cor_Docheon_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Yean2_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16);

dnum = Yuicheon_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Yuicheon_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Yean2_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Mijil_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 4th run
stnm3 ='Yuicheon(kwater)';
stnm4 ='Yean2(mltm)';
stnm2 ='Mijil(mltm)';
stnm1 ='Yean(kwater)';
stnm5 ='Seokdong(mltm)';
stnm6 ='Docheon(mltm)';

r3=Yuicheon_kwater_(:,2);
r4=Yean2_mltm_(:,2);
r2=Mijil_mltm_(:,2);
r1=Yean_kwater_(:,2);
r5=Seokdong_mltm_(:,2);
```

```
r6=cor_Docheon_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Yean_kwater_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16);

dnum = Yuicheon_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Yuicheon_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Yean2_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Mijil_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Yean_kwater_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])


% 5th run
stnm3 ='Yuicheon(kwater)';
stnm4 ='Yean2(mltm)';
stnm2 ='Mijil(mltm)';
stnm5 ='Yean(kwater)';
stnm1 ='Seokdong(mltm)';
stnm6 ='Docheon(mltm)';

r3=Yuicheon_kwater_(:,2);
r4=Yean2_mltm_(:,2);
r2=Mijil_mltm_(:,2);
r5=Yean_kwater_(:,2);
r1=Seokdong_mltm_(:,2);
r6=cor_Docheon_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
```

```
[ cor_Seokdong_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13,
d14, d15, d16);

dnum = Yuicheon_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Yuicheon_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Yean2_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Mijil_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Yean_kwater_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, cor_Seokdong_mltm_), title(ostnm5), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])



%% Group-6

stnm1 ='Andong(kma)';
stnm2 ='Andong(mltm)';
stnm3 ='Seokdong(mltm)';
stnm4 ='Imdong(mltm)';

% for figure
ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;

[Andong_kma_, ~, ~] = xlsread(filename,stnm1 );
[Andong_mltm_, ~, ~] = xlsread(filename,stnm2 );

[Imdong_mltm_, ~, ~] = xlsread(filename,stnm4 );

or1=Andong_kma_(:,2);
or2=Andong_mltm_(:,2);
or3=cor_Seokdong_mltm_;
or4=Imdong_mltm_(:,2);

dnum = Andong_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
```

```
% 1st run
stnm1 ='Andong(kma)';
stnm2 ='Andong(mltm)';
stnm3 ='Seokdong(mltm)';
stnm4 ='Imdong(mltm)';

r1=Andong_kma_(:,2);
r2=Andong_mltm_(:,2);
r3=cor_Seokdong_mltm_;
r4=Imdong_mltm_(:,2);


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Andong_kma_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Andong_kma_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Andong_kma_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm2 ='Andong(kma)';
stnm1 ='Andong(mltm)';
stnm3 ='Seokdong(mltm)';
stnm4 ='Imdong(mltm)';

r2=cor_Andong_kma_;
r1=Andong_mltm_(:,2);
r3=cor_Seokdong_mltm_;
r4=Imdong_mltm_(:,2);


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
```

```
[ cor_Andong_mltm_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Andong_kma_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Andong_kma_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, cor_Andong_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm2 ='Andong(kma)';
stnm4 ='Andong(mltm)';
stnm3 ='Seokdong(mltm)';
stnm1 ='Imdong(mltm)';

r2=cor_Andong_kma_;
r4=cor_Andong_mltm_;
r3=cor_Seokdong_mltm_;
r1=Imdong_mltm_(:,2);


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Imdong_mltm_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Andong_kma_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Andong_kma_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, cor_Andong_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, cor_Seokdong_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, cor_Imdong_mltm_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])



%% Group-7

stnm1 ='Jinbo2(kwater)';
stnm2 ='Seokbo(kwater)';
```

```
stnm3 ='Yeongyang(kwater)';
stnm4 ='Imdong(mltm)';

% for figure
ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;

[Jinbo2_kwater_, ~, ~] = xlsread(filename,stnm1 );
[Seokbo_kwater_, ~, ~] = xlsread(filename,stnm2 );
[Yeongyang_kwater_, ~, ~] = xlsread(filename,stnm3 );
%[IDmltm, ~, ~] = xlsread(filename,stnm4 );

or1=Jinbo2_kwater_(:,2);
or2=Seokbo_kwater_(:,2);
or3=Yeongyang_kwater_(:,2);
or4=cor_Imdong_mltm_;

dnum = Jinbo2_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm1 ='Jinbo2(kwater)';
stnm2 ='Seokbo(kwater)';
stnm3 ='Yeongyang(kwater)';
stnm4 ='Imdong(mltm)';

r1=Jinbo2_kwater_(:,2);
r2=Seokbo_kwater_(:,2);
r3=Yeongyang_kwater_(:,2);
r4=cor_Imdong_mltm_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Jinbo2_kwater_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Jinbo2_kwater_(:,1);
figure() % 2001 upstream
```

```
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Jinbo2_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm2 ='Jinbo2(kwater)';
stnm1 ='Seokbo(kwater)';
stnm3 ='Yeongyang(kwater)';
stnm4 ='Imdong(mltm)';

r2=cor_Jinbo2_kwater_;
r1=Seokbo_kwater_(:,2);
r3=Yeongyang_kwater_(:,2);
r4=cor_Imdong_mltm_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Seokbo_kwater_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Jinbo2_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Jinbo2_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, cor_Seokbo_kwater_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm2 ='Jinbo2(kwater)';
stnm3 ='Seokbo(kwater)';
stnm1 ='Yeongyang(kwater)';
stnm4 ='Imdong(mltm)';

r2=cor_Jinbo2_kwater_;
r3=cor_Seokbo_kwater_;
r1=Yeongyang_kwater_(:,2);
r4=cor_Imdong_mltm_;
```

```
% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Yeongyang_kwater_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Jinbo2_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Jinbo2_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, cor_Seokbo_kwater_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, cor_Yeongyang_kwater_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])


%% Group-8

stnm1 ='Subi2(kwater)';
stnm2 ='Ilweol(kwater)';
stnm3 ='Subi(mltm)';
stnm4 ='Yeongyang(kwater)';

% for figure
ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;

[Subi2_kwater_, ~, ~] = xlsread(filename,stnm1 );
[Ilweol_kwater_, ~, ~] = xlsread(filename,stnm2 );
[Subi_mltm_, ~, ~] = xlsread(filename,stnm3 );
%[IDmltm, ~, ~] = xlsread(filename,stnm4 );

or1=Subi2_kwater_(:,2);
or2=Ilweol_kwater_(:,2);
or3=Subi_mltm_(:,2);
or4=cor_Yeongyang_kwater_;

dnum = Subi2_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
```

```
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm1 ='Subi2(kwater)';
stnm2 ='Ilweol(kwater)';
stnm3 ='Subi(mltm)';
stnm4 ='Yeongyang(kwater)';

r1=Subi2_kwater_(:,2);
r2=Ilweol_kwater_(:,2);
r3=Subi_mltm_(:,2);
r4=cor_Yeongyang_kwater_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Subi2_kwater_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Subi2_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Subi2_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])


% 2nd run
stnm2 ='Subi2(kwater)';
stnm1 ='Ilweol(kwater)';
stnm3 ='Subi(mltm)';
stnm4 ='Yeongyang(kwater)';

r2=cor_Subi2_kwater_;
r1=Ilweol_kwater_(:,2);
r3=Subi_mltm_(:,2);
r4=cor_Yeongyang_kwater_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
```

```
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Ilweol_kwater_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Subi2_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Subi2_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, cor_Ilweol_kwater_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm2 ='Subi2(kwater)';
stnm3 ='Ilweol(kwater)';
stnm1 ='Subi(mltm)';
stnm4 ='Yeongyang(kwater)';

r2=cor_Subi2_kwater_;
r3=cor_Ilweol_kwater_;
r1=Subi_mltm_(:,2);
r4=cor_Yeongyang_kwater_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Subi_mltm_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Subi2_kwater_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Subi2_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, cor_Ilweol_kwater_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, cor_Subi_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% finished missing data filling
% close all;
%%
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% for basin 2002 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
close all
% Group-9

stnm1 ='Giran(mltm)';
stnm2 ='Imdong(mltm)';
stnm3 ='Jinbo2(kwater)';
stnm4 ='Cheongsong(kwater)';

% for figure
ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;

[Giran_mltm_, ~, ~] = xlsread(filename,stnm1 );
%[Ilweol_kwater, ~, ~] = xlsread(filename,stnm2 );
[Jinbo2_kwater_, ~, ~] = xlsread(filename,stnm3 );
[Cheongsong_kwater_, ~, ~] = xlsread(filename,stnm4 );

or1=Giran_mltm_(:,2);
or2=cor_Imdong_mltm_;
or3=Jinbo2_kwater_(:,2);
or4=Cheongsong_kwater_(:,2);

dnum = Giran_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm1 ='Giran(mltm)';
stnm2 ='Imdong(mltm)';
stnm3 ='Jinbo2(kwater)';
stnm4 ='Cheongsong(kwater)';

r1=Giran_mltm_(:,2);
r2=cor_Imdong_mltm_;
r3=Jinbo2_kwater_(:,2);
r4=Cheongsong_kwater_(:,2);


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
```

```
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Giran_mltm_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Giran_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Giran_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm3 ='Giran(mltm)';
stnm2 ='Imdong(mltm)';
stnm1 ='Jinbo2(kwater)';
stnm4 ='Cheongsong(kwater)';

r3=cor_Giran_mltm_;
r2=cor_Imdong_mltm_;
r1=Jinbo2_kwater_(:,2);
r4=Cheongsong_kwater_(:,2);


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Jinbo2_kwater_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Giran_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Giran_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, cor_Jinbo2_kwater_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm3 ='Giran(mltm)';
stnm2 ='Imdong(mltm)';
```

```
stnm4 ='Jinbo2(kwater)';
stnm1 ='Cheongsong(kwater)';

r3=cor_Giran_mltm_;
r2=cor_Imdong_mltm_;
r4=cor_Jinbo2_kwater_;
r1=Cheongsong_kwater_(:,2);


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Cheongsong_kwater_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Giran_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Giran_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, cor_Jinbo2_kwater_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, cor_Cheongsong_kwater_), title(ostnm4),
datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])

% Group-10

stnm1 ='Budong(kwater)';
stnm2 ='Bunam(kwater)';
stnm3 ='Dopyeong(mltm)';
stnm4 ='Cheongsong(kwater)';

% for figure
ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;

[Budong_kwater_, ~, ~] = xlsread(filename,stnm1 );
[Bunam_kwater_, ~, ~] = xlsread(filename,stnm2 );
[Dopyeong_mltm_, ~, ~] = xlsread(filename,stnm3 );
%[Cheongsong_kwater_, ~, ~] = xlsread(filename,stnm4 );

or1=Budong_kwater_(:,2);
or2=Bunam_kwater_(:,2);
or3=Dopyeong_mltm_(:,2);
or4=cor_Cheongsong_kwater_;
```

```
dnum = Giran_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm1 ='Budong(kwater)';
stnm2 ='Bunam(kwater)';
stnm3 ='Dopyeong(mltm)';
stnm4 ='Cheongsong(kwater)';

r1=Budong_kwater_(:,2);
r2=Bunam_kwater_(:,2);
r3=Dopyeong_mltm_(:,2);
r4=cor_Cheongsong_kwater_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Budong_kwater_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Giran_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Budong_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm2 ='Budong(kwater)';
stnm1 ='Bunam(kwater)';
stnm3 ='Dopyeong(mltm)';
stnm4 ='Cheongsong(kwater)';

r2=cor_Budong_kwater_;
r1=Bunam_kwater_(:,2);
r3=Dopyeong_mltm_(:,2);
```

```
r4=cor_Cheongsong_kwater_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Bunam_kwater_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Giran_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Budong_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, cor_Bunam_kwater_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm2 ='Budong(kwater)';
stnm3 ='Bunam(kwater)';
stnm1 ='Dopyeong(mltm)';
stnm4 ='Cheongsong(kwater)';

r2=cor_Budong_kwater_;
r3=cor_Bunam_kwater_;
r1=Dopyeong_mltm_(:,2);
r4=cor_Cheongsong_kwater_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Dopyeong_mltm_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Giran_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Budong_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, cor_Bunam_kwater_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
```

```
subplot(4,1,3), bar(dnum, cor_Dopyeong_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% Group-11

stnm1 ='Gasa(kwater)';
stnm2 ='Hyeonnae(kwater)';
stnm3 ='Hwabuk2(mltm)';
stnm4 ='Dopyeong(mltm)';
stnm5 ='Bunam(kwater)';

% for figure
ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;
ostnm5=stnm5;

[Gasa_kwater_, ~, ~] = xlsread(filename,stnm1 );
[Hyeonnae_kwater_, ~, ~] = xlsread(filename,stnm2 );
[Hwabuk2_mltm_, ~, ~] = xlsread(filename,stnm3 );
%[Cheongsong_kwater_, ~, ~] = xlsread(filename,stnm4 );

or1=Gasa_kwater_(:,2);
or2=Hyeonnae_kwater_(:,2);
or3=Hwabuk2_mltm_(:,2);
or4=cor_Dopyeong_mltm_;
or5=cor_Bunam_kwater_;

dnum = Giran_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(5,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm1 ='Gasa(kwater)';
stnm2 ='Hyeonnae(kwater)';
stnm3 ='Hwabuk2(mltm)';
stnm4 ='Dopyeong(mltm)';
stnm5 ='Bunam(kwater)';

r1=Gasa_kwater_(:,2);
r2=Hyeonnae_kwater_(:,2);
r3=Hwabuk2_mltm_(:,2);
```

```
r4=cor_Dopyeong_mltm_;
r5=cor_Bunam_kwater_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );


% call function Func_idw.m
[ cor_Gasa_kwater_ ] = Func_idw_5pnts( r1, r2, r3, r4, r5, d12, d13, d14,
d15);

dnum = Giran_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(5,1,1), bar(dnum, cor_Gasa_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(5,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(5,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm3 ='Gasa(kwater)';
stnm2 ='Hyeonnae(kwater)';
stnm1 ='Hwabuk2(mltm)';
stnm4 ='Dopyeong(mltm)';

r3=cor_Gasa_kwater_;
r2=Hyeonnae_kwater_(:,2);
r1=Hwabuk2_mltm_(:,2);
r4=cor_Dopyeong_mltm_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Hwabuk2_mltm_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Giran_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
```

```
subplot(4,1,1), bar(dnum, cor_Gasa_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, cor_Hwabuk2_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm3 ='Gasa(kwater)';
stnm1 ='Hyeonnae(kwater)';
stnm2 ='Hwabuk2(mltm)';
stnm4 ='Dopyeong(mltm)';

r3=cor_Gasa_kwater_;
r1=Hyeonnae_kwater_(:,2);
r2=cor_Hwabuk2_mltm_;
r4=cor_Dopyeong_mltm_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Hyeonnae_kwater_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Giran_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Gasa_kwater_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, cor_Hyeonnae_kwater_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, cor_Hwabuk2_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% Group-12

stnm1 ='Hyeonseo(mltm)';
stnm2 ='Seoksan(mltm)';
stnm3 ='Hwabuk2(mltm)';
stnm4 ='Dopyeong(mltm)';

% for figure
ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;
```

```
[Hyeonseo_mltm_, ~, ~] = xlsread(filename,stnm1 );
[Seoksan_mltm_, ~, ~] = xlsread(filename,stnm2 );
%[Hwabuk2_mltm_, ~, ~] = xlsread(filename,stnm3 );
%[Cheongsong_kwater_, ~, ~] = xlsread(filename,stnm4 );

or1=Hyeonseo_mltm_(:,2);
or2=Seoksan_mltm_(:,2);
or3=cor_Hwabuk2_mltm_;
or4=cor_Dopyeong_mltm_;

dnum = Giran_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm1 ='Hyeonseo(mltm)';
stnm2 ='Seoksan(mltm)';
stnm3 ='Hwabuk2(mltm)';
stnm4 ='Dopyeong(mltm)';

r1=Hyeonseo_mltm_(:,2);
r2=Seoksan_mltm_(:,2);
r3=cor_Hwabuk2_mltm_;
r4=cor_Dopyeong_mltm_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Hyeonseo_mltm_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Giran_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Hyeonseo_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
```

```
% 2nd run
stnm2 ='Hyeonseo(mltm)';
stnm1 ='Seoksan(mltm)';
stnm3 ='Hwabuk2(mltm)';
stnm4 ='Dopyeong(mltm)';

r2=cor_Hyeonseo_mltm_;
r1=Seoksan_mltm_(:,2);
r3=cor_Hwabuk2_mltm_;
r4=cor_Dopyeong_mltm_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );


% call function Func_idw.m
[ cor_Seoksan_mltm_ ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14);

dnum = Giran_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(4,1,1), bar(dnum, cor_Hyeonseo_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,2), bar(dnum, cor_Seoksan_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(4,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(4,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])


%% Group-13

stnm1 ='Andong(kma)';
stnm2 ='Andong(mltm)';
stnm3 ='Pungsan(mltm)';
stnm4 ='Iljik1(mltm)';
stnm5 ='Iljik2(mltm)';
stnm6 ='Seokdong(mltm)';

[Andong_kma_, ~, ~] = xlsread(filename,stnm1 );
[Andong_mltm_, ~, ~] = xlsread(filename,stnm2 );
[Pungsan_mltm_, ~, ~] = xlsread(filename,stnm3 );
[Iljik1_mltm_, ~, ~] = xlsread(filename,stnm4 );
[Iljik2_mltm_, ~, ~] = xlsread(filename,stnm5 );

or1=Andong_kma_(:,2);
or2=Andong_mltm_(:,2);
or3=Pungsan_mltm_(:,2);
or4=Iljik1_mltm_(:,2);
or5=Iljik2_mltm_(:,2);
```

```
or6=cor_Seokdong_mltm_;

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(stnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(stnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(stnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm1 ='Andong(kma)';
stnm2 ='Andong(mltm)';
stnm3 ='Pungsan(mltm)';
stnm4 ='Iljik1(mltm)';
stnm5 ='Iljik2(mltm)';
stnm6 ='Seokdong(mltm)';

r1=Andong_kma_(:,2);
r2=Andong_mltm_(:,2);
r3=Pungsan_mltm_(:,2);
r4=Iljik1_mltm_(:,2);
r5=Iljik2_mltm_(:,2);
r6=cor_Seokdong_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Andong_kma_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Andong_kma_), title(stnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(stnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(stnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
```

```
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm2 ='Andong(kma)';
stnm1 ='Andong(mltm)';
stnm3 ='Pungsan(mltm)';
stnm4 ='Iljik1(mltm)';
stnm5 ='Iljik2(mltm)';
stnm6 ='Seokdong(mltm)';

r2=cor_Andong_kma_;
r1=Andong_mltm_(:,2);
r3=Pungsan_mltm_(:,2);
r4=Iljik1_mltm_(:,2);
r5=Iljik2_mltm_(:,2);
r6=cor_Seokdong_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Andong_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Andong_kma_), title(stnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Andong_mltm_), title(stnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(stnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm2 ='Andong(kma)';
stnm3 ='Andong(mltm)';
stnm1 ='Pungsan(mltm)';
stnm4 ='Iljik1(mltm)';
stnm5 ='Iljik2(mltm)';
stnm6 ='Seokdong(mltm)';
r2=cor_Andong_kma_;
```

```
r3=cor_Andong_mltm_;
r1=Pungsan_mltm_(:,2);
r4=Iljik1_mltm_(:,2);
r5=Iljik2_mltm_(:,2);
r6=cor_Seokdong_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Pungsan_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Andong_kma_), title(stnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Andong_mltm_), title(stnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Pungsan_mltm_), title(stnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 4th run
stnm2 ='Andong(kma)';
stnm3 ='Andong(mltm)';
stnm4 ='Pungsan(mltm)';
stnm1 ='Iljik1(mltm)';
stnm5 ='Iljik2(mltm)';
stnm6 ='Seokdong(mltm)';

r2=cor_Andong_kma_;
r3=cor_Andong_mltm_;
r4=cor_Pungsan_mltm_;
r1=Iljik1_mltm_(:,2);
r5=Iljik2_mltm_(:,2);
r6=cor_Seokdong_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );
```

```
% call function Func_idw.m
[ cor_Iljik1_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Andong_kma_), title(stnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Andong_mltm_), title(stnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Pungsan_mltm_), title(stnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Iljik1_mltm_), title(stnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 5th run
stnm2 ='Andong(kma)';
stnm3 ='Andong(mltm)';
stnm4 ='Pungsan(mltm)';
stnm5 ='Iljik1(mltm)';
stnm1 ='Iljik2(mltm)';
stnm6 ='Seokdong(mltm)';

r2=cor_Andong_kma_;
r3=cor_Andong_mltm_;
r4=cor_Pungsan_mltm_;
r5=cor_Iljik1_mltm_;
r1=Iljik2_mltm_(:,2);
r6=cor_Seokdong_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Iljik2_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Andong_kma_), title(stnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Andong_mltm_), title(stnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Pungsan_mltm_), title(stnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
```

```
subplot(6,1,4), bar(dnum, cor_Iljik1_mltm_), title(stnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, cor_Iljik2_mltm_), title(stnm5), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

%% Group-14

stnm1 ='Uiseong(kma)';
stnm2 ='Uiseong(mltm)';
stnm3 ='Angye(mltm)';
stnm4 ='Iljik1(mltm)';
stnm5 ='Iljik2(mltm)';
stnm6 ='Andong(mltm)';

[Uiseong_kma_, ~, ~] = xlsread(filename,stnm1 );
[Uiseong_mltm_, ~, ~] = xlsread(filename,stnm2 );
[Angye_mltm_, ~, ~] = xlsread(filename,stnm3 );
%[Iljik1_mltm_, ~, ~] = xlsread(filename,stnm4 );
%[Iljik2_mltm_, ~, ~] = xlsread(filename,stnm5 );

or1=Uiseong_kma_(:,2);
or2=Uiseong_mltm_(:,2);
or3=Angye_mltm_(:,2);
or4=cor_Iljik1_mltm_;
or5=cor_Iljik2_mltm_;
or6=cor_Andong_mltm_;

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(stnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(stnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(stnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm1 ='Uiseong(kma)';
stnm2 ='Uiseong(mltm)';
stnm3 ='Angye(mltm)';
stnm4 ='Iljik1(mltm)';
stnm5 ='Iljik2(mltm)';
stnm6 ='Andong(mltm)';

r1=Uiseong_kma_(:,2);
r2=Uiseong_mltm_(:,2);
```

```
r3=Angye_mltm_(:,2);
r4=cor_Iljik1_mltm_;
r5=cor_Iljik2_mltm_;
r6=cor_Andong_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Uiseong_kma_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Uiseong_kma_), title(stnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(stnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(stnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm2 ='Uiseong(kma)';
stnm1 ='Uiseong(mltm)';
stnm3 ='Angye(mltm)';
stnm4 ='Iljik1(mltm)';
stnm5 ='Iljik2(mltm)';
stnm6 ='Andong(mltm)';

r2=cor_Uiseong_kma_;
r1=Uiseong_mltm_(:,2);
r3=Angye_mltm_(:,2);
r4=cor_Iljik1_mltm_;
r5=cor_Iljik2_mltm_;
r6=cor_Andong_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );
% call function Func_idw.m
```

```
[ cor_Uiseong_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Uiseong_kma_), title(stnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Uiseong_mltm_), title(stnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(stnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm2 ='Uiseong(kma)';
stnm3 ='Uiseong(mltm)';
stnm1 ='Angye(mltm)';
stnm4 ='Iljik1(mltm)';
stnm5 ='Iljik2(mltm)';
stnm6 ='Andong(mltm)';

r2=cor_Uiseong_kma_;
r3=cor_Uiseong_mltm_;
r1=Angye_mltm_(:,2);
r4=cor_Iljik1_mltm_;
r5=cor_Iljik2_mltm_;
r6=cor_Andong_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Angye_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Uiseong_kma_), title(stnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Uiseong_mltm_), title(stnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Angye_mltm_), title(stnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
```

```
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

%% Group-15

stnm1 ='Jibo(mltm)';
stnm2 ='Sabeol(mltm)';
stnm3 ='Wolpo(mltm)';
stnm4 ='Angye(mltm)';
stnm5 ='Pungsan(mltm)';
stnm6 ='Andong(kma)';

[Jibo_mltm_, ~, ~] = xlsread(filename,stnm1 );
[Sabeol_mltm_, ~, ~] = xlsread(filename,stnm2 );
[Wolpo_mltm_, ~, ~] = xlsread(filename,stnm3 );
%[Wolpo_mltm_, ~, ~] = xlsread(filename,stnm4 );
%[Iljik2_mltm_, ~, ~] = xlsread(filename,stnm5 );

or1=Jibo_mltm_(:,2);
or2=Sabeol_mltm_(:,2);
or3=Wolpo_mltm_(:,2);
or4=cor_Angye_mltm_;
or5=cor_Pungsan_mltm_;
or6=cor_Andong_kma_;

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(stnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(stnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(stnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm1 ='Jibo(mltm)';
stnm2 ='Sabeol(mltm)';
stnm3 ='Wolpo(mltm)';
stnm4 ='Angye(mltm)';
stnm5 ='Pungsan(mltm)';
stnm6 ='Andong(kma)';

r1=Jibo_mltm_(:,2);
r2=Sabeol_mltm_(:,2);
```

```
r3=Wolpo_mltm_(:,2);
r4=cor_Angye_mltm_;
r5=cor_Pungsan_mltm_;
r6=cor_Andong_kma_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Jibo_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Jibo_mltm_), title(stnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(stnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(stnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm2 ='Jibo(mltm)';
stnm1 ='Sabeol(mltm)';
stnm3 ='Wolpo(mltm)';
stnm4 ='Angye(mltm)';
stnm5 ='Pungsan(mltm)';
stnm6 ='Andong(kma)';

r2=cor_Jibo_mltm_;
r1=Sabeol_mltm_(:,2);
r3=Wolpo_mltm_(:,2);
r4=cor_Angye_mltm_;
r5=cor_Pungsan_mltm_;
r6=cor_Andong_kma_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );
% call function Func_idw.m
```

```
[ cor_Sabeol_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Jibo_mltm_), title(stnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Sabeol_mltm_), title(stnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(stnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm2 ='Jibo(mltm)';
stnm3 ='Sabeol(mltm)';
stnm1 ='Wolpo(mltm)';
stnm4 ='Angye(mltm)';
stnm5 ='Pungsan(mltm)';
stnm6 ='Andong(kma)';

r2=cor_Jibo_mltm_;
r3=cor_Sabeol_mltm_;
r1=Wolpo_mltm_(:,2);
r4=cor_Angye_mltm_;
r5=cor_Pungsan_mltm_;
r6=cor_Andong_kma_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Wolpo_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Jibo_mltm_), title(stnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Sabeol_mltm_), title(stnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Wolpo_mltm_), title(stnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
```

```
subplot(6,1,4), bar(dnum, or4), title(stnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(stnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(stnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

%% Group-16

stnm1 ='Sihang(mltm)';
stnm2 ='Dongno2(mltm)';
stnm3 ='Dongno1(mltm)';
stnm4 ='Olsan(mltm)';
stnm5 ='Pungsan(mltm)';
stnm6 ='Andong(kma)';

ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;
ostnm5=stnm5;
ostnm6=stnm6;

[Sihang_mltm_, ~, ~] = xlsread(filename,stnm1 );
[Dongno2_mltm_, ~, ~] = xlsread(filename,stnm2 );
[Dongno1_mltm_, ~, ~] = xlsread(filename,stnm3 );
[Olsan_mltm_, ~, ~] = xlsread(filename,stnm4 );
%[Iljik2_mltm_, ~, ~] = xlsread(filename,stnm5 );

or1=Sihang_mltm_(:,2);
or2=Dongno2_mltm_(:,2);
or3=Dongno1_mltm_(:,2);
or4=Olsan_mltm_(:,2);
or5=cor_Pungsan_mltm_;
or6=cor_Andong_kma_;

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm1 ='Sihang(mltm)';
stnm2 ='Dongno2(mltm)';
```

```
stnm3 ='Dongno1(mltm)';
stnm4 ='Olsan(mltm)';
stnm5 ='Pungsan(mltm)';
stnm6 ='Andong(kma)';

r1=Sihang_mltm_(:,2);
r2=Dongno2_mltm_(:,2);
r3=Dongno1_mltm_(:,2);
r4=Olsan_mltm_(:,2);
r5=cor_Pungsan_mltm_;
r6=cor_Andong_kma_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Sihang_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Sihang_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm2 ='Sihang(mltm)';
stnm1 ='Dongno2(mltm)';
stnm3 ='Dongno1(mltm)';
stnm4 ='Olsan(mltm)';
stnm5 ='Pungsan(mltm)';
stnm6 ='Andong(kma)';

r2=cor_Sihang_mltm_;
r1=Dongno2_mltm_(:,2);
r3=Dongno1_mltm_(:,2);
r4=Olsan_mltm_(:,2);
r5=cor_Pungsan_mltm_;
r6=cor_Andong_kma_;
```

```
% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Dongno2_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Sihang_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Dongno2_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm2 ='Sihang(mltm)';
stnm3 ='Dongno2(mltm)';
stnm1 ='Dongno1(mltm)';
stnm4 ='Olsan(mltm)';
stnm5 ='Pungsan(mltm)';
stnm6 ='Andong(kma)';

r2=cor_Sihang_mltm_;
r3=cor_Dongno2_mltm_;
r1=Dongno1_mltm_(:,2);
r4=Olsan_mltm_(:,2);
r5=cor_Pungsan_mltm_;
r6=cor_Andong_kma_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Dongno1_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );
```

```
dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Sihang_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Dongno2_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Dongno1_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 4th run
stnm2 ='Sihang(mltm)';
stnm3 ='Dongno2(mltm)';
stnm4 ='Dongno1(mltm)';
stnm1 ='Olsan(mltm)';
stnm5 ='Pungsan(mltm)';
stnm6 ='Andong(kma)';

r2=cor_Sihang_mltm_;
r3=cor_Dongno2_mltm_;
r4=cor_Dongno1_mltm_;
r1=Olsan_mltm_(:,2);
r5=cor_Pungsan_mltm_;
r6=cor_Andong_kma_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Olsan_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Sihang_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Dongno2_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Dongno1_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Olsan_mltm_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
```

```
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])



%% Group-17

stnm1 ='Buseok(mltm)';
stnm2 ='Bonghwa(mltm)';
stnm3 ='Docheon(mltm)';
stnm4 ='Bonghwa(kma)';
stnm5 ='Chunyang(kwater)';
stnm6 ='Seokhyeon(mltm)';

ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;
ostnm5=stnm5;
ostnm6=stnm6;

[Buseok_mltm_, ~, ~] = xlsread(filename,stnm1 );
[Bonghwa_mltm_, ~, ~] = xlsread(filename,stnm2 );
%[Dongno1_mltm_, ~, ~] = xlsread(filename,stnm3 );
%[Olsan_mltm_, ~, ~] = xlsread(filename,stnm4 );
%[Iljik2_mltm_, ~, ~] = xlsread(filename,stnm5 );

or1=Buseok_mltm_(:,2);
or2=Bonghwa_mltm_(:,2);
or3=cor_Docheon_mltm_;
or4=cor_Bonghwa_kma_;
or5=cor_Chunyang_kwater_;
or6=cor_Seokhyeon_mltm_;

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm1 ='Buseok(mltm)';
stnm2 ='Bonghwa(mltm)';
stnm3 ='Docheon(mltm)';
stnm4 ='Bonghwa(kma)';
```

```
stnm5 ='Chunyang(kwater)';
stnm6 ='Seokhyeon(mltm)';

r1=Buseok_mltm_(:,2);
r2=Bonghwa_mltm_(:,2);
r3=cor_Docheon_mltm_;
r4=cor_Bonghwa_kma_;
r5=cor_Chunyang_kwater_;
r6=cor_Seokhyeon_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Buseok_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Buseok_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm2 ='Buseok(mltm)';
stnm1 ='Bonghwa(mltm)';
stnm3 ='Docheon(mltm)';
stnm4 ='Bonghwa(kma)';
stnm5 ='Chunyang(kwater)';
stnm6 ='Seokhyeon(mltm)';

r2=cor_Buseok_mltm_;
r1=Bonghwa_mltm_(:,2);
r3=cor_Docheon_mltm_;
r4=cor_Bonghwa_kma_;
r5=cor_Chunyang_kwater_;
r6=cor_Seokhyeon_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
```

```
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Bonghwa_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Buseok_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Bonghwa_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

%% Group-18

stnm1 ='Yeongju(mltm)';
stnm2 ='Yeongju(kma)';
stnm3 ='Punggi(mltm)';
stnm4 ='Huibang(mltm)';
stnm5 ='Buseok(mltm)';
stnm6 ='Sihang(mltm)';

ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;
ostnm5=stnm5;
ostnm6=stnm6;

[Yeongju_mltm_, ~, ~] = xlsread(filename,stnm1 );
[Yeongju_kma_, ~, ~] = xlsread(filename,stnm2 );
[Punggi_mltm_, ~, ~] = xlsread(filename,stnm3 );
[Huibang_mltm_, ~, ~] = xlsread(filename,stnm4 );
%[Iljik2_mltm_, ~, ~] = xlsread(filename,stnm5 );

or1=Yeongju_mltm_(:,2);
or2=Yeongju_kma_(:,2);
or3=Punggi_mltm_(:,2);
or4=Huibang_mltm_(:,2);
or5=cor_Buseok_mltm_;
or6=cor_Sihang_mltm_;
```

```
dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm2 ='Yeongju(mltm)';
stnm1 ='Yeongju(kma)';
stnm3 ='Punggi(mltm)';
stnm4 ='Huibang(mltm)';
stnm5 ='Buseok(mltm)';
stnm6 ='Sihang(mltm)';

r2=Yeongju_mltm_(:,2);
r1=Yeongju_kma_(:,2);
r3=Punggi_mltm_(:,2);
r4=Huibang_mltm_(:,2);
r5=cor_Buseok_mltm_;
r6=cor_Sihang_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Yeongju_kma_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Yeongju_kma_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
```

```
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm4 ='Yeongju(mltm)';
stnm2 ='Yeongju(kma)';
stnm3 ='Punggi(mltm)';
stnm1 ='Huibang(mltm)';
stnm5 ='Buseok(mltm)';
stnm6 ='Sihang(mltm)';

r4=Yeongju_mltm_(:,2);
r2=cor_Yeongju_kma_;
r3=Punggi_mltm_(:,2);
r1=Huibang_mltm_(:,2);
r5=cor_Buseok_mltm_;
r6=cor_Sihang_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Huibang_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14, d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Yeongju_kma_), title(ostnm2), datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Huibang_mltm_), title(ostnm4), datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm1 ='Yeongju(mltm)';
stnm2 ='Yeongju(kma)';
stnm3 ='Punggi(mltm)';
stnm4 ='Huibang(mltm)';
stnm5 ='Buseok(mltm)';
stnm6 ='Sihang(mltm)';

r1=Yeongju_mltm_(:,2);
```

```
r2=cor_Yeongju_kma_;
r3=Punggi_mltm_(:,2);
r4=cor_Huibang_mltm_;
r5=cor_Buseok_mltm_;
r6=cor_Sihang_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Yeongju_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Yeongju_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Yeongju_kma_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Huibang_mltm_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 4th run
stnm3 ='Yeongju(mltm)';
stnm2 ='Yeongju(kma)';
stnm1 ='Punggi(mltm)';
stnm4 ='Huibang(mltm)';
stnm5 ='Buseok(mltm)';
stnm6 ='Sihang(mltm)';

r3=cor_Yeongju_mltm_;
r2=cor_Yeongju_kma_;
r1=Punggi_mltm_(:,2);
r4=cor_Huibang_mltm_;
r5=cor_Buseok_mltm_;
r6=cor_Sihang_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );
```

```
% call function Func_idw.m
[ cor_Punggi_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Yeongju_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Yeongju_kma_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Punggi_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Huibang_mltm_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

%% Group-19

stnm1 ='Jeomchon(mltm)';
stnm2 ='Ian(mltm)';
stnm3 ='Eoeseo(mltm)';
stnm4 ='Munkyeong(kma)';
stnm5 ='Jibo(mltm)';
stnm6 ='Sabeol(mltm)';

ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;
ostnm5=stnm5;
ostnm6=stnm6;

[Jeomchon_mltm_, ~, ~] = xlsread(filename,stnm1 );
[Ian_mltm_, ~, ~] = xlsread(filename,stnm2 );
[Eoeseo_mltm_, ~, ~] = xlsread(filename,stnm3 );
[Munkyeong_kma_, ~, ~] = xlsread(filename,stnm4 );
%[Iljik2_mltm_, ~, ~] = xlsread(filename,stnm5 );

or1=Jeomchon_mltm_(:,2);
or2=Ian_mltm_(:,2);
or3=Eoeseo_mltm_(:,2);
or4=Munkyeong_kma_(:,2);
or5=cor_Jibo_mltm_;
or6=cor_Sabeol_mltm_;

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
```

```
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm4 ='Jeomchon(mltm)';
stnm2 ='Ian(mltm)';
stnm3 ='Eoeseo(mltm)';
stnm1 ='Munkyeong(kma)';
stnm5 ='Jibo(mltm)';
stnm6 ='Sabeol(mltm)';

r4=Jeomchon_mltm_(:,2);
r2=Ian_mltm_(:,2);
r3=Eoeseo_mltm_(:,2);
r1=Munkyeong_kma_(:,2);
r5=cor_Jibo_mltm_;
r6=cor_Sabeol_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Munkyeong_kma_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13,
d14, d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Munkyeong_kma_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm4 ='Jeomchon(mltm)';
```

```
stnm1 ='Ian(mltm)';
stnm3 ='Eoeseo(mltm)';
stnm2 ='Munkyeong(kma)';
stnm5 ='Jibo(mltm)';
stnm6 ='Sabeol(mltm)';

r4=Jeomchon_mltm_(:,2);
r1=Ian_mltm_(:,2);
r3=Eoeseo_mltm_(:,2);
r2=cor_Munkyeong_kma_;
r5=cor_Jibo_mltm_;
r6=cor_Sabeol_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Ian_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Ian_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Munkyeong_kma_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm4 ='Jeomchon(mltm)';
stnm3 ='Ian(mltm)';
stnm1 ='Eoeseo(mltm)';
stnm2 ='Munkyeong(kma)';
stnm5 ='Jibo(mltm)';
stnm6 ='Sabeol(mltm)';

r4=Jeomchon_mltm_(:,2);
r3=cor_Ian_mltm_;
r1=Eoeseo_mltm_(:,2);
r2=cor_Munkyeong_kma_;
r5=cor_Jibo_mltm_;
r6=cor_Sabeol_mltm_;
% distance calculation using Function
```

```
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Eoeseo_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Ian_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Eoeseo_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Munkyeong_kma_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 4th run
stnm1 ='Jeomchon(mltm)';
stnm3 ='Ian(mltm)';
stnm4 ='Eoeseo(mltm)';
stnm2 ='Munkyeong(kma)';
stnm5 ='Jibo(mltm)';
stnm6 ='Sabeol(mltm)';

r1=Jeomchon_mltm_(:,2);
r3=cor_Ian_mltm_;
r4=Eoeseo_mltm_(:,2);
r2=cor_Munkyeong_kma_;
r5=cor_Jibo_mltm_;
r6=cor_Sabeol_mltm_;

% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Jeomchon_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13,
d14, d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
```

```
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Jeomchon_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Ian_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Eoeseo_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Munkyeong_kma_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

%% Group-20

stnm1 ='Donghwawon(mltm)';
stnm2 ='Yeonpung(mltm)';
stnm3 ='Deokjusa(mltm)';
stnm4 ='Munkyeong(kma)';
stnm5 ='Dongno2(mltm)';
stnm6 ='Dongno1(mltm)';

ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;
ostnm5=stnm5;
ostnm6=stnm6;

[Donghwawon_mltm_, ~, ~] = xlsread(filename,stnm1 );
[Yeonpung_mltm_, ~, ~] = xlsread(filename,stnm2 );
[Deokjusa_mltm_, ~, ~] = xlsread(filename,stnm3 );
%[Munkyeong_kma_, ~, ~] = xlsread(filename,stnm4 );
%[Iljik2_mltm_, ~, ~] = xlsread(filename,stnm5 );

or1=Donghwawon_mltm_(:,2);
or2=Yeonpung_mltm_(:,2);
or3=Deokjusa_mltm_(:,2);
or4=cor_Munkyeong_kma_;
or5=cor_Dongno2_mltm_;
or6=cor_Dongno1_mltm_;

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
```

```
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm1 ='Donghwawon(mltm)';
stnm2 ='Yeonpung(mltm)';
stnm3 ='Deokjusa(mltm)';
stnm4 ='Munkyeong(kma)';
stnm5 ='Dongno2(mltm)';
stnm6 ='Dongno1(mltm)';

r1=Donghwawon_mltm_(:,2);
r2=Yeonpung_mltm_(:,2);
r3=Deokjusa_mltm_(:,2);
r4=cor_Munkyeong_kma_;
r5=cor_Dongno2_mltm_;
r6=cor_Dongno1_mltm_;



% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Donghwawon_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13,
d14, d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Donghwawon_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm2 ='Donghwawon(mltm)';
stnm1 ='Yeonpung(mltm)';
stnm3 ='Deokjusa(mltm)';
stnm4 ='Munkyeong(kma)';
stnm5 ='Dongno2(mltm)';
```

```
stnm6 ='Dongno1(mltm)';

r2=cor_Donghwawon_mltm_;
r1=Yeonpung_mltm_(:,2);
r3=Deokjusa_mltm_(:,2);
r4=cor_Munkyeong_kma_;
r5=cor_Dongno2_mltm_;
r6=cor_Dongno1_mltm_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Yeonpung_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13,
d14, d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Donghwawon_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Yeonpung_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm2 ='Donghwawon(mltm)';
stnm3 ='Yeonpung(mltm)';
stnm1 ='Deokjusa(mltm)';
stnm4 ='Munkyeong(kma)';
stnm5 ='Dongno2(mltm)';
stnm6 ='Dongno1(mltm)';

r2=cor_Donghwawon_mltm_;
r3=cor_Yeonpung_mltm_;
r1=Deokjusa_mltm_(:,2);
r4=cor_Munkyeong_kma_;
r5=cor_Dongno2_mltm_;
r6=cor_Dongno1_mltm_;


% distance calculation using Function
```

```
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Deokjusa_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13,
d14, d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Donghwawon_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Yeonpung_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Deokjusa_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

%% Group-21

stnm1 ='Nongam1(mltm)';
stnm2 ='Nongam2(mltm)';
stnm3 ='Hwaseo(mltm)';
stnm4 ='Pyeongon(mltm)';
stnm5 ='Ian(mltm)';
stnm6 ='Eoeseo(mltm)';

ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;
ostnm5=stnm5;
ostnm6=stnm6;

[Nongam1_mltm_, ~, ~] = xlsread(filename,stnm1 );
[Nongam2_mltm_, ~, ~] = xlsread(filename,stnm2 );
[Hwaseo_mltm_, ~, ~] = xlsread(filename,stnm3 );
[Pyeongon_mltm_, ~, ~] = xlsread(filename,stnm4 );
%[Iljik2_mltm_, ~, ~] = xlsread(filename,stnm5 );

or1=Nongam1_mltm_(:,2);
or2=Nongam2_mltm_(:,2);
or3=Hwaseo_mltm_(:,2);
or4=Pyeongon_mltm_(:,2);
or5=cor_Ian_mltm_;
or6=cor_Eoeseo_mltm_;
```

```
dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm3 ='Nongam1(mltm)';
stnm2 ='Nongam2(mltm)';
stnm1 ='Hwaseo(mltm)';
stnm4 ='Pyeongon(mltm)';
stnm5 ='Ian(mltm)';
stnm6 ='Eoeseo(mltm)';

r3=Nongam1_mltm_(:,2);
r2=Nongam2_mltm_(:,2);
r1=Hwaseo_mltm_(:,2);
r4=Pyeongon_mltm_(:,2);
r5=cor_Ian_mltm_;
r6=cor_Eoeseo_mltm_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Hwaseo_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Hwaseo_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
```

```
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm3 ='Nongam1(mltm)';
stnm2 ='Nongam2(mltm)';
stnm4 ='Hwaseo(mltm)';
stnm1 ='Pyeongon(mltm)';
stnm5 ='Ian(mltm)';
stnm6 ='Eoeseo(mltm)';

r3=Nongam1_mltm_(:,2);
r2=Nongam2_mltm_(:,2);
r4=cor_Hwaseo_mltm_;
r1=Pyeongon_mltm_(:,2);
r5=cor_Ian_mltm_;
r6=cor_Eoeseo_mltm_;



% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Pyeongon_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13,
d14, d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Hwaseo_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Pyeongon_mltm_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm1 ='Nongam1(mltm)';
stnm2 ='Nongam2(mltm)';
stnm4 ='Hwaseo(mltm)';
stnm3 ='Pyeongon(mltm)';
stnm5 ='Ian(mltm)';
```

```
stnm6 ='Eoeseo(mltm)';

r1=Nongam1_mltm_(:,2);
r2=Nongam2_mltm_(:,2);
r4=cor_Hwaseo_mltm_;
r3=cor_Pyeongon_mltm_;
r5=cor_Ian_mltm_;
r6=cor_Eoeseo_mltm_;



% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Nongam1_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Nongam1_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Hwaseo_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Pyeongon_mltm_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 4th run
stnm2 ='Nongam1(mltm)';
stnm1 ='Nongam2(mltm)';
stnm4 ='Hwaseo(mltm)';
stnm3 ='Pyeongon(mltm)';
stnm5 ='Ian(mltm)';
stnm6 ='Eoeseo(mltm)';

r2=cor_Nongam1_mltm_;
r1=Nongam2_mltm_(:,2);
r4=cor_Hwaseo_mltm_;
r3=cor_Pyeongon_mltm_;
r5=cor_Ian_mltm_;
r6=cor_Eoeseo_mltm_;



% distance calculation using Function
```

```
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Nongam2_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Nongam1_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Nongam2_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Hwaseo_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Pyeongon_mltm_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

%% Group-22

stnm1 ='Songmyeon(mltm)';
stnm2 ='Ipseok(mltm)';
stnm3 ='Hwabuk1(mltm)';
stnm4 ='Bokcheonam(mltm)';
stnm5 ='Samga(mltm)';
stnm6 ='Nongam2(mltm)';

ostnm1=stnm1;
ostnm2=stnm2;
ostnm3=stnm3;
ostnm4=stnm4;
ostnm5=stnm5;
ostnm6=stnm6;

[Songmyeon_mltm_, ~, ~] = xlsread(filename,stnm1 );
[Ipseok_mltm_, ~, ~] = xlsread(filename,stnm2 );
[Hwabuk1_mltm_, ~, ~] = xlsread(filename,stnm3 );
[Bokcheonam_mltm_, ~, ~] = xlsread(filename,stnm4 );
[Samga_mltm_, ~, ~] = xlsread(filename,stnm5 );

or1=Songmyeon_mltm_(:,2);
or2=Ipseok_mltm_(:,2);
or3=Hwabuk1_mltm_(:,2);
or4=Bokcheonam_mltm_(:,2);
or5=Samga_mltm_(:,2);
or6=cor_Nongam2_mltm_;
```

```
dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, or3), title(ostnm3), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm3 ='Songmyeon(mltm)';
stnm2 ='Ipseok(mltm)';
stnm1 ='Hwabuk1(mltm)';
stnm4 ='Bokcheonam(mltm)';
stnm5 ='Samga(mltm)';
stnm6 ='Nongam2(mltm)';

r3=Songmyeon_mltm_(:,2);
r2=Ipseok_mltm_(:,2);
r1=Hwabuk1_mltm_(:,2);
r4=Bokcheonam_mltm_(:,2);
r5=Samga_mltm_(:,2);
r6=cor_Nongam2_mltm_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Hwabuk1_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Hwabuk1_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
```

```
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 1st run
stnm3 ='Songmyeon(mltm)';
stnm2 ='Ipseok(mltm)';
stnm1 ='Hwabuk1(mltm)';
stnm4 ='Bokcheonam(mltm)';
stnm5 ='Samga(mltm)';
stnm6 ='Nongam2(mltm)';

r3=Songmyeon_mltm_(:,2);
r2=Ipseok_mltm_(:,2);
r1=Hwabuk1_mltm_(:,2);
r4=Bokcheonam_mltm_(:,2);
r5=Samga_mltm_(:,2);
r6=cor_Nongam2_mltm_;



% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Hwabuk1_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, or2), title(ostnm2), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Hwabuk1_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 2nd run
stnm3 ='Songmyeon(mltm)';
stnm1 ='Ipseok(mltm)';
stnm2 ='Hwabuk1(mltm)';
stnm4 ='Bokcheonam(mltm)';
stnm5 ='Samga(mltm)';
```

```
stnm6 ='Nongam2(mltm)';

r3=Songmyeon_mltm_(:,2);
r1=Ipseok_mltm_(:,2);
r2=cor_Hwabuk1_mltm_;
r4=Bokcheonam_mltm_(:,2);
r5=Samga_mltm_(:,2);
r6=cor_Nongam2_mltm_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Ipseok_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Ipseok_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Hwabuk1_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, or5), title(ostnm5), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 3rd run
stnm3 ='Songmyeon(mltm)';
stnm5 ='Ipseok(mltm)';
stnm2 ='Hwabuk1(mltm)';
stnm4 ='Bokcheonam(mltm)';
stnm1 ='Samga(mltm)';
stnm6 ='Nongam2(mltm)';

r3=Songmyeon_mltm_(:,2);
r5=cor_Ipseok_mltm_;
r2=cor_Hwabuk1_mltm_;
r4=Bokcheonam_mltm_(:,2);
r1=Samga_mltm_(:,2);
r6=cor_Nongam2_mltm_;


% distance calculation using Function
```

```
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Samga_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13, d14,
d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Ipseok_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Hwabuk1_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, or4), title(ostnm4), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, cor_Samga_mltm_), title(ostnm5), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 4th run
stnm3 ='Songmyeon(mltm)';
stnm5 ='Ipseok(mltm)';
stnm2 ='Hwabuk1(mltm)';
stnm1 ='Bokcheonam(mltm)';
stnm4 ='Samga(mltm)';
stnm6 ='Nongam2(mltm)';

r3=Songmyeon_mltm_(:,2);
r5=cor_Ipseok_mltm_;
r2=cor_Hwabuk1_mltm_;
r1=Bokcheonam_mltm_(:,2);
r4=cor_Samga_mltm_;
r6=cor_Nongam2_mltm_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Bokcheonam_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13,
d14, d15, d16 );
```

```
dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, or1), title(ostnm1), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Ipseok_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Hwabuk1_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Bokcheonam_mltm_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,5), bar(dnum, cor_Samga_mltm_), title(ostnm5), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

% 5th run
stnm1 ='Songmyeon(mltm)';
stnm5 ='Ipseok(mltm)';
stnm2 ='Hwabuk1(mltm)';
stnm3 ='Bokcheonam(mltm)';
stnm4 ='Samga(mltm)';
stnm6 ='Nongam2(mltm)';

r1=Songmyeon_mltm_(:,2);
r5=cor_Ipseok_mltm_;
r2=cor_Hwabuk1_mltm_;
r3=cor_Bokcheonam_mltm_;
r4=cor_Samga_mltm_;
r6=cor_Nongam2_mltm_;


% distance calculation using Function
% [ stdiskm ] = Func_distcalc( stnm1, stnm2 )
[ d12 ] = Func_distcalc( stnm1, stnm2 );
[ d13 ] = Func_distcalc( stnm1, stnm3 );
[ d14 ] = Func_distcalc( stnm1, stnm4 );
[ d15 ] = Func_distcalc( stnm1, stnm5 );
[ d16 ] = Func_distcalc( stnm1, stnm6 );

% call function Func_idw.m
[ cor_Songmyeon_mltm_ ] = Func_idw_6pnts( r1, r2, r3, r4, r5, r6, d12, d13,
d14, d15, d16 );

dnum = Seokhyeon_mltm_(:,1);
figure() % 2001 upstream
k=725008:365:735964;, set(gca,'XTick',[k]);
subplot(6,1,1), bar(dnum, cor_Songmyeon_mltm_), title(ostnm1), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,2), bar(dnum, cor_Ipseok_mltm_), title(ostnm2), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,3), bar(dnum, cor_Hwabuk1_mltm_), title(ostnm3), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,4), bar(dnum, cor_Bokcheonam_mltm_), title(ostnm4), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
```

```
subplot(6,1,5), bar(dnum, cor_Samga_mltm_), title(ostnm5), datetick('x',
'mm/dd/yyyy', 'keepticks')%, xlim([725008 725008+365])
subplot(6,1,6), bar(dnum, or6), title(ostnm6), datetick('x', 'mm/dd/yyyy',
'keepticks')%, xlim([725008 725008+365])

close all;

%% Display all data in bsn 2001
rf_G1 = [cor_Taebaek_kma_ cor_Hwangji_mltm_ cor_Taebaek_kwater_
cor_Taebaeksan_mltm_ cor_Baekcheon_kwater_ cor_Seokpo_mltm_];
rf_G2 = [cor_Seokhyeon_mltm_ cor_Bonghwa_kma_ cor_Chunyang_kwater_
cor_Goseon2_kwater_ cor_Seomyeon_kwater_ cor_Namhoeryong_mltm_];
rf_G3 = [cor_Docheon_mltm_ cor_Myeongho_kwater_ cor_Galsan_kwater_
cor_Jaesan_mltm_ cor_Subi_mltm_, cor_Ilweol_kwater_];
rf_G4 = [cor_Yean2_mltm_ cor_Yuicheon_kwater_ cor_Yean_kwater_
cor_Mijil_mltm_ cor_Seokdong_mltm_ cor_Imdong_mltm_ cor_Andong_mltm_
cor_Andong_kma_];
leg_G1 = {'Taebaek(kma)', 'Hwangji(mltm)', 'Taebaek(kwater)',
'Taebaeksan(mltm)', 'Baekcheon(kwater)', 'Seokpo(mltm)'};
leg_G2 = {'Seokhyeon(mltm)', 'Bonghwa(kma)', 'Chunyang(kwater)',
'Goseon2(kwater)', 'Seomyeon(kwater)', 'Namhoeryong(mltm)'};
leg_G3 = {'Docheon(mltm)', 'Myeongho(kwater)', 'Galsan(kwater)',
'Jaesan(mltm)' 'Subi(mltm)' 'Ilweol(kwater)'};
leg_G4 = {'Yean2(mltm)', 'Yuicheon(kwater)', 'Yean(kwater)', 'Mijil(mltm)',
'Seokdong(mltm)' 'Imdong(mltm)' 'Andong(mltm)' 'Andong(kma)'};

% Getting cumulative rainfall
cumrf_G1 = cumsum(rf_G1)
cumrf_G2 = cumsum(rf_G2)
cumrf_G3 = cumsum(rf_G3)
cumrf_G4 = cumsum(rf_G4)

figure()
subplot(2,2,1), plot(dnum, cumrf_G1), title('North basin'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G1,
'location', 'northwest')
subplot(2,2,2), plot(dnum, cumrf_G2), title('Northeast basin'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G2,
'location', 'northwest')
subplot(2,2,3), plot(dnum, cumrf_G3), title('Central basin'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G3,
'location', 'northwest')
subplot(2,2,4), plot(dnum, cumrf_G4), title('South basin'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G4,
'location', 'northwest')
ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'Basin 2001','HorizontalAlignment','center','VerticalAlignment',
'top')

% Save the completed rainfall data
completed_rf= [rf_G1 rf_G2 rf_G3 rf_G4]
data =[dnum completed_rf]
header = ['dnum' leg_G1 leg_G2 leg_G3 leg_G4]% rainfall stations
ds = dataset({data, header{:}})
```

```
fname4write = 'bsn2001_after_estimation_missing_records.xlsx';
xlRange = 'A1';
export(ds,'XLSfile',fname4write)

%% Display all data in bsn 2002
rf_G1 = [cor_Subi_mltm_ cor_Ilweol_kwater_ cor_Jaesan_mltm_ cor_Mijil_mltm_
cor_Yeongyang_kwater_ cor_Subi2_kwater_];
rf_G2 = [cor_Andong_mltm_ cor_Iljik2_mltm_ cor_Seokdong_mltm_
cor_Imdong_mltm_ cor_Giran_mltm_ cor_Cheongsong_kwater_ cor_Jinbo2_kwater_
cor_Seokbo_kwater_];
rf_G3 = [cor_Hyeonseo_mltm_ cor_Dopyeong_mltm_ cor_Bunam_kwater_
cor_Budong_kwater_];
rf_G4 = [cor_Seoksan_mltm_ cor_Hwabuk2_mltm_ cor_Hyeonnae_kwater_
cor_Gasa_kwater_];
leg_G1 = {'Subi(mltm)' 'Ilweol(kwater)' 'Jaesan(mltm)' 'Mijil(mltm)'
'Yeongyang(kwater)' 'Subi2(kwater)'};
leg_G2 = {'Andong(mltm)' 'Iljik2(mltm)' 'Seokdong(mltm)' 'Imdong(mltm)'
'Giran(mltm)' 'Cheongsong(kwater)' 'Jinbo2(kwater)' 'Seokbo(kwater)'};
leg_G3 = {'Hyeonseo(mltm)' 'Dopyeong(mltm)' 'Bunam(kwater)' 'Budong(kwater)'};
leg_G4 = {'Seoksan(mltm)' 'Hwabuk2(mltm)' 'Hyeonnae(kwater)' 'Gasa(kwater)'};

% Getting cumulative rainfall
cumrf_G1 = cumsum(rf_G1)
cumrf_G2 = cumsum(rf_G2)
cumrf_G3 = cumsum(rf_G3)
cumrf_G4 = cumsum(rf_G4)

figure()
subplot(2,2,1), plot(dnum, cumrf_G1), title('Northern part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G1,
'location', 'northwest')
subplot(2,2,2), plot(dnum, cumrf_G2), title('Central part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G2,
'location', 'northwest')
subplot(2,2,3), plot(dnum, cumrf_G3), title('Southern part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G3,
'location', 'northwest')
subplot(2,2,4), plot(dnum, cumrf_G4), title('Outer southern part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G4,
'location', 'northwest')
ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'\bf Basin
2002','HorizontalAlignment','center','VerticalAlignment', 'top', 'fontsize',
15)

% Save the completed rainfall data
completed_rf= [rf_G1 rf_G2 rf_G3 rf_G4]
data =[dnum completed_rf]
header = ['dnum' leg_G1 leg_G2 leg_G3 leg_G4]% rainfall stations
ds = dataset({data, header{:}})

fname4write = 'bsn2002_after_estimation_missing_records.xlsx';
xlRange = 'A1';
export(ds,'XLSfile',fname4write)
```

```
%% Display all data in bsn 2003
rf_G1 = [cor_Sabeol_mltm_ cor_Jibo_mltm_ cor_Angye_mltm_ cor_Wolpo_mltm_];
rf_G2 = [cor_Pungsan_mltm_ cor_Andong_kma_ cor_Andong_mltm_ cor_Yean2_mltm_
cor_Iljik1_mltm_];
rf_G3 = [cor_Iljik2_mltm_ cor_Uiseong_kma_ cor_Uiseong_mltm_
cor_Hyeonseo_mltm_ cor_Giran_mltm_];
%rf_G4 = [cor_Seoksan_mltm_ cor_Hwabuk2_mltm_ cor_Hyeonnae_kwater_
cor_Gasa_kwater_];
leg_G1 = {'Sabeol(mltm)' 'Jibo(mltm)' 'Angye(mltm)' 'Wolpo(mltm)'};
leg_G2 = {'Pungsan(mltm)' 'Andong(kma)' 'Andong(mltm)' 'Yean2(mltm)'
'Iljik1(mltm)'};
leg_G3 = {'Iljik2(mltm)' 'Uiseong(kma)' 'Uiseong(mltm)' 'Hyeonseo(mltm)'
'Giran(mltm)'};
%leg_G4 = {'cor_Seoksan_mltm_' 'cor_Hwabuk2_mltm_' 'cor_Hyeonnae_kwater_'
'cor_Gasa_kwater_'};

% Getting cumulative rainfall
cumrf_G1 = cumsum(rf_G1)
cumrf_G2 = cumsum(rf_G2)
cumrf_G3 = cumsum(rf_G3)
%cumrf_G4 = cumsum(rf_G4)

figure()
subplot(2,2,1), plot(dnum, cumrf_G1), title('Eastern part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G1,
'location', 'northwest')
subplot(2,2,2), plot(dnum, cumrf_G2), title('Central part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G2,
'location', 'northwest')
subplot(2,2,3), plot(dnum, cumrf_G3), title('Western part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G3,
'location', 'northwest')
%subplot(2,2,4), plot(dnum, cumrf_G4), title('Outer southern part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G4,
'location', 'northwest')
ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'\bf Basin
2003','HorizontalAlignment','center','VerticalAlignment', 'top', 'fontsize',
15)

% Save the completed rainfall data
completed_rf= [rf_G1 rf_G2 rf_G3]%rf_G4]
data =[dnum completed_rf]
header = ['dnum' leg_G1 leg_G2 leg_G3]% leg_G4]% rainfall stations
ds = dataset({data, header{:}})

fname4write = 'bsn2003_after_estimation_missing_records.xlsx';
xlRange = 'A1';
export(ds,'XLSfile',fname4write)

%% Display all data in bsn 2004
rf_G1 = [cor_Buseok_mltm_ cor_Bonghwa_mltm_ cor_Seokhyeon_mltm_
cor_Bonghwa_kma_ cor_Docheon_mltm_ cor_Myeongho_kwater_];
```

```
rf_G2 = [cor_Huibang_mltm_ cor_Yeongju_kma_ cor_Punggi_mltm_
cor_Yeongju_mltm_ cor_Yean2_mltm_ cor_Olsan_mltm_ cor_Sihang_mltm_
cor_Pungsan_mltm_];
rf_G3 = [cor_Dongno1_mltm_ cor_Donghwawon_mltm_ cor_Dongno2_mltm_
cor_Jeomchon_mltm_ cor_Jibo_mltm_ cor_Wolpo_mltm_];
%rf_G4 = [cor_Seoksan_mltm_ cor_Hwabuk2_mltm_ cor_Hyeonnae_kwater_
cor_Gasa_kwater_];
leg_G1 = {'Buseok(mltm)' 'Bonghwa(mltm)' 'Seokhyeon(mltm)' 'Bonghwa(kma)'
'Docheon(mltm)' 'Myeongho(kwater)'};
leg_G2 = {'Huibang(mltm)' 'Yeongju(kma)' 'Punggi(mltm)' 'Yeongju(mltm)'
'Yean2(mltm)' 'Olsan(mltm)' 'Sihang(mltm)' 'Pungsan(mltm)'};
leg_G3 = {'Dongno1(mltm)' 'Donghwawon(mltm)' 'Dongno2(mltm)' 'Jeomchon(mltm)'
'Jibo(mltm)' 'Wolpo(mltm)'};
%leg_G4 = {'cor_Seoksan_mltm_' 'cor_Hwabuk2_mltm_' 'cor_Hyeonnae_kwater_'
'cor_Gasa_kwater_'};

% Getting cumulative rainfall
cumrf_G1 = cumsum(rf_G1)
cumrf_G2 = cumsum(rf_G2)
cumrf_G3 = cumsum(rf_G3)
%cumrf_G4 = cumsum(rf_G4)

figure()
subplot(2,2,1), plot(dnum, cumrf_G1), title('Eastern part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G1,
'location', 'northwest')
subplot(2,2,2), plot(dnum, cumrf_G2), title('Central part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G2,
'location', 'northwest')
subplot(2,2,3), plot(dnum, cumrf_G3), title('Western part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G3,
'location', 'northwest')
%subplot(2,2,4), plot(dnum, cumrf_G4), title('Outer southern part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G4,
'location', 'northwest')
ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'\bf Basin
2004','HorizontalAlignment','center','VerticalAlignment', 'top', 'fontsize',
15)

% Save the completed rainfall data
completed_rf= [rf_G1 rf_G2 rf_G3]%rf_G4]
data =[dnum completed_rf]
header = ['dnum' leg_G1 leg_G2 leg_G3]% leg_G4]% rainfall stations
ds = dataset({data, header{:}})

fname4write = 'bsn2004_after_estimation_missing_records.xlsx';
xlRange = 'A1';
export(ds,'XLSfile',fname4write)

%% Display all data in bsn 2005
rf_G1 = [cor_Deokjusa_mltm_ cor_Yeonpung_mltm_ cor_Donghwawon_mltm_
cor_Dongno1_mltm_ cor_Dongno2_mltm_ cor_Munkyeong_kma_];
rf_G2 = [cor_Songmyeon_mltm_ cor_Ipseok_mltm_ cor_Bokcheonam_mltm_
cor_Samga_mltm_ cor_Hwabuk1_mltm_ cor_Nongam2_mltm_ cor_Nongam1_mltm_];
```

```
rf_G3 = [cor_Pyeongon_mltm_ cor_Hwaseo_mltm_ cor_Eoeseo_mltm_
cor_Jeomchon_mltm_ cor_Ian_mltm_ cor_Sabeol_mltm_];
%rf_G4 = [cor_Seoksan_mltm_ cor_Hwabuk2_mltm_ cor_Hyeonnae_kwater_
cor_Gasa_kwater_];
leg_G1 = {'Deokjusa(mltm)' 'Yeonpung(mltm)' 'Donghwawon(mltm)'
'Dongno1(mltm)' 'Dongno2(mltm)' 'Munkyeong(kma)'};
leg_G2 = {'Songmyeon(mltm)' 'Ipseok(mltm)' 'Bokcheonam(mltm)' 'Samga(mltm)'
'Hwabuk1(mltm)' 'Nongam2(mltm)' 'Nongam1(mltm)'};
leg_G3 = {'Pyeongon(mltm)' 'Hwaseo(mltm)' 'Eoeseo(mltm)' 'Jeomchon(mltm)'
'Ian(mltm)' 'Sabeol(mltm)'};
%leg_G4 = {'cor_Seoksan_mltm_' 'cor_Hwabuk2_mltm_' 'cor_Hyeonnae_kwater_'
'cor_Gasa_kwater_'};

% Getting cumulative rainfall
cumrf_G1 = cumsum(rf_G1)
cumrf_G2 = cumsum(rf_G2)
cumrf_G3 = cumsum(rf_G3)
%cumrf_G4 = cumsum(rf_G4)

figure()
subplot(2,2,1), plot(dnum, cumrf_G1), title('North-eastern part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G1,
'location', 'northwest')
subplot(2,2,2), plot(dnum, cumrf_G2), title('North-western part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G2,
'location', 'northwest')
subplot(2,2,3), plot(dnum, cumrf_G3), title('Southern part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G3,
'location', 'northwest')
%subplot(2,2,4), plot(dnum, cumrf_G4), title('Outer southern part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G4,
'location', 'northwest')
ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'\bf Basin
2005','HorizontalAlignment','center','VerticalAlignment', 'top', 'fontsize',
15)

% Save the completed rainfall data
completed_rf= [rf_G1 rf_G2 rf_G3]%rf_G4]
data =[dnum completed_rf]
header = ['dnum' leg_G1 leg_G2 leg_G3]% leg_G4]% rainfall stations
ds = dataset({data, header{:}})

fname4write = 'bsn2005_after_estimation_missing_records.xlsx';
xlRange = 'A1';
export(ds,'XLSfile',fname4write)

%% Display all data in bsn 2007
rf_G1 = [cor_Sabeol_mltm_ cor_Jeomchon_mltm_ cor_Jibo_mltm_];
%rf_G2 = [cor_Songmyeon_mltm_ cor_Ipseok_mltm_ cor_Bokcheonam_mltm_
cor_Samga_mltm_ cor_Hwabuk1_mltm_ cor_Nongam2_mltm_ cor_Nongam1_mltm_];
%rf_G3 = [cor_Pyeongon_mltm_ cor_Hwaseo_mltm_ cor_Eoeseo_mltm_
cor_Jeomchon_mltm_ cor_Ian_mltm_ cor_Sabeol_mltm_];
%rf_G4 = [cor_Seoksan_mltm_ cor_Hwabuk2_mltm_ cor_Hyeonnae_kwater_
cor_Gasa_kwater_];
```

```
leg_G1 = {'Sabeol(mltm)' 'Jeomchon(mltm)' 'Jibo(mltm)'};
%leg_G2 = {'cor_Songmyeon_mltm_' 'cor_Ipseok_mltm_' 'cor_Bokcheonam_mltm_'
'cor_Samga_mltm_' 'cor_Hwabuk1_mltm_' 'cor_Nongam2_mltm_'
'cor_Nongam1_mltm_'};
%leg_G3 = {'cor_Pyeongon_mltm_' 'cor_Hwaseo_mltm_' 'cor_Eoeseo_mltm_'
'cor_Jeomchon_mltm_' 'cor_Ian_mltm_' 'cor_Sabeol_mltm_'};
%leg_G4 = {'cor_Seoksan_mltm_' 'cor_Hwabuk2_mltm_' 'cor_Hyeonnae_kwater_'
'cor_Gasa_kwater_'};

% Getting cumulative rainfall
cumrf_G1 = cumsum(rf_G1)
%cumrf_G2 = cumsum(rf_G2)
%cumrf_G3 = cumsum(rf_G3)
%cumrf_G4 = cumsum(rf_G4)


figure()
plot(dnum, cumrf_G1), title('2007 Basin part', 'fontsize', 15),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G1,
'location', 'northwest')
%subplot(2,2,2), plot(dnum, cumrf_G2), title('North-western part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G2,
'location', 'northwest')
%subplot(2,2,3), plot(dnum, cumrf_G3), title('Southern part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G3,
'location', 'northwest')
%subplot(2,2,4), plot(dnum, cumrf_G4), title('Outer southern part'),
ylabel('Cumulative rainfall(mm)'), datetick('x', 'mm/dd/yyyy'), legend(leg_G4,
'location', 'northwest')
%ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
%text(0.5, 1,'\bf Basin
2007','HorizontalAlignment','center','VerticalAlignment', 'top', 'fontsize',
15)

% Save the completed rainfall data
completed_rf= [rf_G1]% rf_G2 rf_G3]%rf_G4]
data =[dnum completed_rf]
header = ['dnum' leg_G1]% leg_G2 leg_G3]% leg_G4]% rainfall stations
ds = dataset({data, header{:}})

fname4write = 'bsn2007_after_estimation_missing_records.xlsx';
xlRange = 'A1';
export(ds,'XLSfile',fname4write)
```

IDW functions

Func_idw_4pnts.m

```
 function [ r1 ] = Func_idw_4pnts( r1, r2, r3, r4, d12, d13, d14 )
%UNTITLED Summary of this function goes here
```

```
%   Detailed explanation goes here

% d12=3;
% d13=4;
% d14=5;
% d15=5;
% d16=7;

id=find(r1==-9999)
size(id)
if isempty(id)
    status=1; % it has no missing data
else
    status=0; % it has more than 1 missing data
end

switch status

    case 1
        r1=r1;

    case 0
        for j = 1:length(id)
            i = id(j)
        R2=r2(i)
        R3=r3(i)
        R4=r4(i)
        %R5=r5(i)
        %R6=r6(i)

        if (R2==-9999) && (R3==-9999) && (R4==-9999)
            cond = 0

        elseif (R2==-9999) && (R3==-9999)
            cond = 4
        elseif (R2==-9999) && (R4==-9999)
            cond = 3
        elseif (R3==-9999) && (R4==-9999)
            cond = 2
        elseif (R4==-9999)
            cond = 23
        elseif (R3==-9999)
            cond = 24

        elseif (R2==-9999)
            cond = 34

        else
            cond = 234
        end


        % Doing IDW(inverse distant weighting method)
        switch cond
            case 0
```

```
                r1(i)=-9999;
            case 2
                r1(i)=((1/d12)^2*R2)/((1/d12)^2);
            case 3
                r1(i)=((1/d13)^2*R3)/((1/d13)^2);
            case 4
                r1(i)=((1/d14)^2*R4)/((1/d14)^2);

            case 23
                r1(i)=((1/d12)^2*R2+(1/d13)^2*R3)/((1/d12)^2+(1/d13)^2);
            case 24
                r1(i)=((1/d12)^2*R2+(1/d14)^2*R4)/((1/d12)^2+(1/d14)^2);

            case 34
                r1(i)=((1/d13)^2*R3+(1/d14)^2*R4)/((1/d13)^2+(1/d14)^2);

            case 234

r1(i)=((1/d12)^2*R2+(1/d13)^2*R3+(1/d14)^2*R4)/((1/d12)^2+(1/d13)^2+(1/d14)^2
);

        end

        end % for i

end % switch status
end
```

Calculation of average areal rainfall

Oct01st2015_Average_areal_rainfall.m

```
%clear all, close all, clc;
% Calculation average areal rainfall using Thiessen method

%% Averaged rainfall for ban2001
filename = 'bsn2001_after_estimation_missing_records.xlsx'
sheet= 'sheet1'
% load the station name
xlrange = 'a1:aa1';
[~, T, ~] = xlsread(filename, sheet, xlrange)
stnm = T(2:end);
% load rainfall data
xlrange= 'a2:aa10958'
[v, T, vT] = xlsread(filename, sheet, xlrange);
dnum = v(:,1); % water stage
rf = v(:,2:length(stnm)+1);

% Read Thiessen polygon ratio
filename = 'ratio_4thiessen_polygon.xlsx'
sheet= 'bsn2001'
```

```
xlrange= 'a2:n27'
[v, T, vT] = xlsread(filename, sheet, xlrange);
ratio=v(:,13);
%cumsum(ratio)
station=vT(:,14);
st = char(station); % convert cellarray into string array
strMat = fstrvcat(st); % convert string(Char) into ASCII code array

% Find corresponding thiessen ratio from GIS thiessen network
thiessen_ratio = zeros(length(stnm),1);
for k = 1:length(stnm)
    rown = findrow(char(stnm(k)),strMat); % find the rownumber what I want to
look for
    thiessen_ratio(k) = ratio(rown)
end

size(strMat)
% making dynamic variables

statement = ['avg_rf = ']
for i=1:length(stnm)
    switch i
        case 1
        code = ['rf(:,' num2str(i) ').*thiessen_ratio(' num2str(i) ')']
        otherwise
        code = ['+rf(:,' num2str(i) ').*thiessen_ratio(' num2str(i) ')']
    end
statement = [statement code]
end
eval([statement])

avg_rf
cum_avg_rf = cumsum(avg_rf)

figure()
subplot(2,1,1), plot(dnum, avg_rf), datetick('x','mm/dd/yyyy'),
ylabel('Average rainfall (mm)')
subplot(2,1,2), plot(dnum, cum_avg_rf), datetick('x','mm/dd/yyyy'),
ylabel('Average rainfall (mm)')
ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'\bf Average rainfall of
bsn2001','HorizontalAlignment','center','VerticalAlignment', 'top')

% Write averaged rainfall to excel file
new_mat=[dnum avg_rf]
filename = 'bsn2001_after_estimation_missing_records.xlsx';
sheet = 'bsn2001_avg_rf';
xlRange = 'A1';
xlswrite(filename,new_mat,sheet,xlRange)

% Write this to text file.
fid = fopen('bsn2001_avg_rf.txt','wt');
for ii = 1:size(new_mat,1)
    fprintf(fid,'%g\t',new_mat(ii,:));
```

```
    fprintf(fid,'\n');
end
fclose(fid)

% comparison of rainfall data
[v, T, vT] = xlsread(filename, sheet);
dnum = v(:,1); % water stage
rf2001 = v(:,2);
sum(rf2001)/30

[v, T, vT] = xlsread(filename, 'sheet1');
dnum = v(:,1); % water stage
rfallstations = v(:,2:end);
sum(rfallstations)./30
figure(), plot(dnum, cumsum(rf2001),'r-',dnum, cumsum(rfallstations), 'k:'),
title('Avg. rainfall vs. all stations in bsn 2001')

%% Averaged rainfall for ban2002
filename = 'bsn2002_after_estimation_missing_records.xlsx'
sheet= 'sheet1'
% load the station name
xlrange = 'a1:w1';
[~, T, ~] = xlsread(filename, sheet, xlrange)
stnm = T(2:end);
% load rainfall data
xlrange= 'a2:w10958'
[v, T, vT] = xlsread(filename, sheet, xlrange);
dnum = v(:,1); % water stage
rf = v(:,2:length(stnm)+1);

% Read Thiessen polygon ratio
filename = 'ratio_4thiessen_polygon.xlsx'
sheet= 'bsn2002'
xlrange= 'a2:n23'
[v, T, vT] = xlsread(filename, sheet, xlrange);
ratio=v(:,13);
station=vT(:,14);
st = char(station); % convert cellarray into string array
strMat = fstrvcat(st); % convert string(Char) into ASCII code array

% Find corresponding thiessen ratio from GIS thiessen network
thiessen_ratio = zeros(length(stnm),1);
size(thiessen_ratio)
for k = 1:length(stnm)
    rown = findrow(char(stnm(k)),strMat); % find the rownumber what I want to
look for
    thiessen_ratio(k) = ratio(rown)
end

size(strMat)
% making dynamic variables

statement = ['avg_rf = ']
for i=1:length(stnm)
    switch i
```

```
        case 1
        code = ['rf(:,' num2str(i) ').*thiessen_ratio(' num2str(i) ')']
        otherwise
        code = ['+rf(:,' num2str(i) ').*thiessen_ratio(' num2str(i) ')']
    end
statement = [statement code]
end
eval([statement])

avg_rf
cum_avg_rf = cumsum(avg_rf)

figure()
subplot(2,1,1), plot(dnum, avg_rf), datetick('x','mm/dd/yyyy'),
ylabel('Average rainfall (mm)')
subplot(2,1,2), plot(dnum, cum_avg_rf), datetick('x','mm/dd/yyyy'),
ylabel('Average rainfall (mm)')
ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'\bf Average rainfall of
bsn2002','HorizontalAlignment','center','VerticalAlignment', 'top')

% Write averated rainfall
new_mat=[dnum avg_rf]
filename = 'bsn2002_after_estimation_missing_records.xlsx';
sheet = 'bsn2002_avg_rf';
xlRange = 'A1';
xlswrite(filename,new_mat,sheet,xlRange)
% Write this to text file.
fid = fopen('bsn2002_avg_rf.txt','wt');
for ii = 1:size(new_mat,1)
    fprintf(fid,'%g\t',new_mat(ii,:));
    fprintf(fid,'\n');
end
fclose(fid)

% comparison of rainfall data
[v, T, vT] = xlsread(filename, sheet);
dnum = v(:,1); % water stage
rf2002 = v(:,2);
sum(rf2002)/30

[v, T, vT] = xlsread(filename, 'sheet1');
dnum = v(:,1); % water stage
rfallstations = v(:,2:end);
sum(rfallstations)./30
figure(), plot(dnum, cumsum(rf2002),'r-',dnum, cumsum(rfallstations), 'k:'),
title('Avg. rainfall vs. all stations in bsn 2002')

%% Averaged rainfall for bsn2003
filename = 'bsn2003_after_estimation_missing_records.xlsx'
sheet= 'sheet1'
% load the station name
xlrange = 'a1:o1';
[~, T, ~] = xlsread(filename, sheet, xlrange)
stnm = T(2:end);
```

```
% load rainfall data
xlrange= 'a2:o10958'
[v, T, vT] = xlsread(filename, sheet, xlrange);
dnum = v(:,1); % water stage
rf = v(:,2:length(stnm)+1);

% Read Thiessen polygon ratio
filename = 'ratio_4thiessen_polygon.xlsx'
sheet= 'bsn2003'
xlrange= 'a2:n16'
[v, T, vT] = xlsread(filename, sheet, xlrange);
ratio=v(:,13);
station=vT(:,14);
st = char(station); % convert cellarray into string array
strMat = fstrvcat(st); % convert string(Char) into ASCII code array

% Find corresponding thiessen ratio from GIS thiessen network
thiessen_ratio = zeros(length(stnm),1);
size(thiessen_ratio)
for k = 1:length(stnm)
    rown = findrow(char(stnm(k)),strMat); % find the rownumber what I want to
look for
    thiessen_ratio(k) = ratio(rown)
end

size(strMat)
% making dynamic variables

statement = ['avg_rf = ']
for i=1:length(stnm)
    switch i
        case 1
        code = ['rf(:,' num2str(i) ').*thiessen_ratio(' num2str(i) ')']
        otherwise
        code = ['+rf(:,' num2str(i) ').*thiessen_ratio(' num2str(i) ')']
    end
statement = [statement code]
end
eval([statement])

avg_rf
cum_avg_rf = cumsum(avg_rf)

figure()
subplot(2,1,1), plot(dnum, avg_rf), datetick('x','mm/dd/yyyy'),
ylabel('Average rainfall (mm)')
subplot(2,1,2), plot(dnum, cum_avg_rf), datetick('x','mm/dd/yyyy'),
ylabel('Average rainfall (mm)')
ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'\bf Average rainfall of
bsn2003','HorizontalAlignment','center','VerticalAlignment', 'top')

% Write averated rainfall
new_mat=[dnum avg_rf]
```

```
filename = 'bsn2003_after_estimation_missing_records.xlsx';
sheet = 'bsn2003_avg_rf';
xlRange = 'A1';
xlswrite(filename,new_mat,sheet,xlRange)
% Write this to text file.
fid = fopen('bsn2003_avg_rf.txt','wt');
for ii = 1:size(new_mat,1)
    fprintf(fid,'%g\t',new_mat(ii,:));
    fprintf(fid,'\n');
end
fclose(fid)

% comparison of rainfall data
[v, T, vT] = xlsread(filename, sheet);
dnum = v(:,1); % water stage
rf2003 = v(:,2);
sum(rf2003)/30

[v, T, vT] = xlsread(filename, 'sheet1');
dnum = v(:,1); % water stage
rfallstations = v(:,2:end);
sum(rfallstations)./30
figure(), plot(dnum, cumsum(rf2003),'r-',dnum, cumsum(rfallstations), 'k:'),
title('Avg. rainfall vs. all stations in bsn 2003')

%% Averaged rainfall for bsn2004
filename = 'bsn2004_after_estimation_missing_records.xlsx'
sheet= 'sheet1'
% load the station name
xlrange = 'a1:u1';
[~, T, ~] = xlsread(filename, sheet, xlrange)
stnm = T(2:end);
% load rainfall data
xlrange= 'a2:u10958'
[v, T, vT] = xlsread(filename, sheet, xlrange);
dnum = v(:,1); % water stage
rf = v(:,2:length(stnm)+1);

% Read Thiessen polygon ratio
filename = 'ratio_4thiessen_polygon.xlsx'
sheet= 'bsn2004'
xlrange= 'a2:n24'
[v, T, vT] = xlsread(filename, sheet, xlrange);
ratio=v(:,13);
station=vT(:,14);
st = char(station); % convert cellarray into string array
strMat = fstrvcat(st); % convert string(Char) into ASCII code array

% Find corresponding thiessen ratio from GIS thiessen network
thiessen_ratio = zeros(length(stnm),1);
size(thiessen_ratio)
for k = 1:length(stnm)
    rown = findrow(char(stnm(k)),strMat); % find the rownumber what I want to
look for
    thiessen_ratio(k) = ratio(rown)
end
```

```
size(strMat)
% making dynamic variables

statement = ['avg_rf = ']
for i=1:length(stnm)
    switch i
        case 1
        code = ['rf(:,' num2str(i) ').*thiessen_ratio(' num2str(i) ')']
        otherwise
        code = ['+rf(:,' num2str(i) ').*thiessen_ratio(' num2str(i) ')']
    end
statement = [statement code]
end
eval([statement])

avg_rf
cum_avg_rf = cumsum(avg_rf)

figure()
subplot(2,1,1), plot(dnum, avg_rf), datetick('x','mm/dd/yyyy'),
ylabel('Average rainfall (mm)')
subplot(2,1,2), plot(dnum, cum_avg_rf), datetick('x','mm/dd/yyyy'),
ylabel('Average rainfall (mm)')
ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'\bf Average rainfall of
bsn2004','HorizontalAlignment','center','VerticalAlignment', 'top')

% Write averated rainfall
new_mat=[dnum avg_rf]
filename = 'bsn2004_after_estimation_missing_records.xlsx';
sheet = 'bsn2004_avg_rf';
xlRange = 'A1';
xlswrite(filename,new_mat,sheet,xlRange)
% Write this to text file.
fid = fopen('bsn2004_avg_rf.txt','wt');
for ii = 1:size(new_mat,1)
    fprintf(fid,'%g\t',new_mat(ii,:));
    fprintf(fid,'\n');
end
fclose(fid)

% comparison of rainfall data
[v, T, vT] = xlsread(filename, sheet);
dnum = v(:,1); % water stage
rf2004 = v(:,2);
sum(rf2004)/30

[v, T, vT] = xlsread(filename, 'sheet1');
dnum = v(:,1); % water stage
rfallstations = v(:,2:end);
sum(rfallstations)./30
figure(), plot(dnum, cumsum(rf2004),'r-',dnum, cumsum(rfallstations), 'k:'),
title('Avg. rainfall vs. all stations in bsn 2004')
```

```
%% Averaged rainfall for bsn2005
filename = 'bsn2005_after_estimation_missing_records.xlsx'
sheet= 'sheet1'
% load the station name
xlrange = 'a1:t1';
[~, T, ~] = xlsread(filename, sheet, xlrange)
stnm = T(2:end);
% load rainfall data
xlrange= 'a2:t10958'
[v, T, vT] = xlsread(filename, sheet, xlrange);
dnum = v(:,1); % water stage
rf = v(:,2:length(stnm)+1);

% Read Thiessen polygon ratio
filename = 'ratio_4thiessen_polygon.xlsx'
sheet= 'bsn2005'
xlrange= 'a2:n20'
[v, T, vT] = xlsread(filename, sheet, xlrange);
ratio=v(:,13);
station=vT(:,14);
st = char(station); % convert cellarray into string array
strMat = fstrvcat(st); % convert string(Char) into ASCII code array

% Find corresponding thiessen ratio from GIS thiessen network
thiessen_ratio = zeros(length(stnm),1);
size(thiessen_ratio)
for k = 1:length(stnm)
    rown = findrow(char(stnm(k)),strMat); % find the rownumber what I want to
look for
    thiessen_ratio(k) = ratio(rown)
end

size(strMat)
% making dynamic variables

statement = ['avg_rf = ']
for i=1:length(stnm)
    switch i
        case 1
        code = ['rf(:,' num2str(i) ').*thiessen_ratio(' num2str(i) ')']
        otherwise
        code = ['+rf(:,' num2str(i) ').*thiessen_ratio(' num2str(i) ')']
    end
statement = [statement code]
end
eval([statement])

avg_rf
cum_avg_rf = cumsum(avg_rf)

figure()
subplot(2,1,1), plot(dnum, avg_rf), datetick('x','mm/dd/yyyy'),
ylabel('Average rainfall (mm)')
```

```
subplot(2,1,2), plot(dnum, cum_avg_rf), datetick('x','mm/dd/yyyy'),
ylabel('Average rainfall (mm)')
ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'\bf Average rainfall of
bsn2005','HorizontalAlignment','center','VerticalAlignment', 'top')

% Write averated rainfall
new_mat=[dnum avg_rf]
filename = 'bsn2005_after_estimation_missing_records.xlsx';
sheet = 'bsn2005_avg_rf';
xlRange = 'A1';
xlswrite(filename,new_mat,sheet,xlRange)
% Write this to text file.
fid = fopen('bsn2005_avg_rf.txt','wt');
for ii = 1:size(new_mat,1)
    fprintf(fid,'%g\t',new_mat(ii,:));
    fprintf(fid,'\n');
end
fclose(fid)

% comparison of rainfall data
[v, T, vT] = xlsread(filename, sheet);
dnum = v(:,1); % water stage
rf2005 = v(:,2);
sum(rf2005)/30

[v, T, vT] = xlsread(filename, 'sheet1');
dnum = v(:,1); % water stage
rfallstations = v(:,2:end);
sum(rfallstations)./30
figure(), plot(dnum, cumsum(rf2005),'r-',dnum, cumsum(rfallstations), 'k:'),
title('Avg. rainfall vs. all stations in bsn 2005')

%% Averaged rainfall for bsn2007
filename = 'bsn2007_after_estimation_missing_records.xlsx'
sheet= 'sheet1'
% load the station name
xlrange = 'a1:d1';
[~, T, ~] = xlsread(filename, sheet, xlrange)
stnm = T(2:end);
% load rainfall data
xlrange= 'a2:d10958'
[v, T, vT] = xlsread(filename, sheet, xlrange);
dnum = v(:,1); % water stage
rf = v(:,2:length(stnm)+1);

% Read Thiessen polygon ratio
filename = 'ratio_4thiessen_polygon.xlsx'
sheet= 'bsn2007'
xlrange= 'a2:n4'
[v, T, vT] = xlsread(filename, sheet, xlrange);
ratio=v(:,13);
station=vT(:,14);
st = char(station); % convert cellarray into string array
strMat = fstrvcat(st); % convert string(Char) into ASCII code array
```

```
% Find corresponding thiessen ratio from GIS thiessen network
thiessen_ratio = zeros(length(stnm),1);
size(thiessen_ratio)
for k = 1:length(stnm)
    rown = findrow(char(stnm(k)),strMat); % find the rownumber what I want to
look for
    thiessen_ratio(k) = ratio(rown)
end

size(strMat)
% making dynamic variables

statement = ['avg_rf = ']
for i=1:length(stnm)
    switch i
        case 1
        code = ['rf(:,' num2str(i) ').*thiessen_ratio(' num2str(i) ')']
        otherwise
        code = ['+rf(:,' num2str(i) ').*thiessen_ratio(' num2str(i) ')']
    end
statement = [statement code]
end
eval([statement])

avg_rf
cum_avg_rf = cumsum(avg_rf)

figure()
subplot(2,1,1), plot(dnum, avg_rf), datetick('x','mm/dd/yyyy'),
ylabel('Average rainfall (mm)')
subplot(2,1,2), plot(dnum, cum_avg_rf), datetick('x','mm/dd/yyyy'),
ylabel('Average rainfall (mm)')
ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'\bf Average rainfall of
bsn2007','HorizontalAlignment','center','VerticalAlignment', 'top')

% Write averated rainfall
new_mat=[dnum avg_rf]
filename = 'bsn2007_after_estimation_missing_records.xlsx';
sheet = 'bsn2007_avg_rf';
xlRange = 'A1';
xlswrite(filename,new_mat,sheet,xlRange)
% Write this to text file.
fid = fopen('bsn2007_avg_rf.txt','wt');
for ii = 1:size(new_mat,1)
    fprintf(fid,'%g\t',new_mat(ii,:));
    fprintf(fid,'\n');
end
fclose(fid)

% comparison of rainfall data
[v, T, vT] = xlsread(filename, sheet);
dnum = v(:,1); % water stage
rf2007 = v(:,2);
sum(rf2007)/30
```

```
[v, T, vT] = xlsread(filename, 'sheet1');
dnum = v(:,1); % water stage
rfallstations = v(:,2:end);
sum(rfallstations)./30
figure(), plot(dnum, cumsum(rf2007),'r-',dnum, cumsum(rfallstations), 'k:'),
title('Avg. rainfall vs. all stations in bsn 2007')


%% Average areal rainfall for Sangju weir basin

% the ratios are from basicinformation_for_runoff.xlsx, among sub-basins
% area ratio.
rf_SJweir = rf2001.*0.22 + rf2002.*0.27 + rf2003.*0.13 + rf2004.*0.25 +
rf2005.*0.12 + rf2007.*0.01

% Write this to text file.
fid = fopen('bsnSJweir_avg_rf.txt','wt');
for ii = 1:size(new_mat,1)
    fprintf(fid,'%g\t',new_mat(ii,:));
    fprintf(fid,'\n');
end
fclose(fid)
```

Tank Simulation

TANKSIM.BAT

```
tank4sim.exe sub2001_input_1.dat sub2001_output.out
tank4sim.exe sub2002_input_1.dat sub2002_output.out
tank4sim.exe sub2003_input_1.dat sub2003_output.out
tank4sim.exe sub2004_input_1.dat sub2004_output.out
tank4sim.exe sub2005_input_1.dat sub2005_output.out
tank4sim.exe sub2007_input_1.dat sub2007_output.out
tank4sim.exe SJweir_input_1.dat SJweir_output.out
```

SUB2001_INPUT.DAT

```
RAINFALL   EVAPO
    0.00     1.5
    0.00     1.2
    0.00     2.4
    0.00     1.9
    0.00     2.1
    0.00     1.7
    0.00     2.0
    0.22     1.6
    0.78     1.8
    0.32     1.9
    0.32     1.2
    0.31     2.8
    0.16     1.6
```

0.44	1.7
1.10	1.4
0.40	1.8
0.00	1.3
0.49	1.7
4.09	0.5
0.88	1.8
0.00	1.6
0.00	1.2
0.00	2.0
0.00	2.4
0.08	2.0
0.00	1.7
0.22	1.4
0.00	1.9
0.00	1.8
0.00	1.8
0.08	1.8
0.00	2.9
0.00	3.5
0.00	2.8
0.00	1.1
0.42	0.3
0.00	1.0
0.00	1.9
3.92	1.3
3.38	0.7
1.67	1.7
0.49	1.6
1.29	2.2
0.08	2.3
0.00	2.3
0.51	1.6
0.50	2.1
0.50	2.3
0.89	0.4
0.74	2.0
0.70	3.1
0.14	3.1
0.00	2.9
0.00	1.8
0.00	2.4
0.35	1.8
0.14	1.5
4.22	1.5
1.59	1.3
1.76	1.5
2.26	0.6
1.08	1.9
0.00	3.1
0.00	3.7
0.74	2.4
11.06	1.6
4.93	1.0
0.84	4.1
0.11	2.0
0.81	1.5
0.00	3.1

~
OMITTED AFTER

SUB2001_OUTPUT.OUT

```
     Name of basin : Sub-basin 2001 (Andong dam)
     Simulation period : 1/ 1/1985 - 12/31/2014

     Annual Pan Eavoporation Coefficient :  .70
     Basin area (square km) : 1628.60
         »ï¸²(%) : 86.50  ,³í(%)  :  1.80  ,¹ç(%) :  8.10  ,±âÅ¸(%) :  3.60

     Tank Parameters
       S1I :   4.0000000
       S2I :   1.0000000
       S3I : 157.0000000
       S4I : 105.0000000
       A11 :    .5000000
       A12 :    .1400000
       A2  :    .1250000
       A3  :    .2550000
       A4  :    .0895000
       B1  :    .0860000
       B2  :    .0511000
       B3  :    .0000000
       H11 :  56.4200000
       H12 :  25.0000000
       H2  :    .0000000
       H3  :        .000
       ALP :    .7000000


<<<<< Simulation Results >>>>>

   Date     R (mm)   ET(mm)    Q(mm)  Qs(cms)  Q1(cms)  Q2(cms)  Q3(cms)  Q4(cms)
--------------------------------------------------------------------------------
-------------
 1/ 1/1985     .00      .00    49.56   934.14      .00     2.36   754.64   177.14
 1/ 2/1985     .00      .34    49.61   935.20      .00     3.10   754.96   177.14
 1/ 3/1985     .00      .69    38.58   727.15      .00     3.09   562.77   161.28
 1/ 4/1985     .00      .55    30.20   569.35      .00     2.93   419.57   146.85
 1/ 5/1985     .00      .60    23.83   449.20      .00     2.64   312.85   133.71
 1/ 6/1985     .00      .49    18.96   357.33      .00     2.28   233.31   121.74
 1/ 7/1985     .00      .58    15.20   286.51      .00     1.67   173.99   110.84
 1/ 8/1985     .22      .85    12.22   230.31      .00      .00   129.39   100.92
 1/ 9/1985     .78      .90     9.96   187.71      .00      .00    95.82    91.89
 1/10/1985     .32      .92     8.07   152.16      .00      .00    68.50    83.67
 1/11/1985     .32      .76     6.64   125.08      .00      .00    48.90    76.18
 1/12/1985     .31     1.13     5.40   101.87      .00      .00    32.51    69.36
 1/13/1985     .16      .85     4.46    84.04      .00      .00    20.89    63.15
 1/14/1985     .44      .88     3.76    70.97      .00      .00    13.47    57.50
 1/15/1985    1.10      .81     3.31    62.45      .00      .06    10.04    52.35
 1/16/1985     .40      .90     2.87    54.13      .00      .00     6.46    47.67
 1/17/1985     .00      .37     2.46    46.46      .00      .00     3.05    43.40
 1/18/1985     .49      .88     2.12    39.94      .00      .00      .42    39.52
 1/19/1985    4.09      .60     1.97    37.07      .00      .71      .39    35.98
 1/20/1985     .88      .90     1.82    34.40      .00     1.22      .41    32.76
 ~
 ~ OMITTED BETWEEN
 ~
 7/23/2014    2.25     1.05      .36     6.72      .00     4.49     2.23      .00
 7/24/2014     .29     2.08      .32     6.08      .00     4.00     2.08      .00
 7/25/2014    7.07     2.47      .35     6.53      .00     4.51     2.02      .00
 7/26/2014     .36     2.82      .33     6.28      .00     4.32     1.96      .00
 7/27/2014     .00     2.13      .29     5.52      .00     3.68     1.84      .00
 7/28/2014     .00      .69      .23     4.37      .00     2.72     1.65      .00
```

7/29/2014	.44	2.63	.00	.00	.00	.00	.00	.00
7/30/2014	.00	2.13	.00	.00	.00	.00	.00	.00
7/31/2014	9.16	1.31	.09	1.76	.00	1.59	.17	.00
8/ 1/2014	.00	2.86	.13	2.54	.00	2.19	.35	.00
8/ 2/2014	.63	2.09	.15	2.81	.00	2.31	.50	.00
8/ 3/2014	38.84	2.15	2.55	48.04	36.85	9.80	1.40	.00
8/ 4/2014	7.33	1.75	2.99	56.29	37.56	16.02	2.71	.00
8/ 5/2014	1.87	2.62	2.41	45.43	21.42	19.91	4.09	.00
8/ 6/2014	2.87	2.89	2.04	38.54	10.86	22.30	5.38	.00
8/ 7/2014	23.76	2.42	4.98	93.95	59.05	27.98	6.92	.00
8/ 8/2014	5.05	2.82	4.56	86.01	45.92	31.64	8.45	.00
8/ 9/2014	1.59	2.42	3.75	70.70	27.68	33.26	9.77	.00
8/10/2014	27.64	2.39	7.03	132.50	82.39	38.79	11.32	.00
8/11/2014	1.95	1.89	5.97	112.53	58.26	41.50	12.76	.00
8/12/2014	.00	2.20	4.74	89.32	33.61	41.84	13.87	.00
8/13/2014	.28	2.49	3.70	69.74	14.52	40.65	14.57	.00
8/14/2014	9.03	2.55	4.14	78.01	22.66	40.30	15.06	.00
8/15/2014	.82	3.09	3.18	59.85	5.88	38.72	15.25	.00
8/16/2014	1.00	3.22	2.74	51.59	.00	36.43	15.16	.00
8/17/2014	3.57	3.12	2.61	49.11	.00	34.25	14.86	.00
8/18/2014	73.87	3.29	28.98	546.33	484.03	46.39	15.91	.00
8/19/2014	29.72	3.15	25.16	474.31	401.71	55.01	17.59	.00
8/20/2014	44.34	3.29	33.87	638.43	553.92	64.66	19.84	.00
8/21/2014	21.76	1.85	22.89	431.54	340.52	69.04	21.98	.00
8/22/2014	1.40	2.59	8.57	161.59	70.81	67.38	23.40	.00
8/23/2014	.00	.06	7.29	137.47	48.98	64.34	24.14	.00
8/24/2014	.02	1.54	5.98	112.72	28.22	60.24	24.26	.00
8/25/2014	35.96	2.82	14.05	264.83	177.57	62.66	24.61	.00
8/26/2014	4.68	2.52	8.31	156.73	69.88	62.05	24.80	.00
8/27/2014	.04	1.76	6.80	128.11	43.86	59.56	24.69	.00
8/28/2014	.41	2.65	5.43	102.42	22.36	55.85	24.21	.00
8/29/2014	.00	.63	4.52	85.27	9.98	51.85	23.44	.00
8/30/2014	.00	2.24	3.71	69.90	.00	47.49	22.42	.00
8/31/2014	.00	2.16	3.41	64.23	.00	43.05	21.19	.00
9/ 1/2014	.00	1.91	3.10	58.48	.00	38.66	19.82	.00
9/ 2/2014	3.30	2.09	2.83	53.43	.00	35.02	18.41	.00
9/ 3/2014	31.81	1.04	5.76	108.58	52.92	37.98	17.68	.00
9/ 4/2014	.00	2.14	4.53	85.48	29.64	38.64	17.20	.00
9/ 5/2014	.00	.65	3.74	70.44	15.57	38.09	16.78	.00
9/ 6/2014	.00	.09	3.15	59.42	6.15	36.92	16.35	.00
9/ 7/2014	.52	1.10	2.71	51.16	.00	35.30	15.86	.00
9/ 8/2014	.00	1.73	2.57	48.47	.00	33.19	15.28	.00
9/ 9/2014	.00	1.65	2.41	45.36	.00	30.77	14.59	.00
9/10/2014	.16	1.66	2.23	41.98	.00	28.17	13.81	.00
9/11/2014	.00	.50	2.05	38.65	.00	25.69	12.96	.00
9/12/2014	.52	1.04	1.88	35.42	.00	23.33	12.09	.00
9/13/2014	.03	1.32	1.70	32.12	.00	20.93	11.19	.00
9/14/2014	.00	.68	1.54	28.96	.00	18.67	10.28	.00
9/15/2014	.00	1.39	1.37	25.78	.00	16.41	9.37	.00
9/16/2014	.00	1.47	1.20	22.62	.00	14.16	8.46	.00
9/17/2014	2.10	1.49	1.06	19.96	.00	12.37	7.59	.00
9/18/2014	.00	2.03	.91	17.17	.00	10.43	6.74	.00
9/19/2014	.00	1.76	.67	12.68	.00	6.93	5.75	.00
9/20/2014	.00	1.32	.38	7.16	.00	2.61	4.55	.00
9/21/2014	.00	1.76	.00	.00	.00	.00	.00	.00
9/22/2014	.00	.91	.00	.00	.00	.00	.00	.00
9/23/2014	1.22	1.92	.00	.00	.00	.00	.00	.00
9/24/2014	96.38	1.44	30.18	568.89	547.64	19.24	2.01	.00
9/25/2014	.17	1.69	6.04	113.91	82.34	27.24	4.33	.00
9/26/2014	.00	1.32	4.92	92.81	54.58	31.70	6.53	.00
9/27/2014	.00	1.58	3.95	74.46	32.41	33.67	8.38	.00
9/28/2014	.00	.94	3.23	60.82	16.92	34.11	9.80	.00
9/29/2014	.64	.67	2.75	51.89	7.34	33.73	10.81	.00

9/30/2014	.34	1.49	2.34	44.08	.00	32.62	11.46	.00
10/ 1/2014	.00	1.14	2.27	42.84	.00	31.06	11.77	.00
10/ 2/2014	.02	.86	2.18	41.07	.00	29.25	11.82	.00
10/ 3/2014	.01	1.10	2.06	38.86	.00	27.22	11.64	.00
10/ 4/2014	.00	1.41	1.92	36.27	.00	24.99	11.28	.00
10/ 5/2014	.00	1.14	1.78	33.47	.00	22.70	10.77	.00
10/ 6/2014	.03	.73	1.63	30.66	.00	20.50	10.16	.00
10/ 7/2014	.00	1.00	1.47	27.80	.00	18.32	9.48	.00
10/ 8/2014	.00	.59	1.33	25.05	.00	16.29	8.76	.00
10/ 9/2014	.00	.83	1.19	22.36	.00	14.34	8.02	.00
10/10/2014	.02	.11	1.06	19.93	.00	12.64	7.29	.00
10/11/2014	.00	1.65	.92	17.39	.00	10.83	6.56	.00
10/12/2014	.00	1.34	.79	14.86	.00	9.03	5.83	.00
10/13/2014	25.44	1.45	.96	18.04	.00	12.40	5.64	.00
10/14/2014	.00	.76	1.08	20.32	.00	14.60	5.72	.00
10/15/2014	.00	.83	1.16	21.78	.00	15.87	5.92	.00
10/16/2014	.82	1.19	1.20	22.63	.00	16.50	6.13	.00
10/17/2014	.00	.80	1.21	22.87	.00	16.57	6.29	.00
10/18/2014	.00	1.00	1.20	22.55	.00	16.17	6.37	.00
10/19/2014	.00	.86	1.16	21.81	.00	15.45	6.36	.00
10/20/2014	15.72	1.08	1.28	24.21	.00	17.64	6.58	.00
10/21/2014	66.42	1.34	26.26	494.93	454.47	32.20	8.26	.00
10/22/2014	6.24	1.13	9.75	183.75	134.72	38.84	10.20	.00
10/23/2014	.00	1.00	5.97	112.49	58.97	41.59	11.93	.00
10/24/2014	.00	.97	4.93	92.91	37.42	42.21	13.29	.00
10/25/2014	.00	.76	4.08	76.97	21.28	41.47	14.22	.00
10/26/2014	.00	1.03	3.32	62.67	8.06	39.85	14.75	.00
10/27/2014	.00	.80	2.80	52.71	.00	37.78	14.93	.00
10/28/2014	.00	.66	2.67	50.34	.00	35.52	14.82	.00
10/29/2014	.00	.73	2.53	47.63	.00	33.13	14.50	.00
10/30/2014	.00	.86	2.37	44.65	.00	30.65	14.00	.00
10/31/2014	26.97	1.11	4.76	89.72	42.23	33.56	13.93	.00
11/ 1/2014	12.60	.86	5.80	109.40	57.98	37.17	14.25	.00
11/ 2/2014	.24	.55	4.86	91.66	38.38	38.64	14.64	.00
11/ 3/2014	.00	.20	4.09	77.16	23.51	38.70	14.94	.00
11/ 4/2014	.00	.36	3.42	64.48	11.56	37.84	15.08	.00
11/ 5/2014	.00	.34	2.86	53.85	2.39	36.43	15.03	.00
11/ 6/2014	.00	.14	2.63	49.58	.00	34.76	14.82	.00
11/ 7/2014	.01	1.07	2.50	47.21	.00	32.76	14.46	.00
11/ 8/2014	.31	.86	2.37	44.60	.00	30.64	13.96	.00
11/ 9/2014	.00	.20	2.22	41.92	.00	28.54	13.38	.00
11/10/2014	.00	.96	2.07	39.05	.00	26.34	12.71	.00
11/11/2014	.00	.88	1.91	36.08	.00	24.10	11.98	.00
11/12/2014	.56	1.01	1.76	33.17	.00	21.96	11.22	.00
11/13/2014	.00	.47	1.61	30.35	.00	19.92	10.43	.00
11/14/2014	.00	.25	1.47	27.68	.00	18.03	9.65	.00
11/15/2014	.00	.50	1.33	25.11	.00	16.23	8.88	.00
11/16/2014	.00	.36	1.20	22.69	.00	14.56	8.13	.00
11/17/2014	.00	.66	1.08	20.35	.00	12.94	7.41	.00
11/18/2014	.00	.91	.96	18.05	.00	11.34	6.70	.00
11/19/2014	.00	.66	.84	15.86	.00	9.84	6.02	.00
11/20/2014	.00	.61	.73	13.79	.00	8.43	5.36	.00
11/21/2014	.00	.55	.63	11.87	.00	7.13	4.74	.00
11/22/2014	.02	.61	.53	10.07	.00	5.92	4.15	.00
11/23/2014	.00	.44	.42	7.91	.00	4.36	3.54	.00
11/24/2014	11.07	1.53	.46	8.74	.00	5.53	3.22	.00
11/25/2014	2.21	1.01	.51	9.64	.00	6.56	3.08	.00
11/26/2014	.00	.44	.54	10.20	.00	7.16	3.04	.00
11/27/2014	.00	.01	.56	10.54	.00	7.49	3.05	.00
11/28/2014	2.74	.82	.59	11.12	.00	8.02	3.11	.00
11/29/2014	.02	.42	.60	11.38	.00	8.21	3.17	.00
11/30/2014	6.79	.84	.68	12.79	.00	9.44	3.35	.00
12/ 1/2014	.49	.53	.73	13.77	.00	10.21	3.56	.00

12/ 2/2014	.00	.21	.76	14.35	.00	10.60	3.76	.00
12/ 3/2014	.00	.21	.77	14.60	.00	10.68	3.91	.00
12/ 4/2014	.03	.34	.77	14.53	.00	10.52	4.01	.00
12/ 5/2014	.00	.15	.76	14.27	.00	10.21	4.05	.00
12/ 6/2014	.00	.48	.73	13.76	.00	9.73	4.03	.00
12/ 7/2014	.00	.21	.70	13.13	.00	9.17	3.96	.00
12/ 8/2014	.84	.53	.66	12.53	.00	8.67	3.85	.00
12/ 9/2014	.00	.21	.63	11.84	.00	8.12	3.72	.00
12/10/2014	.05	.21	.59	11.11	.00	7.55	3.56	.00
12/11/2014	.03	.17	.55	10.36	.00	6.98	3.38	.00
12/12/2014	.00	.34	.51	9.56	.00	6.38	3.18	.00
12/13/2014	.00	.28	.46	8.74	.00	5.77	2.97	.00
12/14/2014	.00	.21	.42	7.93	.00	5.18	2.75	.00
12/15/2014	.09	.48	.38	7.11	.00	4.58	2.53	.00
12/16/2014	4.88	.52	.39	7.34	.00	4.94	2.40	.00
12/17/2014	.00	.19	.39	7.42	.00	5.10	2.32	.00
12/18/2014	.01	.30	.39	7.34	.00	5.08	2.26	.00
12/19/2014	.04	.44	.38	7.10	.00	4.91	2.19	.00
12/20/2014	.54	.56	.36	6.83	.00	4.70	2.12	.00
12/21/2014	.00	.32	.34	6.45	.00	4.41	2.04	.00
12/22/2014	.03	.26	.32	6.02	.00	4.08	1.95	.00
12/23/2014	.00	.32	.29	5.54	.00	3.70	1.84	.00
12/24/2014	.00	.26	.27	5.02	.00	3.31	1.71	.00
12/25/2014	.00	.26	.24	4.49	.00	2.91	1.58	.00
12/26/2014	.03	.30	.21	3.95	.00	2.52	1.44	.00
12/27/2014	.00	.24	.18	3.42	.00	2.13	1.29	.00
12/28/2014	.00	.30	.15	2.81	.00	1.67	1.14	.00
12/29/2014	.00	.42	.07	1.27	.00	.38	.89	.00
12/30/2014	.00	.34	.00	.00	.00	.00	.00	.00
12/31/2014	.35	.66	.00	.00	.00	.00	.00	.00

PART 2: SEDIMENT TRANSPORT MODELING

- **MAIN Code**

main_for_Feb25th2016_Func_MCDA_v9_SEMEPP_corFactor.m (finalized on May 10th, 2016)

```
clear all; close all; clc;
starting_time =now()
t=[]

analyzing_period = 20 % analyzing period is fixed with 20 years
%i=1
for i=[1:5]

    switch i
        case 1
        CASE_NO = 1; % Base: current condition
        stagecontrol = 1; % 0 is no stage control, 1 is stagecontrol
        manage_WS = 47.0;
        irrSeason_WS = manage_WS;
        fldSeason_WS = manage_WS;
        Qcontrol = 0;  % 0 is no Q control, 1 is Q control
        control_Q = 0;

        case 2
        CASE_NO = 2; % Threshold water stage
        stagecontrol = 1;
        manage_WS = 43.61;
        irrSeason_WS = manage_WS;
        fldSeason_WS = manage_WS;
        Qcontrol = 0;
        control_Q = 0;

        case 3
        CASE_NO = 3; % lowest water stage
        stagecontrol = 1;
        manage_WS = 37.2; % to show the differences changes from 37.18 to
37.2
        irrSeason_WS = manage_WS;
        fldSeason_WS = manage_WS;
        Qcontrol = 0;
        control_Q = 0;

        case 4
        CASE_NO = 4; % Base + consideration of flood & irrigation season
        stagecontrol = 1;
        manage_WS = 47.0;
        irrSeason_WS=47.0;
        fldSeason_WS=46.0;
        Qcontrol = 0;
        control_Q = 0;

        case 5
        CASE_NO = 5; % Base, Flood season + Q control in flood season
```

```
        stagecontrol = 1;
        manage_WS = 47.0;
        irrSeason_WS=46.0; % meaningless for this case
        fldSeason_WS=44.5; % meaningless for this case
        Qcontrol = 0;
        control_Q = 620; % Threshold discharge when B/C ratio is equal to 1

        case 6
        CASE_NO = 6; % 6 natural state
        stagecontrol = 0; % 0 is no stage control, 1 is stagecontrol
        manage_WS = 47.0;
        irrSeason_WS=manage_WS; % meaningless for this case
        fldSeason_WS=manage_WS; % meaningless for this case
        Qcontrol = 0;  % 0 is no Q control, 1 is Q control
        control_Q = 0;

        otherwise
    end

            tt=[]
            %[ds,
t4mcda]=Aug07th2015_Func_calculation_for_MCDA_v3_unitchangetoBillion(ws,
analyzing_period)
            %[t4daily_ds,
t4mcda_ds]=Nov01st2015_Func_MCDA_v7b_special_Scontrol_floodseason(CASE_NO,
analyzing_period,stagecontrol, manage_WS, irrSeason_WS, fldSeason_WS,
Qcontrol, control_Q)
            [t4daily_ds,
t4mcda_ds]=Feb25th2016_Func_MCDA_v9_SEMEPP_corFactor(CASE_NO,
analyzing_period,stagecontrol, manage_WS, irrSeason_WS, fldSeason_WS,
Qcontrol, control_Q)
            t = [t; t4mcda_ds]; % for overall
            tt= [tt; t4daily_ds]; % for detail

        %% analysis graph

        figure()
        set(gcf, 'units', 'inches', 'position', [0.5 0.5 18 11]) % 0.5, 0.5
is low-left point of screen, 15 is length, 10 is hight from origin point
        set(gca, 'LooseInset', [0.05 0.1 0.05 0.03]) % Left/ Bottom / Right /
Top
        hold off

        subplot(4,3,1) % water stage plot
        plot(tt.d_dnum,tt.s_hwl, tt.d_dnum,tt.s_twl, tt.d_dnum, tt.avg_WS)
        title('Water stage')
        formatIn = 'mm/dd/yyyy';
        set(gca,'XTick')%,[ini_date:180:end_date])
        datetick('x','mm/dd/yyyy','keepticks')
        xlabel('Date (mm/dd/yyyy)')
        ylabel('Stage (El.m)')
        ylim([36 48])
        legend('Upstream water stage', 'Downstream water stage', 'Average
upstream water stage', 'location', 'Southeast')
        grid on
        %xticklabel_rotate
```

```
        subplot(4,3,2)% inflow and outflow plot
        plot(tt.d_dnum,tt.Qin, tt.d_dnum,tt.Qout, tt.d_dnum,tt.avg_Q)
        title('Inflow and outflow')
        formatIn = 'mm/dd/yyyy';
        set(gca,'XTick')%,[ini_date:180:end_date])
        datetick('x','mm/dd/yyyy','keepticks')
        xlabel('Date (mm/dd/yyyy)')
        ylabel('discharge (m^3/s)')
        legend('Inflow', 'Discharge', 'Average discharge')%, 'location',
'best')
        grid on

        subplot(4,3,3)% inflow and outflow plot
        plot(tt.d_dnum ,tt.daily_Turb, tt.d_dnum, tt.avg_Turb)
        title('Turbidity')
        formatIn = 'mm/dd/yyyy';
        set(gca,'XTick')%,[ini_date:180:end_date])
        datetick('x','mm/dd/yyyy','keepticks')
        xlabel('Date (mm/dd/yyyy)')
        ylabel('Turbidity (NTU)')
        legend('Daily trubidity', 'Average Turbidity')%, 'location', 'best')
        grid on

        subplot(4,3,4)
        diff = cumsum(tt.Bene_hp)-cumsum(tt.Cost_dred);
        semilogy(tt.d_dnum, cumsum(tt.Bene_hp), tt.d_dnum,
cumsum(tt.Cost_dred))%, tt.d_dnum, diff)
        title('Accumulative revenue and cost')
        formatIn = 'mm/dd/yyyy';
        set(gca,'XTick')%,[ini_date:180:end_date])
        datetick('x','mm/dd/yyyy','keepticks')
        xlabel('Date (mm/dd/yyyy)')
        ylabel('Revenue or cost (USD)')
        legend('Acc. hydropower revenue', 'Acc. dredging cost', 'location',
'Southeast')
        xticklabel_rotate



        subplot(4,3,5)
        %figure() % Qposs vs Benefit and Cost, Qposs = Qin - 2.0 (fish path)
        loglog(tt.Qposs, tt.Bene_hp, 'bo', tt.Qposs, tt.Cost_dred, 'k*')
        title ('HP revenue vs. Dred costs')
        xlabel('Qposs (m^3/s)')
        ylabel('HP benefit and Dredging cost (USD)')
        legend('Hydropower revenue','Dredging Cost', 'location', 'Northwest')
        %ylim([0 8*10^4])

        subplot(4,3,6)
        %figure() % water stage vs daily BCratio
        plot(tt.s_hwl, tt.daily_BCratio, 'bo')
        title('Water stage vs. Daily B/C ratio')
        xlabel('Water Stage (El.m)')
        ylabel('Daily B/C ratio')
        legend('Daily B/C ratio', 'location', 'Southwest')
        %ylim([0 60])
        xlim([36 48])
```

```
         subplot(4,3,7)
        %figure() % dH vs daily BC ratio
        plot(tt.dH, tt.daily_BCratio, 'bo')
        title('dH vs. Daily B/C ratio')
        xlabel('dH (m)')
        ylabel('Daily B/C ratio')
        legend('Daily B/C ratio', 'location', 'Northeast')
        xlim([0 10])
        %ylim([0 60])

        subplot(4,3,8)
        %figure() % Qin vs daily BC ratio
        semilogx(tt.Qin, tt.daily_BCratio, 'bo', tt.Qout, tt.daily_BCratio,
'ko' )
        title('Q vs. Daily B/C ratio')
        xlabel('Q (m^3/s)')
        ylabel('Daily B/C ratio')
        legend('Qin', 'Qout', 'location', 'Northeast')
        %ylim([0 60])

        subplot(4,3,9)
        %figure() % TE vs BCratio
        plot(tt.daily_BCratio, tt.avgTE_ns, 'ro', tt.daily_BCratio,
tt.avgTE_yg, 'bo', tt.daily_BCratio, tt.avgTE_nd, 'ko')
        title('T_E vs Daily B/C ratio')
        ylabel('Average T_E')
        xlabel('Daily B/C ratio')
        legend('Naesung stream', 'Yeong stream', 'Nakdong river', 'location',
'Southeast')
        %xlim([0 60])
        ylim([0.5 1])

        subplot(4,3,10)
        %figure() % Qin vs TE
        semilogx(tt.Qin, tt.avgTE_ns, 'ro', tt.Qin, tt.avgTE_yg, 'bo', tt.Qin,
tt.avgTE_nd, 'ko')
        title('Qin vs T_E')
        xlabel('Qin (m^3/s)')
        ylabel('Average Trap efficiency')
        legend('Naesung stream','Yeong stream', 'Nakdong river', 'location',
'Southwest')
        ylim([0.5 1])

        subplot(4,3,11)
        %figure() % manage_WS vs total BC ratio
        total_profit = sum(double(tt.Bene_hp))
        total_loss = sum(double(tt.Cost_dred))
        total_profit/total_loss
        bar([total_profit total_loss], 0.5)
        title('Total profit and loss')
        xlabel('Average water stage (El.m)')
        ylabel('Revenue or cost (USD)')
        set(gca,'XTick')
        New_XTickLable = [{'Revenue' 'Cost'}]
        set(gca, 'XTickLabel', New_XTickLable);
```

```
        subplot(4,3,12)
        %figure() % manage_WS vs total BC ratio
        BCRatio = total_profit / total_loss
        avg_WS = tt(1,2)
        plot(avg_WS, BCRatio, 'ko', 'markerfacecolor', 'r')
        title('Mean water stage vs BC ratio')
        xlabel('Average water stage (El.m)')
        ylabel('Total BC/ratio')
        legend('BC ratio', 'location', 'Northeast')
        xlim([36 48])
        %ylim([0 10])
        grid on
        %text(double(avg_WS), BCRatio*1.1, strcat('WS=',
num2str(double(avg_WS))))
        text(double(avg_WS), BCRatio*1.05, strcat('B/C=', num2str(BCRatio)))


        % Main Title for the whole subplots
        %maintitle = strcat('Analyzing period=',
num2str(analyzing_period),'years, Case: Stage El.', num2str(double(avg_WS)),
'm')
        maintitle = ['Case ' num2str(CASE_NO) '(Nor.: El.' num2str(manage_WS)
'm, Fld.: El.' num2str(fldSeason_WS) 'm, Irr.: El.' num2str(irrSeason_WS)
'm)']
        ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
        text(0.5,
1,maintitle,'HorizontalAlignment','center','VerticalAlignment', 'top')

        % result figure save
        fig_fname = ['Result_CASE_' num2str(CASE_NO) '_daily_figure']
        print(fig_fname, '-dmeta')


        %% new figure for summary

        figure()
        set(gcf, 'units', 'inches', 'position', [0.5 0.5 18 11]) % 0.5, 0.5
is low-left point of screen, 15 is length, 10 is hight from origin point
        set(gca, 'LooseInset', [0.05 0.1 0.05 0.03]) % Left/ Bottom / Right /
Top
        hold off

        subplot(2,3,1) % water stage plot
        plot(tt.d_dnum,tt.s_hwl, tt.d_dnum,tt.s_twl, tt.d_dnum, tt.avg_WS)
        title('Water stage')
        formatIn = 'mm/dd/yyyy';
        set(gca,'XTick')%,[ini_date:180:end_date])
        datetick('x','mm/dd/yyyy','keepticks')
        xlabel('Date (mm/dd/yyyy)')
        ylabel('Stage (El.m)')
        ylim([36 48])
        legend('Upstream water stage', 'Downstream water stage', 'Average
upstream water stage', 'location', 'Southeast')
        grid on
```

```
        xticklabel_rotate

        subplot(2,3,2)% inflow and outflow plot
        plot(tt.d_dnum,tt.Qin, tt.d_dnum,tt.Qout, tt.d_dnum,tt.avg_Q)
        title('Inflow and outflow')
        formatIn = 'mm/dd/yyyy';
        set(gca,'XTick')%,[ini_date:180:end_date])
        datetick('x','mm/dd/yyyy','keepticks')
        xlabel('Date (mm/dd/yyyy)')
        ylabel('Discharge (m^3/s)')
        legend('Inflow', 'Discharge', 'Average discharge')%, 'location',
'best')
        grid on
        xticklabel_rotate

        subplot(2,3,3)
        diff = cumsum(tt.Bene_hp)-cumsum(tt.Cost_dred);
        semilogy(tt.d_dnum, cumsum(tt.Bene_hp), tt.d_dnum,
cumsum(tt.Cost_dred))%, tt.d_dnum, diff)
        title('Accumulative revenue and cost')
        formatIn = 'mm/dd/yyyy';
        set(gca,'XTick')%,[ini_date:180:end_date])
        datetick('x','mm/dd/yyyy','keepticks')
        xlabel('Date (mm/dd/yyyy)')
        ylabel('Revenue or cost (USD)')
        ylim([10^2 10^8])
        legend('Acc. hydropower revenue', 'Acc. dredging cost', 'location',
'Southeast')
        xticklabel_rotate
        hold on
        diground = @(x,d) round(x*10^d)/10^d;% round function
        BCRatio = diground(BCRatio,2);
        text(datenum('20140101','yyyymmdd'),10^4, strcat('B/C ratio=',
num2str(BCRatio)), 'fontsize', 14)


        subplot(2,3,4)
        %figure() % Qposs vs Benefit and Cost, Qposs = Qin - 2.0 (fish path)
        loglog(tt.Qposs, tt.Bene_hp, 'bo', tt.Qposs, tt.Cost_dred, 'k*')
        title ('HP revenue vs. Dred costs')
        xlabel('Qposs (m^3/s)')
        ylabel('HP benefit and Dredging cost (USD)')
        legend('Hydropower revenue','Dredging Cost', 'location', 'Northwest')
        ylim([10^-1 10^7])

        subplot(2,3,5)
        %figure() % Qin vs daily BC ratio
        semilogx(tt.Qin, tt.daily_BCratio, 'bo', tt.Qout, tt.daily_BCratio,
'ko' )
        title('Q vs. Daily B/C ratio')
        xlabel('Q (m^3/s)')
        ylabel('Daily B/C ratio')
        legend('Qin', 'Qout', 'location', 'Northeast')
        ylim([0 80])

        subplot(2,3,6)
```

```
        %figure() % dH vs daily BC ratio
        plot(tt.dH, tt.daily_BCratio, 'bo')
        title('dH vs. Daily B/C ratio')
        xlabel('dH (m)')
        ylabel('Daily B/C ratio')
        legend('Daily B/C ratio', 'location', 'Northwest')
        xlim([0 10])
        ylim([0 80])

        % Main Title for the whole subplots
        average_waterstage=diground(tt.avg_WS(end),2);
        maintitle = ['Case ' num2str(CASE_NO) '(Nor.: El.' num2str(manage_WS)
'm, Fld.: El.' num2str(fldSeason_WS) 'm, Irr.: El.' num2str(irrSeason_WS)
'm)']
        ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
        text(0.5,
1,maintitle,'HorizontalAlignment','center','VerticalAlignment', 'top',
'fontsize', 15)
        % for pictitle

        fig_fname = ['Result_CASE_' num2str(CASE_NO) '_daily_figure_summary']
        print(fig_fname, '-dmeta')


        ending_time = now()
end % for i


%% Table and Graph for MCDA input
t
t_col_name = get(t, 'VarNames');
t_col_name = {'Case No.' 'Average water stage (El.m)' 'Average discharge
(m^3/s)' 'Turbidity (NTU)'...
              'Total sediment yield (tons)' 'Average Trap efficiency' 'Total
reservoir sedimentation (tons)' 'Total reservoir sedimentation (m^3)'
'Reservoir fill ratio (%)' 'Dredging cost (USD)'...
              'Average hydropower(kW)' 'Hydopower production (kWh)'
'Hydropower revenues (USD)'...
              'BC ratio' 'Volume for water supply (m^3)' 'Volume for flood
prevention (m^3)' 'XS area for flood conveyance (m^2)'...
              'Good view station ratio (%)'}
% export table
t4final_fname = ['Result_Total_MCDA_input_summary_table.xlsx'];
export(t, 'XLSfile', t4final_fname)

figure()
set(gcf, 'units', 'inches', 'position', [0.5 0.5 18 11]) % 0.5, 0.5 is low-
left point of screen, 15 is length, 10 is hight from origin point
set(gca, 'LooseInset', [0.05 0.1 0.05 0.03]) % Left/ Bottom / Right / Top
hold off
for i=2:17
subplot(4,4,i-1), plot(t(:,1),t(:,i+1),'o-'),
%title(char(t_col_name(i+1))),
xlabel('Case No.'), ylabel(t_col_name(i+1)), grid on
```

```
end
% Making main title
maintitle = ['Main variables for MCDA input']
%maintitle = strcat('Case: Analyzing period=',
num2str(analyzing_period),'years, The simulation result for MCDA input')
ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,maintitle,'HorizontalAlignment','center','VerticalAlignment',
'top', 'fontsize', 15)

fig_fname = ['Result_Total_MCDA_input_summary_figure']
print(fig_fname, '-dmeta')


% figure()
% plot(t.avg_Q, t.BCRatio, 'bo-')
% xlabel('Water stage (El.m)')
% ylabel('B/C ratio')


%% summary of results
% added

exp_T = []
for i=1:5

filename = ['Result_CASE_', num2str(i), '_daily_table.xlsx'];
%filename = 'Result_CASE_1_daily_table.xlsx';

sheet = 'Sheet1';
[v, T, vT] = xlsread(filename, sheet, 'A1:AO8036' );

totTE = sum(v(:,35)) / sum(v(:,28))*100

avg_WS = mean(v(:,11)); % change median after Fontane meeting

Dep_vol = sum(v(:,37))
Cost_dred = sum(v(:,38))
avg_dH=mean(v(:,13))
avg_Qa=mean(v(:,18))+mean(v(:,19))
Pkwh = sum(v(:,23))
Bene_hp = sum(v(:,24))

% storage calculation for water supply
[stored_vol, surf_area, XSarea]=Sep11th2015_Func_catch_vol_surf_area(avg_WS);
avgWSA = surf_area
Current_vol_of_floodprevention = stored_vol;

[stored_vol, ~, ~ ]=Sep11th2015_Func_catch_vol_surf_area(44.155);% Pungyang
Intake level is 44.155, Saboelmaehoe 41.5
Critical_vol_of_watersupply = stored_vol;
vol_for_watersupply = Current_vol_of_floodprevention-
Critical_vol_of_watersupply
```

```
% Flood prevention
[stored_vol, ~, XSarea ]=Sep11th2015_Func_catch_vol_surf_area(52);% Bank
Elevation
max_vol_of_floodprevention = stored_vol;
max_XSarea = XSarea;

switch i
    case 1
        fldseason_WS = avg_WS
    case 2
        fldseason_WS = avg_WS
    case 3
        fldseason_WS = avg_WS
    case 4
        fldseason_WS = 46.0
    case 5
        fldseason_WS = 44.5
    otherwise
        fldseason_WS = avg_WS
end

[stored_vol, ~, XSarea ]=Sep11th2015_Func_catch_vol_surf_area(fldseason_WS);%
Bank Elevation
Current_vol_of_floodprevention = stored_vol;
Current_XSarea = XSarea;

vol_for_floodprevention = max_vol_of_floodprevention -
Current_vol_of_floodprevention
XSarea_for_floodconveyance = max_XSarea - Current_XSarea


% Turbidity
avg_Turb = median(v(:,41))

% Tourism
[good_view_station_ratio]=Sep11th2015_Func_flow_width_ratio_calculation(avg_W
S);%
good_view_station_ratio

exp_table = [i; totTE; avg_WS; avgWSA; Dep_vol; Cost_dred; avg_dH; avg_Qa;...
             Pkwh; Bene_hp; vol_for_watersupply; vol_for_floodprevention;...
             XSarea_for_floodconveyance; avg_Turb; good_view_station_ratio]
exp_T = [exp_T exp_table]

end % for i


header = {'case'; 'totTE'; 'avg_WS'; 'avgWSA'; 'Dep_vol'; 'Cost_dred';
'avg_dH'; 'avg_Qa';...
             'Pkwh'; 'Bene_hp'; 'vol_for_watersupply';
'vol_for_floodprevention';...
             'XSarea_for_floodconveyance'; 'avg_Turb';
'good_view_station_ratio'}
header = header'
exp_T = exp_T'
```

```
ds = dataset({exp_T, header{:}})

exp_fname = 'MCDAinput_from_Simulations.xlsx';
export(ds, 'XLSfile', exp_fname)


%% Q threshold analysis

[v, T, vT] = xlsread('4700noHcontrol_Result_CASE_6_daily_table.xlsx')
Qin =v(:,15)
Bene_hp=v(:,24)
Cost_dred=v(:,38)

figure()
        %figure() % Qposs vs Benefit and Cost, Qposs = Qin - 2.0 (fish path)
        loglog(Qin, Bene_hp, 'bo', Qin, Cost_dred, 'k*', 'Markersize', 3),
hold on
        title ('HP revenues vs. Dred costs')
        xlabel('Q (m^3/s)')
        ylabel('HP benefit and Dredging cost (USD)')
        legend('Hydropower revenue','Dredging Cost', 'location', 'Northwest')
        ylim([10^-1 10^7])
        xlim([10^-1 10^4])
        loglog([620 620], [10,10^5], 'r-')
        text(570, 7, '\uparrow Q threshold')

print('Fig_Q_threshold', '-dmeta')


%% H threshold analysis (added on Nov.29th, 2015)

% from the simulation results (folder name Nov18th2015_draft_v1b)
ws = [37.2 41.5 42 42.5 43.0 43.2 43.4 43.5 43.55 43.60 43.65 43.7 43.8 44.0
44.5 45.0 45.5 46.0 46.5 47.0];
bc = [0 0 0 0 0.01 0.03 0.52 0.83 0.94 1.01 1.09 1.14 1.18 1.26 1.45 1.64
1.84 2.04 2.24 2.34];
size(ws)
size(bc)
figure()
        plot(ws, bc, 'bo-', 'Markersize', 5), hold on
        xlabel('WS (El.m)')
        ylabel('B/C ratio')
        plot([37 43.6], [1.01,1.01], 'r-')
        plot([43.6 43.6], [0,1.01], 'r-')
        plot(43.6, 1.01, 'ro', 'markerfacecolor', 'r')
        text(43.6+0.1, 1.01, '\leftarrow WS threshold')
        xlim([41 47])
        print('Fig_WS_threshold', '-dmeta')


simulation_duration =datevec(ending_time-starting_time)
```

- **SUB-FUNCTIONS**

Feb25th2016_Func_MCDA_v9_SEMEPP_corFactor.m (finalized on May 10th, 2016)

```
function [t4daily_ds, t4mcda_ds] =
Feb25th2016_Func_MCDA_v9_SEMEPP_corFactor(CASE_NO, analyzing_period,
stagecontrol, manage_WS, irrSeason_WS, fldSeason_WS, Qcontrol, control_Q)

clc;close all;%clear all;
format shortG;

%% A. Hydropower benefit
% Read operation data from the K-water database
filename='20120716_20150301_operation.txt';  % dimliter must be tab.
fid = fopen(filename, 'r');
data =
textscan(fid,'%s %f32 %f32 %f32 %f32 %f %f %f %f %f %f %f %f %f %f %f %f %f',
'headerLines', 1, 'delimiter', '\t');
fclose(fid);

% getting datevector from text type date&time
dates = data{1};
datev = datevec(dates,'yyyymmddHHMM');
daten = datenum(datev);

% filtering with certain period
%ini_date = input('Enter starting date, ex)20120718:');
ini_date = datenum(datevec('201301010000','yyyymmddHHMM'));
end_date = datenum(datevec('201412312350','yyyymmddHHMM'));
% giving conditions
ind = find(daten >= ini_date & daten <= end_date);

ind_date = datev(ind,1:6);
s_date=datenum(ind_date) % filtered date and time vector

d_date=reshape(s_date, 144, []); % reshape the table into one column with 144
records length
d_dnum=d_date(1,:)' % choose the first row and transpose
d_dvec= datevec(d_dnum) % convert datenum into date vector

hwl = double(data{2}); % get head water level and converte cell into double
s_hwl=hwl(ind);        % filter hwl with certain datecondition
twl = double(data{3});  % get head water level and converte cell into double
s_twl=twl(ind);
inf = double(data{6}); % inflow
s_inf=inf(ind);
outf = double(data{7}); % outflow
s_outf=outf(ind);

dat = [s_hwl s_twl s_inf s_outf];

[row col] = size(dat); % dat_daily is quearyied matrix with condition
```

```
for i = 1:col
d(:,i)  = mean(reshape(dat(:,i), 144, []))';  % average all data
end

% fill nan value with previous data
for k = find(isnan(d))
    d(k)=d(k-1);
end

s_t = [d_dvec d]; % selected table; filtered table

nday = datenum(d_dvec);
datevec(nday(1:10))
datevec(nday)

t_final = [nday d]; % dnum wsup wsdn inflow outflow
size(t_final)


%% extending analysis period

% call function for additional table
% must change the simulation year in the branket, i.g. 10, 20, or 30 yrs
% over 32yrs is impossible

%%
%analyzing_period=20; %%%%%

switch analyzing_period>0

    case 1
        %[period, lastdate, no_of_day,
t_final_to_add]=Aug07th2015_Func_making_additional_Inflow_table
(analyzing_period);
        [period, lastdate, no_of_day, t_final_to_add, dnum_1985_2014,
dnum_2015_2034, dnum_1985_2034,dnum_2013_2014, dnum_2013_2034,...
         Qns_historical, Qns_prediction, Qns_wholeperiod, Qyg_historical,
Qyg_prediction, Qyg_wholeperiod,...
         Qnd_historical, Qnd_prediction, Qnd_wholeperiod, Qsj_historical,
Qsj_prediction, Qsj_wholeperiod,...
         Qsj_observation,
Qsj_obs_n_prediction]=Nov01st2015_Func_making_additional_Inflow_table_v2;

        period
        lastdate
        no_of_day
        t_final_to_add; % SJ weir whole period data (2015-2034)
        a = t_final_to_add(:,2);
        a(a==0)=0.001;
        t_final_to_add = [dnum_2015_2034 a]
        size(t_final_to_add)

        % imported date and inflow data using Function making additional
        % inflow
```

```
        dnum_1985_2014;
        dnum_2015_2034;
        dnum_1985_2034;
        dnum_2013_2014;
        dnum_2013_2034;


        Qns_historical;
        Qns_prediction;
        Qns_prediction(Qns_prediction==0)=0.001;

        Qns_wholeperiod;
        size(Qns_wholeperiod)
        Qns_wholeperiod(Qns_wholeperiod==0)=0.001;

        Qyg_historical;
        Qyg_prediction;
        Qyg_prediction(Qyg_prediction==0)=0.001;

        Qyg_wholeperiod;
        Qyg_wholeperiod(Qyg_wholeperiod==0)=0.001;

        Qnd_historical;
        Qnd_prediction;
        Qnd_prediction(Qnd_prediction==0)=0.001;

        Qnd_wholeperiod;
        Qnd_wholeperiod(Qnd_wholeperiod==0)=0.001;

        Qsj_historical; % Simulated data (1985-2014, 30yrs)
        Qsj_prediction;
        Qsj_prediction(Qsj_prediction==0)=0.001;

        Qsj_wholeperiod;
        Qsj_wholeperiod(Qsj_wholeperiod==0)=0.001;

        Qsj_observation; % Actually observed data (2013-2014)
        Qsj_obs_n_prediction;
        size(Qsj_obs_n_prediction)
        Qsj_obs_n_prediction(Qsj_obs_n_prediction==0)=0.001;

        % t_final_to_add data is the same as Qsj_prediction
        figure()
        subplot(3,1,1), plot(dnum_2015_2034, t_final_to_add(:,2))
        subplot(3,1,2), plot(dnum_2015_2034, Qsj_prediction)
        subplot(3,1,3), plot(dnum_2015_2034, Qsj_prediction-
t_final_to_add(:,2))


        t_of_ws = [t_final(:,2) t_final(:,3)]; % water stages of upstream and
downstream

        %data for 34yrs with same pattern of 2013-2014
```

```
        t_of_ws =
[t_of_ws;t_of_ws;t_of_ws;t_of_ws;t_of_ws;t_of_ws;t_of_ws;t_of_ws;t_of_ws;t_of
_ws;t_of_ws;t_of_ws;t_of_ws;t_of_ws;t_of_ws;t_of_ws;t_of_ws];
        size(t_of_ws);

        %selectiong same length of data with the number of inflow for
addition days
        index = (1:no_of_day)';
        t_of_ws_to_add = t_of_ws(index,:);
        size(t_of_ws_to_add);

        % making final table to add
        %t_final_to_add = [t_final_to_add(:,1) t_of_ws_to_add(:,1:2)
t_final_to_add(:,2) t_final_to_add(:,2)];
        t_final_to_add = [dnum_2015_2034 t_of_ws_to_add Qsj_prediction
Qsj_prediction]; % discharge from SJ weir assumed as same as SJ inflow
        size(t_final_to_add);

        % The combined table (2013-2034)
        t_final = [t_final; t_final_to_add]
        size(t_final);

    case 0
        t_final = t_final;

end

[nrow_of_final_table, ncol] = size(t_final)

%% discharge plot for whole period
figure()
plot(t_final(:,1), t_final(:,4)), datetick('x', 'mm/dd/yyyy', 'keepticks')

%% for simulation time saving
%t_final = t_final(1:20,:)
%[nrow_of_final_table, ncol] = size(t_final)

%% Controal water stage
wsup= t_final(:,2);
%size(wsup)
%When fixed water stage : 40.95 is break-even point

%%
%stagecontrol = 1
%manage_WS = 47

switch stagecontrol

    case 0
        new_wsup =wsup;
    case 1
        manage_WS%=input('Management water stage? If you want to run previous
condition, do not input anything?');
```

```
        %manage_WS = []%44.149; % Water Stage Threshold for break-even point

         new_wsup = zeros(length(wsup),1);
         for n = 1:length(wsup)
             new_wsup(n)=manage_WS;
         end
%          figure(), plot(new_wsup)
%          size(new_wsup)
end % for switch

%% add seasonal stage changes (add Aug. 6th, 2015)

CASE_NO

switch CASE_NO
    case 4
        irrSeason_WS=manage_WS;
        fldSeason_WS=fldSeason_WS;

        daten=t_final(:,1);
        %size(daten)
        datev=datevec(daten);
        yearvec=unique(datev(:,1));

        % revising management water stage for irrigation season (May 1-Sep.30)
        for i=1:length(yearvec)
            irr_strt_date= datenum([yearvec(i) 5 1 0 0 0]);
            irr_fnsh_date= datenum([yearvec(i) 9 30 0 0 0]);
            irr_ind = find(daten >= irr_strt_date & daten <= irr_fnsh_date);
            irr_ws = new_wsup(irr_ind);
            new_wsup(irr_ind,1) = ones(length(irr_ws),1).*irrSeason_WS;
            %new_wsup(irr_ind,1) = ones(length(irr_ws),1).*45
        end

        % figure()
        % plot(daten, new_wsup, 'b-')
        % datetick('x','mm/dd/yyyy')
        % ylim([40 55])

        % revising management water stage for flood season (June 21st-Sep.
20th)
        for i=1:length(yearvec)
            fld_strt_date= datenum([yearvec(i) 6 21 0 0 0]);
            fld_fnsh_date= datenum([yearvec(i) 9 20 0 0 0]);
            fld_ind = find(daten >= fld_strt_date & daten <= fld_fnsh_date);
            fld_ws = new_wsup(fld_ind);
            new_wsup(fld_ind,1) = ones(length(fld_ws),1).*fldSeason_WS;
            %new_wsup(fld_ind,1) = ones(length(fld_ws),1).*46
        end

    case 5
        irrSeason_WS; % meaningless
        fldSeason_WS; % meaningless

        % definition of stages corresponding discharge range
```

```
        WS_smallQthan25 = 47;
        WS_btwQ25and620 = 46;
        WS_bigQthan620 = 44.5;

        Qin = t_final(:,4);
        % water stage changes according to inflow
        id4smallQ25and620= find(Qin<50)
        new_wsup(id4smallQ25and620)=WS_smallQthan25
        id4btwQ25and620= find(Qin>50 & Qin<620)
        new_wsup(id4btwQ25and620)=WS_btwQ25and620
        id4bigQthan620 = find(Qin>620)
        new_wsup(id4bigQthan620)=WS_bigQthan620

    case 6
      % noting to do but no stage control

    otherwise % case no 1,2 etc with steady water stage
        irrSeason_WS=manage_WS;
        fldSeason_WS=manage_WS;

        daten=t_final(:,1);
        %size(daten)
        datev=datevec(daten);
        yearvec=unique(datev(:,1));

        % revising management water stage for irrigation season (May 1-Sep.30)
        for i=1:length(yearvec)
            irr_strt_date= datenum([yearvec(i) 5 1 0 0 0]);
            irr_fnsh_date= datenum([yearvec(i) 9 30 0 0 0]);
            irr_ind = find(daten >= irr_strt_date & daten <= irr_fnsh_date);
            irr_ws = new_wsup(irr_ind);
            new_wsup(irr_ind,1) = ones(length(irr_ws),1).*irrSeason_WS;
            %new_wsup(irr_ind,1) = ones(length(irr_ws),1).*45
        end

%         figure()
%         plot(daten, new_wsup, 'b-'), title(['case No:' num2str(CASE_NO)])
%         datetick('x','mm/dd/yyyy')
%         ylim([40 55])

        % revising management water stage for flood season (June 21st-Sep.
20th)
        for i=1:length(yearvec)
            fld_strt_date= datenum([yearvec(i) 6 21 0 0 0]);
            fld_fnsh_date= datenum([yearvec(i) 9 20 0 0 0]);
            fld_ind = find(daten >= fld_strt_date & daten <= fld_fnsh_date);
            fld_ws = new_wsup(fld_ind);
            new_wsup(fld_ind,1) = ones(length(fld_ws),1).*fldSeason_WS;
            %new_wsup(fld_ind,1) = ones(length(fld_ws),1).*46
        end

end % for CASE_NO

figure()
plot(t_final(:,1), new_wsup, 'b-'), title(['case No:' num2str(CASE_NO)])
```

```
datetick('x','mm/dd/yyyy')
ylim([40 55])


%==================================================================

wsdn= t_final(:,3);
%size(wsdn)

%% Control discharge

Qout = t_final(:,5);
        %size(Qout)
%Qin = t_final(:,4);

%Qcontrol = 1;
%control_Q= 500;

switch Qcontrol
    case 0
        Qin = t_final(:,4);  % 9=inflow, 10=total discharge
        %size(Qin)

    case 1
        control_Q%=input('Controlled discharge?');
         % %control_Q = 461; % Dscharge threshold for break-even point

         %fld_Q = Qout(fld_ind); %getting discharge corresponding flood
season
         Qout(Qout>control_Q)=control_Q;

%           figure()
%           plot(daten, Qin)
%           ylim([0 10000])
    otherwise
end

%% Calculating Hydropower generation

dH = new_wsup - wsdn; % effective fall
diground = @(x,d) round(x*10^d)/10^d;
dH = diground(dH,2);
find(dH<0);
dH(dH<0)=0;

% str = num2str(dH)
% dH=str2num(str)


Ha = dH - 0.25;       % Head loss
Ha(Ha<0)=0;

Qposs = Qin - 2.0; % Fish path discharge
diground = @(x,d) round(x*10^d)/10^d;
```

```
Qposs = diground(Qposs,2);
Qposs(Qposs<0)=0;
size(Qposs);

% For getting corresponding Qrated from Sangju Weir Table
H = [6.25; 6.45; 6.50; 6.75; 7.00; 7.50; 8.00; 8.50; 9.00; 9.50; 10.00;
10.50];
Q = [27.00; 26.00; 25.72; 24.61; 23.60; 21.83; 20.40; 19.64; 18.09; 17.11;
16.30; 15.55];

% plot(H, Q, 'bo-')
% xlabel('Ha, Effective head (m)')
% ylabel('Qa, Rated discharge (m^3/s)')

% turbine efficiency curve when dH=6.75
% Qratio =[100; 90; 80; 70; 60; 50; 40]

% Qt =[26; 23.4; 20.8; 18.2; 15.6; 13.0; 10.4];
% eta_t =[0.9197; 0.9266; 0.9317;0.9340;0.9323;0.9229;0.9021];

% Gear efficiency table
% Pratio =[100; 75; 50; 25]
Pini =[1500; 1125; 750; 375];
eta_g =[0.985; 0.984; 0.98;0.97];


% Getting Qrated
Qrated = zeros(length(Ha),1);
for i = 1:length(Ha)
    if Ha(i) <= 6.25
        Qrated(i) = 27.0;
    elseif Ha(i) >= 10.50
        Qrated(i) = 15.55;
    else
        Qrated(i)=interp1(H,Q,Ha(i));
    end
end

diground = @(x,d) round(x*10^d)/10^d;
Qrated = diground(Qrated,2);
size(Qrated);

% Operational distortion and mismatch with Optimal operational condition,
% 1500/1580
adjusting_factor = 1.0; % because H and Q are operated for 1500 kW production
line

% Correction factor: Observation(July2012-Dec.2014)/Modeling results = 79%
due to maintenance issues
C_factor = 1.0;%0.79;

for i = 1:length(Qrated)

    i
```

```
% Judgement of Qposs conditions
if Qposs(i) >= 2 * Qrated(i)
cond(i) = 1;
elseif Qposs(i) <= Qrated(i)
cond(i) = 2;
else
cond(i) =3;
end

% Case
switch cond(i)
case 1
Qa1(i)=Qrated(i);
Qa2(i)=Qrated(i);
% call function eta calculation using H and Q variables
[ eta_for_dHdQ ] = Aug07th2015_Func_eta_interpolation( Ha(i), Qa1(i));
eta_t1(i) = eta_for_dHdQ / 100;
[ eta_for_dHdQ ] = Aug07th2015_Func_eta_interpolation( Ha(i), Qa2(i));
eta_t2(i) = eta_for_dHdQ / 100;

Pini1(i)=9.81*Qa1(i)*Ha(i)*eta_t1(i);
Pini2(i)=9.81*Qa2(i)*Ha(i)*eta_t2(i);

if Pini1(i) > 1500
eta_g1(i)=0.985;
elseif Pini1(i) < 375
eta_g1(i)=0.97;
else
eta_g1(i) = interp1(Pini, eta_g, Pini1(i));
end

if Pini2(i) > 1500
eta_g2(i)=0.985;
elseif Pini2(i) < 375
eta_g2(i)=0.97;
else
eta_g2(i) = interp1(Pini, eta_g, Pini2(i));
end

Pkw1(i) = Pini1(i)*eta_g1(i)*adjusting_factor*C_factor;
Pkw2(i) = Pini2(i)*eta_g2(i)*adjusting_factor*C_factor;

case 2
Qa1(i)=Qposs(i);
Qa2(i)=0;
% call function eta calculation using H and Q variables
[ eta_for_dHdQ ] = Aug07th2015_Func_eta_interpolation( Ha(i), Qa1(i));
eta_t1(i) = eta_for_dHdQ / 100;
[ eta_for_dHdQ ] = Aug07th2015_Func_eta_interpolation( Ha(i), Qa2(i));
eta_t2(i) = eta_for_dHdQ / 100;

Pini1(i)=9.81*Qa1(i)*Ha(i)*eta_t1(i);
Pini2(i)=0;

if Pini1(i) > 1500
```

```
    eta_g1(i)=0.985;
    elseif Pini1(i) < 375
    eta_g1(i)=0.97;
    else
    eta_g1(i) = interp1(Pini, eta_g, Pini1(i));
    end

    %eta_g1(i)=interp1(Pini,eta_g,Pini1(i));
    eta_g2(i)=0;

    Pkw1(i) = Pini1(i)*eta_g1(i)*adjusting_factor*C_factor;
    Pkw2(i) = 0;

    case 3
    Qa1(i)=Qrated(i);
    Qa2(i)=Qposs(i)-Qrated(i);
    % call function eta calculation using H and Q variables
    [ eta_for_dHdQ ] = Aug07th2015_Func_eta_interpolation( Ha(i), Qa1(i));
    eta_t1(i) = eta_for_dHdQ / 100;
    [ eta_for_dHdQ ] = Aug07th2015_Func_eta_interpolation( Ha(i), Qa2(i));
    eta_t2(i) = eta_for_dHdQ / 100;

    Pini1(i)=9.81*Qa1(i)*Ha(i)*eta_t1(i);
    Pini2(i)=9.81*Qa2(i)*Ha(i)*eta_t2(i);

    if Pini1(i) > 1500
    eta_g1(i)=0.985;
    elseif Pini1(i) < 375
    eta_g1(i)=0.97;
    else
    eta_g1(i) = interp1(Pini, eta_g, Pini1(i));
    end

    if Pini2(i) > 1500
    eta_g2(i)=0.985;
    elseif Pini2(i) < 375
    eta_g2(i)=0.97;
    else
    eta_g2(i) = interp1(Pini, eta_g, Pini2(i));
    end

    Pkw1(i) = Pini1(i)*eta_g1(i)*adjusting_factor*C_factor;
    Pkw2(i) = Pini2(i)*eta_g2(i)*adjusting_factor*C_factor;
    otherwise
    end

end

Pkw=Pkw1'+Pkw2';
%Pkw=Pkw*10^(3)*10^(-9); % change into Giga Watt
Pkwh=Pkw * 24; % Giga Watt hour
%[Ha Qposs Qa1' eta_t1' eta_g1' Pkw1' Qa2' eta_t2' eta_g2' Pkw2']

sum_Pkwh = sum(Pkwh) % Total Hydropower
Bene_hp = Pkwh .* 0.13; % USD/kWh
```

```
sum_Bene_hp = sum(Bene_hp) % sum of revenue of hydropower generation


%% Calculating Dredging cost

% Developing Flow duration curve (Nov.12th, 2015)
daten = dnum_1985_2014; % from Tank simulation
datev = datevec(daten);
yearvec =unique(datev(:,1))
prevYear = datenum(datev(:,1) - 1,12,31)
dayofYear = daten-prevYear

TT=linspace(0.0001,1,10^4);

% (a) interpolation for every year and plot (Naeseong)

FD = [];
cor_Q=[];
Pe_tot=[];
FL_tot=[];



figure()
for i = 1:length(yearvec)
    inds = find(datev(:,1) == yearvec(i)); % finding rank corresponding the
every year (366-730) in case 1978
    max_dayofYear = dayofYear(inds(end))
    Pe = dayofYear(inds)./(max_dayofYear+1)
    FL = sort(Qns_historical(inds), 'descend')

    %intp_val=interp1(Pe,FL,TT,'spline');
    %intp_val=interp1(Pe,FL,TT,'linear');
    intp_val=interp1(Pe,FL,TT, 'cubic');

    int_data(:,i)=intp_val';  %save interpolated value for average

    semilogx(Pe, FL, 'ko', TT, intp_val)
    hold on

    Pe_tot=[Pe_tot; Pe];
    FL_tot = [FL_tot; FL];
end

size(Pe_tot)
size(FL_tot)

% obtaining average of interpolated curve
FL_Avg = zeros(length(TT),1);
for i =1:length(TT)
     FL_Avg(i) = mean(int_data(i,:));
end

semilogx(TT, FL_Avg, 'ro-', 'Markersize', 7, 'Markerfacecolor', 'r')
xlabel('Exceedance probability')
```

```
ylabel('Q (cms)')
title('Naesung Stream FD (1985-2014)')
ylim([0 4500])

print('Fig_NSstr_FDcurve', '-dmeta', '-r600')

FD(:,1) = FL_Avg; % for Naeseong Stream


% (b) interpolation for every year and plot (Yeong Stream)

Pe_tot=[];
FL_tot=[];

figure()
for i = 1:length(yearvec)
    inds = find(datev(:,1) == yearvec(i)); % finding rank corresponding the
every year (366-730) in case 1978
    max_dayofYear = dayofYear(inds(end))
    Pe = dayofYear(inds)./(max_dayofYear+1)
    FL = sort(Qyg_historical(inds), 'descend')

    %intp_val=interp1(Pe,FL,TT,'spline');
    %intp_val=interp1(Pe,FL,TT,'linear');
    intp_val=interp1(Pe,FL,TT, 'cubic');

    int_data(:,i)=intp_val';  %save interpolated value for average

    semilogx(Pe, FL, 'ko', TT, intp_val)
    hold on

    Pe_tot=[Pe_tot; Pe];
    FL_tot = [FL_tot; FL];
end

size(Pe_tot)
size(FL_tot)

% obtaining average of interpolated curve
FL_Avg = zeros(length(TT),1);
for i =1:length(TT)
     FL_Avg(i) = mean(int_data(i,:));
end

semilogx(TT, FL_Avg, 'ro-', 'Markersize', 7, 'Markerfacecolor', 'r')
xlabel('Exceedance probability')
ylabel('Q (cms)')
title('Yeong Stream FD (1985-2014)')
ylim([0 4500])

print('Fig_YGstr_FDcurve', '-dmeta', '-r300')

FD(:,2) = FL_Avg; % for Naeseong Stream
```

```
% (c) interpolation for every year and plot (Nakdong River)

Pe_tot=[];
FL_tot=[];

figure()
for i = 1:length(yearvec)
    inds = find(datev(:,1) == yearvec(i)); % finding rank corresponding the
every year (366-730) in case 1978
    max_dayofYear = dayofYear(inds(end))
    Pe = dayofYear(inds)./(max_dayofYear+1)
    FL = sort(Qnd_historical(inds), 'descend')

    %intp_val=interp1(Pe,FL,TT,'spline');
    %intp_val=interp1(Pe,FL,TT,'linear');
    intp_val=interp1(Pe,FL,TT, 'cubic');

    int_data(:,i)=intp_val';  %save interpolated value for average

    semilogx(Pe,FL,'ko',TT,intp_val);
    hold on

    Pe_tot=[Pe_tot; Pe];
    FL_tot = [FL_tot; FL];
end

size(Pe_tot)
size(FL_tot)

% obtaining average of interpolated curve
FL_Avg = zeros(length(TT),1);
for i =1:length(TT)
     FL_Avg(i) = mean(int_data(i,:));
end

semilogx(TT, FL_Avg, 'ro-', 'Markersize', 7, 'Markerfacecolor', 'r')
xlabel('Exceedance probability')
ylabel('Q (cms)')
title('Nakdong River FD (1985-2014)')
ylim([0 4500])

print('Fig_NDrvr_FDcurve', '-dmeta', '-r300')

FD(:,3) = FL_Avg; % for Nakdong River

size(FD)

% plotting Exceedance Probability vs Q line graph (interpolated data)
figure()
semilogx(TT, FD)
hold on
%title('Flow duration conversion')
xlabel('Exceedance probability')
ylabel('Q(cms)')
```

```
hold on

% picking up discharges corresponding midpoints of exceedance probability

Pe_indx= [0.0001 0.0006 0.003 0.01 0.0325 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
0.975];

for i=1:3 % Naeseong, Yeong, Nakdong River gasin
Intp(:,i)= interp1(TT, FD(:,i), TT);
    for j=1:length(Pe_indx)
    cor_Q(j,i)=interp1(TT,FD(:,i),Pe_indx(j)); % interpolated discharge
corresponding every point of time exceedance
    end
    semilogx(Pe_indx, cor_Q(:,i), 'o', 'Markerfacecolor','g')
end
hold on
legend('Naesung Stream', 'Yeong Stream', 'Nakdong River','Discharges
corresponding PE',...
     'location', 'NorthEast')

print('Fig_Flow_Duration_Curves', '-dmeta', '-r300')

% exporting corresponding Q
cor_Q;
PE_INDX = Pe_indx';
% adding header to sediment yield and deposition table and Export to Excel
cor_Q_table = [PE_INDX cor_Q];
header = {'Probability', 'Naeseong_Stream', 'Yeong_Stream', 'Nakdong_River'};
ds = dataset({cor_Q_table,header{:}});
filename_export = 'Nov01st2015_Cor_Q_table.xlsx';       % file name
corresponding discharge
export(ds,'XLSfile',filename_export);


%% (d) interpolation for every year and plot (Sangju Weir, whole period)

figure()
plot(dnum_1985_2014, Qsj_historical)
datetick('x', 'mm/dd/yyyy')
xlabel('Date (mm/dd/yyyy)')
ylabel('Discharge (m^3/s)')
title('SJ Weir simulated dischage (1985-2014)')
grid on
print('Fig_SJ Weir discharge (1985-2014)', '-dmeta', '-r300')



Pe_tot=[];
FL_tot=[];
Pe =[];
FL = [];

% for SJ weir FD curve generation
n_daten = dnum_1985_2014;
n_datev = datevec(n_daten);
n_yearvec =unique(n_datev(:,1))
```

```
length(n_yearvec)
n_prevYear = datenum(n_datev(:,1) - 1,12,31)
n_dayofYear = daten-prevYear

rval=1
gval=1
bvals = linspace(0,1,length(n_yearvec))

figure()
for i=2:length(n_yearvec) % recored of 1985 was omitted because Tank generate
unusually high values at the first year
    inds = find(n_datev(:,1) == n_yearvec(i));
    %plot(n_dayofYear(inds), Qsj_historical(inds), 'Color', [rval,
gval,bvals(i)])
    plot(n_dayofYear(inds), Qsj_historical(inds), 'Color', [0, 0, 1])
    hold on
end
legend('1985-2014')
hold on
dailyAvgQ = zeros(max(n_dayofYear),1);
for i=1:max(n_dayofYear)
dailyAvgQ(i) = mean(Qsj_historical(dayofYear == i));
end
plot([1:max(n_dayofYear)],dailyAvgQ,'r','LineWidth',4)
xlabel('Day of year')
ylabel('Discharge (m^3/s)')

print('Fig_SJweir_daily_Q_1985_2014_All_year', '-dmeta', '-r300')



figure()
for i = 1:length(n_yearvec)
    inds = find(n_datev(:,1) == n_yearvec(i)); % finding rank corresponding
the every year (366-730) in case 1978
    n_max_dayofYear = n_dayofYear(inds(end))
    Pe = n_dayofYear(inds)./(n_max_dayofYear+1)
    FL = sort(Qsj_historical(inds), 'descend')

    %intp_val=interp1(Pe,FL,TT,'spline');
    %intp_val=interp1(Pe,FL,TT,'linear');
    intp_val=interp1(Pe,FL,TT, 'cubic');

    int_data(:,i)=intp_val';  %save interpolated value for average

    semilogx(Pe,FL,'ko',TT,intp_val);
    hold on

    Pe_tot=[Pe_tot; Pe];
    FL_tot = [FL_tot; FL];
end

size(Pe_tot)
size(FL_tot)
% obtaining average of interpolated curve
```

```
FL_Avg = zeros(length(TT),1);
for i =1:length(TT)
     FL_Avg(i) = mean(int_data(i,:));
end

hold on
semilogx(TT, FL_Avg, 'ro-', 'Markersize', 7, 'Markerfacecolor', 'r')
xlabel('Exceedance probability')
ylabel('Q (cms)')
title('Sangju Weir FD Curve')
ylim([0 6000])

hold on

% picking up discharges corresponding midpoints of exceedance probability

Pe_indx= [0.0001 0.0006 0.003 0.01 0.0325 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
0.975];

FD=[FD FL_Avg] % add Sangju Weir Flow duration Jan28th2016

for i=4:4 % Just Sangju Weir
Intp(:,i)= interp1(TT, FD(:,i), TT);
    for j=1:length(Pe_indx)
    cor_Q(j,i)=interp1(TT,FD(:,i),Pe_indx(j)); % interpolated discharge
corresponding every point of time exceedance
    end
    semilogx(Pe_indx, cor_Q(:,i), 'o', 'Markerfacecolor','g')
end
hold on

print('Fig_SJweir_inflow_1984_2014_All_FDcurve', '-dmeta', '-r300')

FD_SJweir = FL_Avg; % for Sangju Weir inflow


%% plotting Exceedance Probability vs Q line graph (interpolated data)
% modified on March 9th, 2016 for Paper 1 (Hydraulic Thresholds to Mitigate
% Sedimentation Problem at Sangju Weir, South Korea
%
figure()
ftsz = 14; % for figure
loglog(TT, FD_SJweir)
hold on

% picking up discharges corresponding midpoints of exceedance probability
Pe_indx= [0.0001 0.0006 0.003 0.01 0.0325 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
0.975];

for i=4:4 % Just Sangju Weir
Intp(:,i)= interp1(TT, FD(:,i), TT);
    for j=1:length(Pe_indx)
    cor_Q(j,i)=interp1(TT,FD(:,i),Pe_indx(j)); % interpolated discharge
corresponding every point of time exceedance
```

```
    end
    %semilogx(Pe_indx, cor_Q(:,i), 'o', 'Markerfacecolor','r')
    loglog(Pe_indx, cor_Q(:,i), 'o', 'Markerfacecolor','r')
end

%title('Flow duration conversion')
xlabel('Probability of exceedance (P_E)', 'fontsize', ftsz)
ylabel('Sangju Weir discharge(m^3/s)', 'fontsize', ftsz)
grid on
legend('Flow duration curve ', 'Discharges (m^3/s)', 'location', 'southwest')
% title('SJ Weir FD curve')
set(gca, 'fontsize', ftsz)
print('Fig_Paper01_SJ_FDcurve_inflow_1984_2014_Apr16th2016', '-dmeta', '-
r300')

%% FD/SDR method ==> Long-term sediment yield calculation and making table
for excel (Nov. 12th, 2015)

beg_TI = [0; 0.02e-2;0.1e-2;0.5e-2; 1.5e-2;5e-2;15e-2;25e-2;35e-2;45e-2;55e-
2;65e-2;75e-2;85e-2;95e-2];
end_TI = [0.02e-2;0.1e-2;0.5e-2; 1.5e-2;5e-2;15e-2;25e-2;35e-2;45e-2;55e-
2;65e-2;75e-2;85e-2;95e-2;100e-2];
mid_TI = (end_TI + beg_TI)./2;
del_P = end_TI - beg_TI;

for i=1:3 % 1=NS, 2=YG, 3=ND, 4=SJ Weir
    diground = @(x,d) round(x*10^d)/10^d;
    switch i
        case 1
           Q_NS = cor_Q(:,i);
           Q_NS = round(Q_NS); % added Feb. 25th, 2016
           C_NS = 10.478*Q_NS.^0.4748;% Hyangseok
           C_NS = round(C_NS);

           QdP_NS = Q_NS.*del_P; % product of Q and delta P
           QdP_NS = diground(QdP_NS,1);

           Qp_NS = round(31.56*C_NS.*QdP_NS); %partial sediment load (ENS p.
299-300)
           sum_Qp_NS = sum(Qp_NS)
           per_Qp_NS = diground(Qp_NS/sum_Qp_NS*100,1)
           sum(per_Qp_NS)


           Q_NS(Q_NS == 0)=0.1;
           qpqt_NS = 0.0482*log(Q_NS)+0.619; % correction factor is function
of Q (2/25/16)
           qpqt_NS = diground(qpqt_NS,3);

           Qt_NS = round(Qp_NS./qpqt_NS); % Total Sediment load
           sum_Qt_NS = sum(Qt_NS)
           per_Qt_NS = diground(Qt_NS/sum_Qt_NS*100,1)
           sum(per_Qt_NS)
           %FDSDR_NS = [beg_TI end_TI mid_TI del_P Q_NS C_NS QdP_NS QsdP_NS];
```

```
            FDSDR_NS = [beg_TI end_TI mid_TI del_P Q_NS C_NS QdP_NS Qp_NS
per_Qp_NS qpqt_NS Qt_NS per_Qt_NS];
            %Qs_NS = sum(QsdP_NS);% sum of sediment yield for NS stream

        case 2
            Q_YG = round(cor_Q(:,i));
            C_YG = round(0.3493*Q_YG.^0.9661); % Joemchon
            QdP_YG = diground(Q_YG.*del_P,1);

            Qp_YG = round(31.56*C_YG.*QdP_YG);  % Qs = 31.56 C Q (in cms)
            sum_Qp_YG = sum(Qp_YG);
            per_Qp_YG = diground(Qp_YG/sum_Qp_YG*100,1);
            sum(per_Qp_YG)

            Q_YG(Q_YG == 0)=0.1;
            qpqt_YG = diground(0.0885*log(Q_YG)+0.3638,3); % correction factor
is function of Q (2/25/16)

            Qt_YG = round(Qp_YG./qpqt_YG);
            sum_Qt_YG = sum(Qt_YG)
            per_Qt_YG = diground(Qt_YG/sum_Qt_YG*100,1)
            sum(per_Qt_YG)

            %FDSDR_YG = [beg_TI end_TI mid_TI del_P Q_YG C_YG QdP_YG QsdP_YG];
            FDSDR_YG = [beg_TI end_TI mid_TI del_P Q_YG C_YG QdP_YG Qp_YG
per_Qp_YG qpqt_YG Qt_YG per_Qt_YG];
            %Qs_YG = sum(QsdP_YG);% sum of sediment yield for YG stream

        case 3
            Q_ND = round(cor_Q(:,i));
            C_ND = round(0.0374*Q_ND.^1.1072); % Waegwan
            QdP_ND = diground(Q_ND.*del_P,1);

            Qp_ND = round(31.56*C_ND.*QdP_ND);  % Qs = 31.56 C Q (in cms)
            sum_Qp_ND = sum(Qp_ND);
            per_Qp_ND = diground(Qp_ND/sum_Qp_ND*100,1);
            sum(per_Qp_ND)

            Q_ND(Q_ND == 0)=0.1;
            qpqt_ND = diground(0.0216*log(Q_ND)+0.7956,3);

            Qt_ND = round(Qp_ND./qpqt_ND);
            sum_Qt_ND = sum(Qt_ND)
            per_Qt_ND = diground(Qt_ND/sum_Qt_ND*100,1)
            sum(per_Qt_ND)

            FDSDR_ND = [beg_TI end_TI mid_TI del_P Q_ND C_ND QdP_ND Qp_ND
per_Qp_ND qpqt_ND Qt_ND per_Qt_ND];
            %Qs_ND = sum(QsdP_ND);% sum of sediment yield for ND River
        otherwise
    end

end % for i
```

```
FDSDR_NS
FDSDR_YG
FDSDR_ND
Qs_NS = sum_Qt_NS
Qs_YG = sum_Qt_YG
Qs_ND = sum_Qt_ND

tot_SY = Qs_NS + Qs_YG + Qs_ND % total sediment yield in study area


%% Calculation of trap efficiency

% (1) Water surface Area
% Relationship of water stage (wl) vs. water surface area (WSA)
% Surface area was changed in July 22nd, 2015
% modified on March 9th, 2016 for Paper 1
%
filename = 'Aug07th2015_WS_SurfArea_Volume_v2.xlsx';
%sheet = 'summary_revised';
sheet = 'summary';
[v, T, vT] = xlsread(filename, sheet);

wl = v(:,3); % water stage
wl = wl(1:17);
mea_WSA = v(:,4);% surface area
mea_WSA = mea_WSA(1:17);
wl4vol = v(:,1);
vol = v(:,2); % volume

% Drawing Surface Area and Volume Curve of Sangju Weir
%
figure()
ftsz=12; % for figure
set(gca, 'fontsize', ftsz)% for ax(1)
xlabels{1} = 'Volume (m^3)';
xlabels{2} = 'Surface Area (m^2)';
ylabels{1} = 'Water Stage (EL.m)';
ylabels{2} = 'Water Stage (EL.m)';
[ax,hlT,hlS] = plotxx(vol,wl4vol,mea_WSA,wl,xlabels,ylabels);

set(gca, 'fontsize', ftsz)% for ax(2)

set(ax(1), 'Xlim', [0 27000000])
set(ax(2), 'Xlim', [0 5500000])
set(ax(2), 'Xdir', 'reverse')% Water surface area
set(ax(2), 'Xcolor', [0 0 1])

set(get(ax(1),'xlabel'),'string',xlabels{1}, 'fontsize', ftsz)
set(get(ax(2),'xlabel'),'string',xlabels{2}, 'fontsize', ftsz)
set(get(ax(1),'ylabel'),'string',ylabels{1}, 'fontsize', ftsz)
set(get(ax(2),'ylabel'),'string',ylabels{2}, 'fontsize', ftsz)

set(ax(1),'Position',[0.12 0.15 0.75 0.70])
set(ax(2),'Position',[0.12 0.15 0.75 0.70])
```

```
grid on

picname = 'Fig_paper01_SJ_AVcurve'
print(picname, '-dmeta', '-r300')

% interpolation of WSA
XX = linspace(36,52,1600 ); % by 1cm 37.18 elevation of overflow section,
49.60 Flood Water Level, 52.61 elevation of the bank
WSA = interp1(wl,mea_WSA,XX); %linear interpolation
%figure(), plot(XX, WSA, 'b:')


% (2) Fall velocity (w)

st_ds = [64; 32; 16; 8; 4; 2; 1; 0.5; 0.25; 0.125; 0.0625; 0.031; 0.016;
0.008; 0.004; 0.002; 0.001; 0.0005; 0.00024]; % in milimeter
ds = st_ds.*10^-3; % in meter
nu = 1*10^-6;      % kinematic viscosity at 20 Celcius degree (m^2/s)
G = 2.65;          % Specific weight
g = 9.81;          % Graviatational accelleration (m/s^2)
dstar = ds.*((G-1)*g./nu^2)^(1/3);             % dimensionless grain size
omega = 8*nu*((1+0.0139*dstar.^3).^0.5-1)./ds; % fall velocity (m/s)

% getting Average trap efficiency
FDSDR_NS_ori =FDSDR_NS
FDSDR_YG_ori =FDSDR_YG
FDSDR_ND_ori =FDSDR_ND

% Calculation of average trap efficiency and completion of Longterm
% sediment Yield tables (Nov. 12th, 2015)
for WS= [37.18 47.0]; % Elvation of reservoir level

int_WSA = interp1(wl,mea_WSA,WS,'cubic');

% calculation for three watersheds
for l=1:3 % 1= NS, 2=YG, 3=ND
% discharge Q
watershed = l;
%watershed = input('Enter watershed code, 2=NS, 3=YG, 4=ND:');
discharge = cor_Q(:,watershed);

DDS = linspace(0.00024,0.002,10^4);   % for trap efficiency
DDS3 = linspace(0.0020001,0.004,10^4);
DDS7 = linspace(0.0040001,0.016,10^4);
DDS8 = linspace(0.0160001,0.0625,10^4);
DDS9 = linspace(0.06250001,64,10^4);
DDS=[DDS DDS3 DDS7 DDS8 DDS9]

DDS1 = linspace(0.0625,32,10^3);      % for bed material

DDS2 = linspace(0.00024,0.002,10^3);    % for suspended load
DDS4 = linspace(0.002001,0.016,10^3);    % for suspended load
DDS5 = linspace(0.016001,0.5,10^3);    % for suspended load
DDS6 = linspace(0.500001,0.8,10^3);    % for suspended load
```

```
DDS2=[DDS2 DDS4 DDS5 DDS6]

% Trap efficiency calculation
int_TE = []
for i=1:length(discharge)
TE(:,i) = 1-exp(-omega.*int_WSA./discharge(i));
int_TE(:,i) = interp1(st_ds,TE(:,i),DDS,'cubic'); % interpolation of cubic
spline for plot
%y05(:,i) = interp1(int_TE(:,i),DDS,0.05,'cubic') % find x-axis value at y =
0.05
end

figure ()
%semilogx(st_ds, TE, 'o'); hold on
semilogx(DDS, int_TE,'b'); hold on % plot for interpolated trap efficiency
curves
%semilogx(st_ds, TE, 'o', DDS, int_TE,'g',y05,0.05,'s', 'linewidth', .5)
hold on

% classification of particle size material
clssfy = {'SC'; 'VCG'; 'CG'; 'MG'; 'FG'; 'VFG'; 'VCS'; 'CS'; 'MS'; 'FS';
'VFS'; 'CM'; 'MM'; 'FM'; 'VFM'; 'CC'; 'MC'; 'FC'; 'VFC'}; % must use {  } for
string matrix

% plot y-grid
yGrid = 0.1:0.1:0.9;
for i =1:length(yGrid)
    switch i
         case 1
          plot([0.00024,4], [yGrid(i),yGrid(i)], 'k:','linewidth',0.5);
         case 2
          plot([0.00024,4], [yGrid(i),yGrid(i)], 'k:','linewidth',0.5);
         case 3
          plot([0.00024,4], [yGrid(i),yGrid(i)], 'k:','linewidth',0.5);
         case 4
          plot([0.00024,4], [yGrid(i),yGrid(i)], 'k:','linewidth',0.5);
         case 5
          plot([0.00024,4], [yGrid(i),yGrid(i)], 'k:','linewidth',0.5);
        otherwise
          plot([0.00024,64], [yGrid(i),yGrid(i)], 'k:','linewidth',0.5);
    end
end

for i=1:length(st_ds)

    % plot grain size line
    switch st_ds(i)
        case 8
            plot([st_ds(i),st_ds(i)], [0.6,1], 'k:','linewidth',0.5);% grain
size indication line
        case 16
            plot([st_ds(i),st_ds(i)], [0.6,1], 'k:','linewidth',0.5);% grain
size indication line
        case 32
            plot([st_ds(i),st_ds(i)], [0.6,1], 'k:','linewidth',0.5);% grain
size indication line
```

```
        otherwise
            plot([st_ds(i),st_ds(i)], [0,1], 'k:','linewidth',0.5);% grain
size indication line
    end


ftsize = 12;

text(st_ds(i),1+0.02, num2str(st_ds(i)),'fontsize', ftsize,
'horizontalalignment', 'center','Edgecolor', 'none', 'linewidth', 1,
'margin', 0.5,'backgroundcolor', 'none');
text(st_ds(i),1+0.04, strcat('|\rightarrow ', clssfy(i)),'fontsize',
ftsize,'horizontalalignment', 'left','Edgecolor', 'none', 'linewidth',
1,'margin', 0.5,'backgroundcolor', 'none');

    switch st_ds(i)
        case 64
        text(st_ds(i),1+0.060, strcat('|\rightarrow ', 'Cobble'),'fontsize',
ftsize,'horizontalalignment', 'left','Edgecolor', 'none', 'linewidth',
1,'margin', 0.5,'backgroundcolor', 'none');
        case 2
        text(st_ds(i),1+0.060, strcat('|\rightarrow ', 'Gravel'),'fontsize',
ftsize,'horizontalalignment', 'left','Edgecolor', 'none', 'linewidth',
1,'margin', 0.5,'backgroundcolor', 'none');
        case 0.0625
        text(st_ds(i),1+0.060, strcat('|\rightarrow ', 'Sand'),'fontsize',
ftsize,'horizontalalignment', 'left','Edgecolor', 'none', 'linewidth',
1,'margin', 0.5,'backgroundcolor', 'none');
        case 0.004
        text(st_ds(i),1+0.060, strcat('|\rightarrow ', 'Silt'),'fontsize',
ftsize,'horizontalalignment', 'left','Edgecolor', 'none', 'linewidth',
1,'margin', 0.5,'backgroundcolor', 'none');
        case 0.00024
        text(st_ds(i),1+0.060, strcat('|\rightarrow ', 'Clay'),'fontsize',
ftsize,'horizontalalignment', 'left','Edgecolor', 'none', 'linewidth',
1,'margin', 0.5,'backgroundcolor', 'none');
        otherwise
    end
end

set (gca, 'Fontsize', 12)
set (gca, 'Gridlinestyle');
set(gca, 'XGrid', 'off', 'YGrid', 'off');


ttitle = '';
xtitle = 'Grain size (ds, mm)';
ytitle = 'Trap efficiency, TE';
%ylim([0 1]);
xlim([0.00024 64]);
title(ttitle);
xlabel(xtitle, 'Fontsize', ftsize);
ylabel(ytitle, 'Fontsize', ftsize);

hold on
```

```
%% bed material distribution

%k = input('Enter code for bed-material 2=NS, 3=YG, 4=ND:');
k= 1; % k=1= Naesung stream

switch k
    case 1
        filename_bed = 'bed_NS_2013.xlsx';
        filename_sus = 'sus_HS_2012.xlsx';
        filename_export = ['EL' num2str(WS) 'm_FDSDR_1NS.xlsx']; % consider
Water Stage
        picname_export = ['EL' num2str(WS) 'm_FDSDR_1NS' ]; % consider Water
Stage
        bname = 'NS Stream';
    case 2
        filename_bed = 'bed_JC_2013.xlsx';
        filename_sus = 'sus_JC_2013.xlsx';
        filename_export = ['EL' num2str(WS) 'm_FDSDR_2YG.xlsx'];
        picname_export = ['EL' num2str(WS) 'm_FDSDR_2YG' ]; % consider Water
Stage
        bname = 'YG Stream';
    case 3
        filename_bed = 'bed_WG_2013.xlsx';
        filename_sus = 'sus_WG_2013.xlsx';
        filename_export = ['EL' num2str(WS) 'm_FDSDR_3ND.xlsx'];
        picname_export = ['EL' num2str(WS) 'm_FDSDR_3ND']; % consider Water
Stage
        bname = 'ND River';
    otherwise
end

sheet = 'tot'
[v, T, vT] =xlsread(filename_bed, sheet)
ds = dataset({v,T{:}})
%semilogx(ds.ds_mm,ds(:,2:length(v)-1),'k-');
hold on;
semilogx(ds.ds_mm,ds.Avg, 'ko','linewidth',0.5)

ibed = interp1(ds.ds_mm,ds.Avg,DDS1,'cubic');   % interpolation with cubic
spline interpolation
semilogx(DDS1, ibed, 'k:', 'linewidth', 2)             % plot for
interpolated data
hold on


%% suspended load distribution

%filename_sus = 'sus_HS_2012.xlsx';
sheet = 'tot'
[v, T, vT] =xlsread(filename_sus, sheet)
ds = dataset({v,T{:}})
%semilogx(ds.ds_mm,ds(:,2:length(v)-1),'g-');
hold on;
ylim([0 1])
%semilogx(ds.ds_mm,ds.Avg, 'r-', 'linewidth',3)
```

```
hold on

semilogx(ds.ds_mm, ds.Avg, 'o') % measured data points
hold on

iNS = interp1(ds.ds_mm,ds.Avg,DDS2,'cubic'); % interpolation with cubic
spline interpolation
semilogx(DDS2, iNS, 'r:', 'linewidth', 2) % plot for interpolated data
hold on


% Calculation of average trap efficiency

frac = 0.05:0.1:0.95; % fractions to calculate average TE

% Obtaining x-value corresponding y= fractions stand for 10% like 0.05,
0.15 ... 0.95
[A1,index] = sort(iNS);
A2 = iNS(index);
uniq = [true, diff(A1) ~= 0];
x05 = interp1(iNS(uniq), DDS2(uniq), frac,'cubic'); % finding x-value using
interpolated suspended load distribution when frac = 0.05, 0.15...0.95

semilogx(x05,frac,'k*', 'linewidth', 1)             % selected data points
hold on

% Obtaining y-value (TE) corresponding 'x' of suspended load distribution
according to various discharges
y_Q = interp1(DDS, int_TE, x05, 'cubic');
semilogx(x05, y_Q(:,1), 'rs' )
hold on

% Ploting auxilary lines
for i = 1:10
%plot([0.00024, x05(i)], [frac(i),frac(i)], 'k-', 'linewidth', 0.5);
plot([x05(i), x05(i)], [frac(i),y_Q(i,1)], 'g-', 'linewidth', 0.5);
plot([0.00024, x05(i)], [y_Q(i,1),y_Q(i,1)], 'g-', 'linewidth', 0.5);
end

mean(y_Q)
% Average of trap efficiency
switch l
    case 1 % Naesung
    avgTE_NS = (mean(y_Q))';
    case 2
    avgTE_YG = (mean(y_Q))';
    case 3
    avgTE_ND = (mean(y_Q))';
    otherwise
end

% Adding legend
ypos = 0.60;
%text(9,ypos, 'LEGEND', 'fontsize', ftsize+1)
plot([5 10], [ypos-0.03 ypos-0.03], 'k:', 'linewidth', 2);
```

```
text(11,ypos-0.03, 'Bed material distribution', 'fontsize', ftsize)
plot([5 10], [ypos-0.06 ypos-0.06], 'r:', 'linewidth', 2);
text(11,ypos-0.06, 'Suspended load distribution', 'fontsize', ftsize)
plot([5 10], [ypos-0.09 ypos-0.09], 'b-', 'linewidth', 2);
text(11,ypos-0.09, 'Trap efficiency curves', 'fontsize', ftsize)
plot(7.5, ypos-0.12, 'bo');
text(11,ypos-0.12, 'Field measurement data', 'fontsize', ftsize)
plot(7.5, ypos-0.15, 'k*');
text(11,ypos-0.15, '10% increment points', 'fontsize', ftsize)
plot(7.5, ypos-0.18, 'rs');
text(11,ypos-0.18, 'TE corresponding increment', 'fontsize', ftsize)
plot([5 10], [ypos-0.21 ypos-0.21], 'g-', 'linewidth', 1);
text(11,ypos-0.21, 'Auxiliary line', 'fontsize', ftsize)

% denoting averaged trap efficiency according to discharges on the plot
pictitle = ['Averaged TE for ' bname ' (EL.' num2str(WS) 'm)']
text(5,0.35, pictitle, 'fontsize', ftsize+1)
txt_pos = 0.32:-0.02:0.01;        % y-points to note
% inline function
diground = @(x,d) round(x*10^d)/10^d;
round_dis = diground(discharge,1);
%round_dis = round(discharge);     % round of discharge

switch l
        case 1
        round_avgTE = diground(avgTE_NS.*100,1);  % round of trap efficiency
        case 2
        round_avgTE = diground(avgTE_YG.*100,1);  % round of trap efficiency
        case 3
        round_avgTE = diground(avgTE_ND.*100,1);  % round of trap efficiency
        otherwise
end

    for i = 1:length(discharge)       % plotting on figure
    str = ['TE = ',num2str(round_avgTE(i)),'%, Q=',num2str(round_dis(i)), '
m^3/s'];
    text(7.5,txt_pos(i),str,'HorizontalAlignment','left',  'fontsize',  ftsize);
    end

% Jongseok helped me this part
set(gcf, 'units', 'inches', 'position', [0.5 0.0 18 11]) % 0.5, 0.5 is low-
left point of screen, 15 is length, 10 is hight from origin point
set(gca, 'LooseInset', [0.05 0.1 0.05 0.07]) % Left/ Bottom / Right / Top
hold off
print(picname_export, '-dmeta', '-r1200')




%% Arranging FDSDR table adding Average trap efficiency

 switch l
     case 1
            Deposit_NS = round(FDSDR_NS_ori(:,11).*diground(avgTE_NS,3)); %
estimation of deposit in Sangju Weir
```

```
            per_Deposit_NS = diground(Deposit_NS./sum(Deposit_NS)*100,1)
            sum(per_Deposit_NS)

            FDSDR_NS = [FDSDR_NS_ori diground(avgTE_NS,3) Deposit_NS
per_Deposit_NS] % renewal of FDSDR table
            header = {'NS_ini_TI', 'end_TI', 'mid_TI', 'dP', 'Q', 'Cm', 'QdP',
'Qp', 'per_Qp', 'qpqt_ratio', 'Qt', 'per_Qt', 'avgTE', 'Deposit',
'per_Deposit'}
            ds = dataset({FDSDR_NS,header{:}})
            filename_export = [filename_export(1:18) '_' num2str(20160225)
'.xlsx']
            export(ds,'XLSfile',filename_export);
       case 2
            Deposit_YG = round(FDSDR_YG_ori(:,11).*diground(avgTE_YG,3)); %
estimation of deposit in Sangju Weir
            per_Deposit_YG = diground(Deposit_YG./sum(Deposit_YG)*100,1)
            sum(per_Deposit_YG)

            FDSDR_YG = [FDSDR_YG_ori diground(avgTE_YG,3) Deposit_YG
per_Deposit_YG] % renewal of FDSDR table
            header = {'YG_ini_TI', 'end_TI', 'mid_TI', 'dP', 'Q', 'Cm', 'QdP',
'Qp', 'per_Qp', 'qpqt_ratio', 'Qt', 'per_Qt', 'avgTE', 'Deposit',
'per_Deposit'}
            ds = dataset({FDSDR_YG,header{:}})
            filename_export = [filename_export(1:18) '_' num2str(20160225)
'.xlsx']
            export(ds,'XLSfile',filename_export);
       case 3
            Deposit_ND = round(FDSDR_ND_ori(:,11).*diground(avgTE_ND,3)); %
estimation of deposit in Sangju Weir
            per_Deposit_ND = diground(Deposit_ND./sum(Deposit_ND)*100,1)
            sum(per_Deposit_ND)

            FDSDR_ND = [FDSDR_ND_ori diground(avgTE_ND,3) Deposit_ND
per_Deposit_ND] % renewal of FDSDR table
            header = {'ND_ini_TI', 'end_TI', 'mid_TI', 'dP', 'Q', 'Cm', 'QdP',
'Qp', 'per_Qp', 'qpqt_ratio', 'Qt', 'per_Qt', 'avgTE', 'Deposit',
'per_Deposit'}
            ds = dataset({FDSDR_ND,header{:}})
            filename_export = [filename_export(1:18) '_' num2str(20160225)
'.xlsx']
            export(ds,'XLSfile',filename_export);
        otherwise

 end


end % for l

% Longterm Sediment Yield Result Summary
% Feb. 28th, 2016
WS
sum_Qp_NS
sum_Qt_NS
avg_qpqt_NS = diground(sum_Qp_NS/sum_Qt_NS,3)
```

```
sum_Deposit_NS = sum(Deposit_NS)
avg_TE_NS = diground(sum_Deposit_NS/sum_Qt_NS,3)
sum_Deposit_vol_NS = round(sum_Deposit_NS/1.6)
LT_summary_NS = [WS 1 sum_Qp_NS avg_qpqt_NS sum_Qt_NS avg_TE_NS
sum_Deposit_NS sum_Deposit_vol_NS 0]

sum_Qp_YG
sum_Qt_YG
avg_qpqt_YG = diground(sum_Qp_YG/sum_Qt_YG,3)
sum_Deposit_YG = sum(Deposit_YG)
avg_TE_YG = diground(sum_Deposit_YG/sum_Qt_YG,3)
sum_Deposit_vol_YG = round(sum_Deposit_YG/1.6)
LT_summary_YG = [WS 2 sum_Qp_YG avg_qpqt_YG sum_Qt_YG avg_TE_YG
sum_Deposit_YG sum_Deposit_vol_YG 0]

sum_Qp_ND
sum_Qt_ND
avg_qpqt_ND = diground(sum_Qp_ND/sum_Qt_ND,3)
sum_Deposit_ND = sum(Deposit_ND)
avg_TE_ND = diground(sum_Deposit_ND/sum_Qt_ND,3)
sum_Deposit_vol_ND = round(sum_Deposit_ND/1.6)
LT_summary_ND = [WS 3 sum_Qp_ND avg_qpqt_ND sum_Qt_ND avg_TE_ND
sum_Deposit_ND sum_Deposit_vol_ND 0]

switch WS
    case 37.18
        LT_summary_37=[LT_summary_NS; LT_summary_YG; LT_summary_ND]

        sum_LT_summary_37= sum(LT_summary_37)
        tot_Qp = sum_LT_summary_37(3)
        tot_Qt = sum_LT_summary_37(5)
        tot_qpqt = diground(tot_Qp/tot_Qt,3)
        tot_Dep = sum_LT_summary_37(7)
        tot_Dep_vol = sum_LT_summary_37(8)
        tot_TE = diground(tot_Dep/tot_Qt,3)
        ResfillRate = diground(tot_Dep_vol/27400000*100,2)
        TOT_summary_37 = [0 0 tot_Qp tot_qpqt tot_Qt tot_TE tot_Dep
tot_Dep_vol ResfillRate]

        F_table = [LT_summary_37;TOT_summary_37]

        header = {'WS', 'Basin', 'Qp', 'SEMEPP_factor', 'Qt', 'TE',
'Dep_tons', 'Dep_vol', 'ResFilRate'}
        ds = dataset({F_table,header{:}})
        filename_export = ['LongTerm_SY_summary_El' num2str(WS) 'm_'
num2str(20160225) '.xlsx']
        export(ds,'XLSfile',filename_export);

    case 47
        LT_summary_47=[LT_summary_NS; LT_summary_YG; LT_summary_ND]

        sum_LT_summary_47= sum(LT_summary_47)
        tot_Qp = sum_LT_summary_47(3)
        tot_Qt = sum_LT_summary_47(5)
        tot_qpqt = diground(tot_Qp/tot_Qt,3)
```

```
        tot_Dep = sum_LT_summary_47(7)
        tot_Dep_vol = sum_LT_summary_47(8)
        tot_TE = diground(tot_Dep/tot_Qt,3)
        ResfillRate = diground(tot_Dep_vol/27400000*100,2)
        TOT_summary_47 = [0 0 tot_Qp tot_qpqt tot_Qt tot_TE tot_Dep
tot_Dep_vol ResfillRate]

        F_table = [LT_summary_47;TOT_summary_47]

        header = {'WS', 'Basin', 'Qp', 'SEMEPP_factor', 'Qt', 'TE',
'Dep_tons', 'Dep_vol', 'ResFilRate'}
        ds = dataset({F_table,header{:}})
        filename_export = ['LongTerm_SY_summary_El' num2str(WS) 'm_'
num2str(20160225) '.xlsx']
        export(ds,'XLSfile',filename_export);
    otherwise

end




end % for WS




%% Daily Sediment modeling

datevec(t_final(:,1)); % for 22years modeling (2013-2034)
size(t_final);

% select inflows during 2013-2034 (22yrs)
id = find(dnum_1985_2034>=datenum('1/1/2013', 'mm/dd/yyyy'));
%size(id)
Q_ns=Qns_wholeperiod(id);
size(Qns_wholeperiod)
size(Q_ns)
figure(), plot(dnum_1985_2034, Qns_wholeperiod)
figure(), plot(dnum_2013_2034, Q_ns)

Q_yg=Qyg_wholeperiod(id);
Q_nd=Qnd_wholeperiod(id);

figure(), plot(dnum_2013_2034, Q_yg)
figure(), plot(dnum_2013_2034, Q_nd)

size(Q_nd);

% making empty array for writing average TE
avgTE_ns = zeros(length(new_wsup),1);
avgTE_yg = zeros(length(new_wsup),1);
avgTE_nd = zeros(length(new_wsup),1);
```

```
for l= 1:3

         switch l
            case 1
                filename_bed = 'bed_NS_2013.xlsx';
                filename_sus = 'sus_HS_2012.xlsx';
                filename_export = ['EL' num2str(WS) 'm_FDSDR_1NS.xlsx']; %
consider Water Stage
                picname_export = ['EL' num2str(WS) 'm_FDSDR_1NS' ]; %
consider Water Stage
                bname = 'NS Stream';
                Q4TEcalc = Q_ns;
            case 2
                filename_bed = 'bed_JC_2013.xlsx';
                filename_sus = 'sus_JC_2013.xlsx';
                filename_export = ['EL' num2str(WS) 'm_FDSDR_2YG.xlsx'];
                picname_export = ['EL' num2str(WS) 'm_FDSDR_2YG' ]; %
consider Water Stage
                bname = 'YG Stream';
                Q4TEcalc = Q_yg;
            case 3
                filename_bed = 'bed_WG_2013.xlsx';
                filename_sus = 'sus_WG_2013.xlsx';
                filename_export = ['EL' num2str(WS) 'm_FDSDR_3ND.xlsx'];
                picname_export = ['EL' num2str(WS) 'm_FDSDR_3ND']; % consider
Water Stage
                bname = 'ND River';
                Q4TEcalc = Q_nd;
             otherwise
         end

        %% load bedmaterial data
        sheet = 'tot';
        [v, T, vT] =xlsread(filename_bed, sheet);
        ds = dataset({v,T{:}});

% % % %         hold on;
% % % %         semilogx(ds(:,1),ds(:,length(ds)), 'ko','linewidth',0.5)

        %ibed = interp1(v(:,1),v(:,length(ds)),DDS1,'cubic');   %
interpolation with cubic spline interpolation
        ibed = interp1(ds.ds_mm,ds.Avg,DDS1,'cubic');   % interpolation with
cubic spline interpolation
% % % %         semilogx(DDS1, ibed, 'k:', 'linewidth', 2)             % plot
for interpolated data
% % % %         hold on


        %% load suspended load distribution

        sheet = 'tot';
        [v, T, vT] =xlsread(filename_sus, sheet);
        ds = dataset({v,T{:}});

% % % %         hold on;
```

```
% % % %         ylim([0 1])
% % % %
% % % %         hold on
% % % %
% % % %         semilogx(ds.ds_mm, ds.Avg, 'o') % measured data points
% % % %         hold on

        iNS = interp1(ds.ds_mm,ds.Avg,DDS2,'cubic'); % interpolation with
cubic spline interpolation

% % % %         figure(), semilogx(DDS2, iNS, 'r:', 'linewidth', 2) % plot
for interpolated data
% % % %         hold on


        %% Calculation of average trap efficiency
        %

        for m=1:length(new_wsup)

            m

            WS = new_wsup(m); % from operational data 'wsup'
            int_WSA = interp1(wl,mea_WSA,WS,'cubic');

            discharge = Q4TEcalc(m);

            DDS;% for trap efficiency
            DDS1;% for bed material
            DDS2;% for suspended load

            % Trap efficiency calculation
            TE = 1-exp(-omega.*int_WSA./discharge);
            int_TE = interp1(st_ds,TE,DDS,'cubic'); % interpolation of cubic
spline for plot

            frac = 0.05:0.1:0.95; % fractions to calculate average TE

            % Obtaining x-value corresponding y= fractions stand for 10% like
0.05, 0.15 ... 0.95
            [A1,index] = sort(iNS); % interpolated suspend load data and
ascending order
            %kkk = (linspace(10,-10,20))'
            %[A1, id]=sort(kkk)
            %A2 = kkk(id)

            A2 = iNS(index); % A2 is sorted matrix
            uniq = [true, diff(A1) ~= 0];
            %figure(), plot(diff(A1))
            x05 = interp1(iNS(uniq), DDS2(uniq), frac,'cubic'); % finding x-
value using interpolated suspended load distribution when frac = 0.05,
0.15...0.95
```

```
% % % %         semilogx(x05,frac,'k*', 'linewidth', 1)             %
selected data points
% % % %         hold on
                %semilogx(DDS, int_TE, 'b-')
            % Obtaining y-value (TE) corresponding 'x' of suspended load
distribution according to various discharges
            y_Q = interp1(DDS, int_TE, x05, 'cubic');

% % % %         semilogx(x05, y_Q, 'ks' )
% % % %         hold on

% % % %         % Ploting auxilary lines
% % % %         for i = 1:10
% % % %         plot([x05(i), x05(i)], [frac(i),y_Q(i)], 'g:', 'linewidth',
0.5);
% % % %         plot([0.00024, x05(i)], [y_Q(i),y_Q(i)], 'g:', 'linewidth',
0.5);
% % % %         end

            % Average of trap efficiency
            switch l
                case 1
                avgTE_NS = mean(y_Q);
                %sum(y_Q)/10
                avgTE_ns(m) = avgTE_NS;
                case 2
                avgTE_YG = mean(y_Q);
                avgTE_yg(m) = avgTE_YG;
                case 3
                avgTE_ND = mean(y_Q);
                avgTE_nd(m) = avgTE_ND;
                otherwise
            end

        end % for m


 end % for l

figure(), subplot(3,1,1), plot(avgTE_ns), subplot(3,1,2), plot(avgTE_yg),
subplot(3,1,3), plot(avgTE_nd)
max(avgTE_ns)

%% drawing sample figure

switch CASE_NO

    case 1

            %Q4fig=[1 10 100 1000]'
            %WS4fig=[37.18 41 45 47]'

            Q4fig=[30 300 3000]'
            WS4fig=[37.18 47]'
```

```
             for m = 1:length(Q4fig)

            m

            for k = 1:length(WS4fig)

                WS = WS4fig(k); % from operational data 'wsup'

            int_WSA = interp1(wl,mea_WSA,WS,'cubic');

            % % To consider Q control in CASE 5 (Qin--> Qout), Aug23rd2015
revised
            % Q_ns(m);
            % Q_yg(m);
            % Q_nd(m);

            % calculation for three watersheds
            for l=1:3 % 1= NS, 2=YG, 3=ND

            switch l
                case 1
                discharge = Q4fig(m);
                case 2
                discharge = Q4fig(m);
                case 3
                discharge = Q4fig(m);
                otherwise
            end

            DDS;% for trap efficiency
            DDS1;% for bed material
            DDS2;% for suspended load

            % Trap efficiency calculation
            for i=1:length(discharge)
            TE = 1-exp(-omega.*int_WSA./discharge);
            int_TE = interp1(st_ds,TE,DDS,'cubic'); % interpolation of cubic
spline for plot
            end

                    % figures will not show because 'Visible' 'off' option
                    %
                    figure()
                    semilogx(st_ds, TE, 'o'); hold on
                    semilogx(DDS, int_TE,'b'); hold on

                    % classification of particle size material
                    clssfy = {'SC'; 'VCG'; 'CG'; 'MG'; 'FG'; 'VFG'; 'VCS';
'CS'; 'MS'; 'FS'; 'VFS'; 'CM'; 'MM'; 'FM'; 'VFM'; 'CC'; 'MC'; 'FC'; 'VFC'}; %
must use {  } for string matrix

                    % plot y-grid
                    yGrid = 0.1:0.1:0.9;
                    for i =1:length(yGrid)
```

```
                    switch i
                         case 1
                          plot([0.00024,4], [yGrid(i),yGrid(i)],
'k:','linewidth',0.5);
                         case 2
                          plot([0.00024,4], [yGrid(i),yGrid(i)],
'k:','linewidth',0.5);
                         case 3
                          plot([0.00024,4], [yGrid(i),yGrid(i)],
'k:','linewidth',0.5);
                         case 4
                          plot([0.00024,4], [yGrid(i),yGrid(i)],
'k:','linewidth',0.5);
                         case 5
                          plot([0.00024,4], [yGrid(i),yGrid(i)],
'k:','linewidth',0.5);
                        otherwise
                          plot([0.00024,64], [yGrid(i),yGrid(i)],
'k:','linewidth',0.5);
                    end
                end

                for i=1:length(st_ds)

                    % plot grain size line
                    switch st_ds(i)
                        case 8
                            plot([st_ds(i),st_ds(i)], [0.6,1],
'k:','linewidth',0.5);% grain size indication line
                        case 16
                            plot([st_ds(i),st_ds(i)], [0.6,1],
'k:','linewidth',0.5);% grain size indication line
                        case 32
                            plot([st_ds(i),st_ds(i)], [0.6,1],
'k:','linewidth',0.5);% grain size indication line
                        otherwise
                            plot([st_ds(i),st_ds(i)], [0,1],
'k:','linewidth',0.5);% grain size indication line
                    end


                ftsize = 11;

                text(st_ds(i),-0.06, num2str(st_ds(i)),'fontsize', ftsize,
'horizontalalignment', 'center','Edgecolor', 'none', 'linewidth', 1,
'margin', 0.5,'backgroundcolor', 'none');
                text(st_ds(i),-0.08, strcat('|\rightarrow ',
clssfy(i)),'fontsize', ftsize,'horizontalalignment', 'left','Edgecolor',
'none', 'linewidth', 1,'margin', 0.5,'backgroundcolor', 'none');

                    switch st_ds(i)
                        case 64
                        text(st_ds(i),-0.10, strcat('|\rightarrow ',
'Cobble'),'fontsize', ftsize,'horizontalalignment', 'left','Edgecolor',
'none', 'linewidth', 1,'margin', 0.5,'backgroundcolor', 'none');
                        case 0.0625
```

```
                            text(st_ds(i),-0.10, strcat('|\rightarrow ',
'Sand'),'fontsize', ftsize,'horizontalalignment', 'left','Edgecolor', 'none',
'linewidth', 1,'margin', 0.5,'backgroundcolor', 'none');
                            case 0.004
                            text(st_ds(i),-0.10, strcat('|\rightarrow ',
'Silt'),'fontsize', ftsize,'horizontalalignment', 'left','Edgecolor', 'none',
'linewidth', 1,'margin', 0.5,'backgroundcolor', 'none');
                            case 0.00024
                            text(st_ds(i),-0.10, strcat('|\rightarrow ',
'Clay'),'fontsize', ftsize,'horizontalalignment', 'left','Edgecolor', 'none',
'linewidth', 1,'margin', 0.5,'backgroundcolor', 'none');
                            otherwise
                        end
                    end


                    set (gca, 'Gridlinestyle');
                    set(gca, 'XGrid', 'off', 'YGrid', 'off');


                    ttitle = '';
                    xtitle = 'Ds (mm)';
                    ytitle = 'Trap efficiency (T_E)';
                    xlim([0.00024 64]);
                    title(ttitle);
                    ylabel(ytitle, 'Fontsize', 15);
                    xlabel('Grain size (mm)', 'Fontsize', 15)

                    hold on

                    %% bed material distribution

                    k= l; % k=l= Naesung stream

                    switch k
                        case 1
                            filename_bed = 'bed_NS_2013.xlsx';
                            filename_sus = 'sus_HS_2012.xlsx';
                            filename_export = ['EL' num2str(WS)
'm_FDSDR_1NS.xlsx']; % consider Water Stage
                            picname_export = ['EL' num2str(WS)
'm_FDSDR_1NS' ]; % consider Water Stage
                            bname = 'NS Stream';
                        case 2
                            filename_bed = 'bed_JC_2013.xlsx';
                            filename_sus = 'sus_JC_2013.xlsx';
                            filename_export = ['EL' num2str(WS)
'm_FDSDR_2YG.xlsx'];
                            picname_export = ['EL' num2str(WS)
'm_FDSDR_2YG' ]; % consider Water Stage
                            bname = 'YG Stream';
                        case 3
                            filename_bed = 'bed_WG_2013.xlsx';
                            filename_sus = 'sus_WG_2013.xlsx';
```

```
                            filename_export = ['EL' num2str(WS)
'm_FDSDR_3ND.xlsx'];
                            picname_export = ['EL' num2str(WS)
'm_FDSDR_3ND']; % consider Water Stage
                            bname = 'ND River';
                        otherwise
                    end

                    sheet = 'tot';
                    [v, T, vT] =xlsread(filename_bed, sheet);
                    ds = dataset({v,T{:}});

                    hold on;
                    %semilogx(ds(:,1),ds(:,length(ds)), 'ko','linewidth',0.5)
                    semilogx(ds.ds_mm,ds.Avg, 'ko','linewidth',0.5)

                    ibed = interp1(ds.ds_mm,ds.Avg,DDS1,'cubic');    %
interpolation with cubic spline interpolation
                    semilogx(DDS1, ibed, 'k:', 'linewidth', 2)             %
plot for interpolated data
                    hold on


                    %% suspended load distribution

                    sheet = 'tot';
                    [v, T, vT] =xlsread(filename_sus, sheet);
                    ds = dataset({v,T{:}});

                    hold on;
                    ylim([0 1])

                    semilogx(ds.ds_mm, ds.Avg, 'ro') % measured data points
                    hold on

                    iNS = interp1(ds.ds_mm,ds.Avg,DDS2,'cubic'); %
interpolation with cubic spline interpolation

                    semilogx(DDS2, iNS, 'r:', 'linewidth', 2) % plot for
interpolated data
                    hold on

                    %% -------------------------------------------------------
--------------------------------
                    % Calculation of average trap efficiency
                    %
                    frac = 0.05:0.1:0.95; % fractions to calculate average TE

                    % Obtaining x-value corresponding y= fractions stand for
10% like 0.05, 0.15 ... 0.95
                    [A1,index] = sort(iNS);
                    A2 = iNS(index);
                    uniq = [true, diff(A1) ~= 0];
```

```
                    x05 = interp1(iNS(uniq), DDS2(uniq), frac,'cubic'); %
finding x-value using interpolated suspended load distribution when frac =
0.05, 0.15...0.95

                    semilogx(x05,frac,'k*', 'linewidth', 1)             %
selected data points
                    hold on

                    % Obtaining y-value (TE) corresponding 'x' of suspended
load distribution according to various discharges
                    y_Q = interp1(DDS, int_TE, x05, 'cubic');

                    semilogx(x05, y_Q, 'ks' )
                    hold on

                    % Ploting auxilary lines
                    for i = 1:10
                    plot([x05(i), x05(i)], [frac(i),y_Q(i)], 'g:',
'linewidth', 0.5);
                    plot([0.00024, x05(i)], [y_Q(i),y_Q(i)], 'g:',
'linewidth', 0.5);
                    end

                    % Average of trap efficiency
                    switch l
                        case 1 % Naesung
                        avgTE_NS = mean(y_Q);
                        avgTE_ns_4fig(m) = avgTE_NS;
                        case 2
                        avgTE_YG = mean(y_Q);
                        avgTE_yg_4fig(m) = avgTE_YG;
                        case 3
                        avgTE_ND = mean(y_Q);
                        avgTE_nd_4fig(m) = avgTE_ND;
                        otherwise
                    end

                    % Adding legend
                    ypos = 0.60;
                    %text(9,ypos, 'LEGEND', 'fontsize', ftsize+1)
                    plot([5 10], [ypos-0.03 ypos-0.03], 'k:', 'linewidth', 2);
                    text(11,ypos-0.03, 'Bed material distribution',
'fontsize', ftsize)
                    plot([5 10], [ypos-0.06 ypos-0.06], 'r:', 'linewidth', 2);
                    text(11,ypos-0.06, 'Suspended load distribution',
'fontsize', ftsize)
                    plot([5 10], [ypos-0.09 ypos-0.09], 'b-', 'linewidth', 2);
                    text(11,ypos-0.09, 'Trap efficiency curves', 'fontsize',
ftsize)
                    plot(7.5, ypos-0.12, 'bo');
                    text(11,ypos-0.12, 'Field measurement data', 'fontsize',
ftsize)
                    plot(7.5, ypos-0.15, 'k*');
                    text(11,ypos-0.15, '10% increment points', 'fontsize',
ftsize)
                    plot(7.5, ypos-0.18, 'ks');
```

```
                    text(11,ypos-0.18, 'TE corresponding increment',
'fontsize', ftsize)
                    plot([5 10], [ypos-0.21 ypos-0.21], 'g-', 'linewidth', 1);
                    text(11,ypos-0.21, 'Auxiliary line', 'fontsize', ftsize)

                    % denoting averaged trap efficiency according to
discharges on the plot
                    pictitle = [bname ' (EL.' num2str(WS) 'm and Q= '
num2str(Q4fig(m)) 'm^3/s)']
                    text(5,0.35, pictitle, 'fontsize', ftsize+1)
                    txt_pos = 0.32:-0.02:0.01;        % y-points to note

                    round_dis = diground(discharge,1);     % round of
discharge

                    switch l
                            case 1
                            round_avgTE = diground(avgTE_NS.*100,1);  % round
of trap efficiency
                            case 2
                            round_avgTE = diground(avgTE_YG.*100,1);  % round
of trap efficiency
                            case 3
                            round_avgTE = diground(avgTE_ND.*100,1);  % round
of trap efficiency
                            otherwise
                    end

                        for i = 1:length(y_Q)       % plotting on figure
                        str = ['cor. TE =
',num2str(diground(y_Q(i)*100,1)),'%, Int.
Mid.=',num2str(diground((frac(i))*100,1)), ' %'];
                        text(7.5,txt_pos(i),str,'HorizontalAlignment','left',
'fontsize', ftsize);
                        end

                        str = ['Average TE = ',num2str(round_avgTE),'%'];
                        text(7.5,txt_pos(12),str,'HorizontalAlignment','left',
'fontsize', ftsize);

                        str = ['when Q=',num2str(round_dis), ' m^3/s'];
                        text(7.5,txt_pos(13),str,'HorizontalAlignment','left',
'fontsize', ftsize);

                    % Jongseok helped me in this part
                    set(gcf, 'units', 'inches', 'position', [0.5 0.5 18 11]) %
0.5, 0.5 is low-left point of screen, 15 is length, 10 is hight from origin
point
                    set(gca, 'LooseInset', [0.05 0.1 0.05 0.03]) % Left/
Bottom / Right / Top
                    hold off

                    % save picture
                    picturename = ['Drawing_of_getting_AvgTE_' bname '_'
num2str(round(WS)) 'm_' num2str(Q4fig(m)) 'cms']
```

```
                    print(picturename, '-dmeta', '-r300')


            end % for l

            end % for k

            end % for m: water stage (new_wsup)
    otherwise
end % for Case No

%% Sediment concentration (C)

% Converting to Naesung/Yeong/Nakdong stream

% catchment Area (km^2)
A_NS_Str = 1816;
A_YG_Str = 914;
A_ND_Rvr = 4676;
A_YJ_Dam = 500;
A_SJ_Weir = 7406;
A_AD_Dam = 1584;



% factor
fac_NS = A_NS_Str/A_SJ_Weir;
fac_YG = A_YG_Str/A_SJ_Weir;
fac_ND = A_ND_Rvr/A_SJ_Weir;
%fac_NS+fac_YG+fac_ND



Q_ns = Qsj_obs_n_prediction.*fac_NS
Q_yg = Qsj_obs_n_prediction.*fac_YG
Q_nd = Qsj_obs_n_prediction.*fac_ND

size(Q_ns)

C_ns = 10.478 .* Q_ns.^0.4748;
C_yg = 0.3493 .* Q_yg.^0.9661;
C_nd = 0.0374 .* Q_nd.^1.1072;

% Sediment load (Qs)
% Qs_ns = 0.00006 .* C_ns;     % hourly cf. p296 daily Qs (metric tons/day) =
0.0864 Cmg/l * Qcms
% Qs_yg = 0.00006 .* C_yg;
% Qs_nd = 0.00006 .* C_nd;

sf_ns = 0.0482.*log(Q_ns)+0.619; % SEMEPP factor for Naesung (added on Feb.
25th 2016)
sf_yg = 0.0885.*log(Q_yg)+0.3638;
sf_nd = 0.0216.*log(Q_nd)+0.7956;

Qs_ns = 0.0864 .* C_ns .* Q_ns ./ sf_ns; %0.91; % daily Qs (metric tons/day)
= 0.0864 Cmg/l * Qcms
```

```
Qs_yg = 0.0864 .* C_yg .* Q_yg ./ sf_yg; %0.82;        % 0.8 is coefficient
of h_measured / htotal p.289
Qs_nd = 0.0864 .* C_nd .* Q_nd ./ sf_nd; % 0.94;        % these coefficient
was changed in August 1st, 2015, h_hm_ratio.xlsx

Qs_tot = Qs_ns + Qs_yg + Qs_nd;

figure(), loglog(Q_ns, Qs_ns, 'k*'), xlabel('Qns (cms)'), ylabel('Qs(ns)')
figure(), loglog(Q_yg, Qs_yg, 'k*'), xlabel('Qyg (cms)'), ylabel('Qs(yg)')
figure(), loglog(Q_nd, Qs_nd, 'k*'), xlabel('Qnd (cms)'), ylabel('Qs(nd)')
figure(), loglog(Qin, Qs_tot, 'k*'), xlabel('Qsj (cms)'), ylabel('Qs(tot)')

figure(), loglog(Q_ns, Qs_ns, 'k*', Q_yg, Qs_yg, 'bo', Q_nd, Qs_nd, 'rs'),
xlabel('Q (cms)'), ylabel('Qs'), legend('ns', 'yg', 'nd')
figure(), loglog(Qsj_obs_n_prediction, Qs_tot, 'r*'), xlabel('Qsum (cms)'),
ylabel('Qs(sum)'), legend('sj')

sum_Qs_tot = sum(Qs_tot);

% Reservoir deposition
Dep_ns = Qs_ns.* avgTE_ns;
Dep_yg = Qs_yg.* avgTE_yg;
Dep_nd = Qs_nd.* avgTE_nd;
Dep_tot = Dep_ns + Dep_yg + Dep_nd;
sum_Dep_ton = sum(Dep_tot);

% convert into volume (m3)
Dep_vol = Dep_tot / 1.6; % sand = 1.6 tons/m3
sum_Dep_vol = sum(Dep_vol);

% Estimation of dredging cost
Cost_dred = Dep_vol * 6.31; % dredging cost = tons/specific weight, dredging
cost=6.31 USD/m3
sum_Cost_dred = sum(Cost_dred);

%% Summary

% BC ratio
daily_profit_loss = Bene_hp-Cost_dred; % daily profit and loss
daily_BCratio = Bene_hp./Cost_dred; % daily b/c ratio

avg_Pkw = mean(Pkw)
sum_Pkwh
sum_Bene_hp % USD

sum_Qs_tot
sum_Dep_ton % tons/day
size(Dep_tot)
size(Qs_tot)
daily_avgTE = Dep_tot./Qs_tot   % to calculate daily average TE (revised
Aug28th 2015)
avgTE = sum_Dep_ton / sum_Qs_tot

sum_Dep_vol
```

```
Dep_ratio = sum_Dep_vol / 27400000 * 100 % deposition ratio Volume of the
Sangju Weir is 28million m3

sum_Cost_dred

BCRatio=sum_Bene_hp / sum_Cost_dred

% making nrow is the length of t_final
duration = ones(nrow_of_final_table,1).*analyzing_period;
size(duration)
avg_WS = mean(new_wsup)
%figure(), plot(new_wsup)
mean_WS = ones(nrow_of_final_table,1).*avg_WS;
avg_Q = mean(Qout)
mean_Q = ones(nrow_of_final_table,1).*avg_Q;
size(mean_Q)
daily_Turb = 0.05.*Qout + 3.3; % the result of regression using Haepyeong
data
avg_Turb = mean(daily_Turb);
mean_Turb = ones(nrow_of_final_table,1).*avg_Turb;

% export daily operation result table
%Summary_Table = [duration mean_WS mean_Q t_final(:,1) datevec(t_final(:,1))
new_wsup wsdn dH Ha Qin Qout Qposs Qa1' Qa2'...
%                  Pkw1' Pkw2' Pkw Pkwh Bene_hp Qs_ns' Qs_yg' Qs_nd' Qs_tot
avgTE_ns' avgTE_yg' avgTE_nd' Dep_ns' Dep_yg' Dep_nd' Dep_tot Dep_vol
Cost_dred daily_profit_loss daily_BCratio daily_Turb mean_Turb];
Summary_Table = [duration mean_WS mean_Q t_final(:,1) datevec(t_final(:,1))
new_wsup wsdn dH Ha Qin Qout Qposs Qa1' Qa2'...
                 Pkw1' Pkw2' Pkw Pkwh Bene_hp Qs_ns Qs_yg Qs_nd Qs_tot
avgTE_ns avgTE_yg avgTE_nd Dep_ns Dep_yg Dep_nd Dep_tot...
                 daily_avgTE Dep_vol Cost_dred daily_profit_loss
daily_BCratio daily_Turb mean_Turb];
size(mean_Turb)
header = {'analyzing_period' 'avg_WS' 'avg_Q' 'd_dnum', 'yyyy', 'mm', 'dd',
'HH', 'MM', 'SS', 's_hwl', 's_twl', 'dH', 'Ha', 'Qin', 'Qout', 'Qposs', 'Qa1',
'Qa2',...
          'Pkw1', 'Pkw2', 'Pkw', 'Pkwh', 'Bene_hp', 'Qs_ns', 'Qs_yg', 'Qs_nd',
'Qs_tot', 'avgTE_ns', 'avgTE_yg', 'avgTE_nd', 'Dep_ns', 'Dep_yg', 'Dep_nd',
'Dep_tot', 'daily_avgTE', 'Dep_vol', 'Cost_dred', 'daily_profit_loss',
'daily_BCratio',...
          'daily_Turb', 'avg_Turb'};
t4daily_ds = dataset({Summary_Table, header{:}});
ds_fname = ['Result_CASE_' num2str(CASE_NO) '_daily_table.xlsx'];
export(t4daily_ds, 'XLSfile', ds_fname)


%% For MCDA

%1. Turbidity downstream
avg_WS
avg_Q
Turbidity = 0.05*avg_Q + 3.3 % the result of regression using Haepyeong data

%2. Reservoir Sedimentation
```

```
sum_Qs_tot
avgTE
sum_Dep_ton
sum_Dep_vol
Dep_ratio
sum_Cost_dred

%3. Hydropower production
avg_Pkw
sum_Pkwh
sum_Bene_hp
BCRatio

%4. Water supply stability
%[stored_vol, ~, ~ ]=Func_catch_vol_surf_area(manage_WS);
[stored_vol, ~, ~ ]=Sep11th2015_Func_catch_vol_surf_area(avg_WS);
Current_vol = stored_vol;
[stored_vol, ~, ~ ]=Sep11th2015_Func_catch_vol_surf_area(44.155);% Pungyang
Intake level is 44.155, Saboelmaehoe 41.5
Critical_vol = stored_vol;
vol_for_watersupply = Current_vol-Critical_vol

%5. Flood conveyancy
%[stored_vol, ~, ~ ]=Func_catch_vol_surf_area(manage_WS);%
[stored_vol, ~, ~ ]=Sep11th2015_Func_catch_vol_surf_area(avg_WS);%
Current_vol = stored_vol;
[stored_vol, ~, ~ ]=Sep11th2015_Func_catch_vol_surf_area(52);% Bank Elevation
Full_vol = stored_vol;
vol_for_floodprevention = Full_vol-Current_vol

%[~, ~, XSarea ]=Func_catch_vol_surf_area(manage_WS);% Bank Elevation
[~, ~, XSarea ]=Sep11th2015_Func_catch_vol_surf_area(avg_WS);% Bank Elevation
Current_XSarea = XSarea;
[~, ~, XSarea ]=Sep11th2015_Func_catch_vol_surf_area(52);% Bank Elevation
max_XSarea = XSarea;
XSarea_for_floodconveyance = max_XSarea - Current_XSarea

%6. Flow width ratio
[good_view_station_ratio]=Sep11th2015_Func_flow_width_ratio_calculation(avg_W
S);%
good_view_station_ratio

% Export summary table for MCDA
%t4mcda = [analyzing_period avg_WS avg_Q Turbidity sum_Qs_tot avgTE
sum_Dep_ton sum_Dep_vol Dep_ratio...
t4mcda = [CASE_NO avg_WS avg_Q Turbidity sum_Qs_tot avgTE sum_Dep_ton
sum_Dep_vol Dep_ratio...
          sum_Cost_dred avg_Pkw sum_Pkwh sum_Bene_hp BCRatio
vol_for_watersupply vol_for_floodprevention...
          XSarea_for_floodconveyance good_view_station_ratio];
header = {'Case_NO' 'manage_WS' 'avg_Q' 'Turbidity' 'sum_Qs_tot' 'avgTE'
'sum_Dep_ton' 'sum_Dep_vol' 'Dep_ratio'...
          'sum_Cost_dred' 'avg_Pkw' 'sum_Pkwh' 'sum_Bene_hp' 'BCRatio'
'vol_for_watersupply' 'vol_for_floodprevention'...
          'XSarea_for_floodconveyance' 'good_view_station_ratio'};
t4mcda_ds = dataset({t4mcda, header{:}});
```

```
t4mcda_fname = ['Result_CASE_' num2str(CASE_NO) '_MCDA_input_table.xlsx'];
export(t4mcda_ds, 'XLSfile', t4mcda_fname)



end
```

Nov01st2015_Func_making_additional_Inflow_table_v2.m

```
function [ period, lastdate, no_of_day, t_final_to_add, dnum_1985_2014,
dnum_2015_2034, dnum_1985_2034,dnum_2013_2014, dnum_2013_2034,...
           Qns_historical, Qns_prediction, Qns_wholeperiod, Qyg_historical,
Qyg_prediction, Qyg_wholeperiod,...
           Qnd_historical, Qnd_prediction, Qnd_wholeperiod, Qsj_historical,
Qsj_prediction, Qsj_wholeperiod,...
           Qsj_observation, Qsj_obs_n_prediction] =
Nov01st2015_Func_making_additional_Inflow_table_v2
% Nov. 1st, 2015 (Hwa Y. Kim)
% This function generate inflows for (1) Naseong Str. Subbasin, (2) Yeong
% Str. Subbasin, (3) Nakdong Rvr. Subbasin, and (4) Sangju Weir Basin,
% using (1) Tank runoff simulation and (2) Proportional method simulation.
%
% Also this includes comparison between two methods and the determination
% process of appropriate runoff method.
%
% Finally, Tank runoff method was chosen for the research.


%close all; clc;

% 2001 basin, generated by Tank simulation
filename='sub2001_output.out';
fid = fopen(filename, 'r');
formatSpec = '%10s%8f%9f%9f%9f%9f%9f%9f%9f';
data = textscan(fid,formatSpec, 'headerLines', 31, 'delimiter', '');
fclose(fid);

date=data{1}  % 1985-2014
%date(1)
dnum_1985_2014=datenum(date,'mm/dd/yyyy')
Q2001_1985_2014=data{5}
simulated_AD_Q30yrs=Q2001_1985_2014.*0.97 % Andong dam watershed occupies 97%
of subbasin 2001.
simulated_AD_dnum30yrs=dnum_1985_2014
datevec(simulated_AD_dnum30yrs)
size(simulated_AD_dnum30yrs)
% ---------------------------------------------------------------------------
---------
% date setting
dnum_2015_2034 =
(datenum('01/01/2015','mm/dd/yyyy'):datenum('12/31/2034','mm/dd/yyyy'))'
```

```
[ndays, ~] = size(dnum_2015_2034);  % 20yrs length (2015-2034)
[tndays, ~] = size(dnum_1985_2014); % 30yrs length (1985-2014)
strt_idx = tndays - (ndays-1);
% -----------------------------------------------------------------------------
---------
% for verification and comparison with observed data...
dnum1995_2014_for_verification = simulated_AD_dnum30yrs(strt_idx:tndays)
size(dnum1995_2014_for_verification)
datevec(dnum1995_2014_for_verification)
%-----------------------------------------------------------------------------
----------
Q2001 = Q2001_1985_2014(strt_idx:tndays)
T2001 = [dnum_2015_2034 Q2001]

figure(), plot(T2001(:,1), T2001(:,2)), datetick('x','mm/dd/yyyy'), axis
tight, grid on, ylabel('Q (m^3/s)'), title(filename(1:7))

% 2002 basin
filename='sub2002_output.out';
fid = fopen(filename, 'r');
formatSpec = '%10s%8f%9f%9f%9f%9f%9f%9f%9f';
data = textscan(fid,formatSpec, 'headerLines', 31, 'delimiter', '');
fclose(fid);

date=data{1}
dnum_1985_2014=datenum(date,'mm/dd/yyyy')
Q2002_1985_2014=data{5}

Q2002 = Q2002_1985_2014(strt_idx:tndays)
T2002 = [dnum_2015_2034 Q2002]

figure(), plot(T2002(:,1), T2002(:,2)), datetick('x','mm/dd/yyyy'), axis
tight, grid on, ylabel('Q (m^3/s)'), title(filename(1:7))


% 2003 basin
filename='sub2003_output.out';
fid = fopen(filename, 'r');
formatSpec = '%10s%8f%9f%9f%9f%9f%9f%9f%9f';
data = textscan(fid,formatSpec, 'headerLines', 31, 'delimiter', '');
fclose(fid);

date=data{1}
dnum_1985_2014=datenum(date,'mm/dd/yyyy')
Q2003_1985_2014=data{5}

Q2003 = Q2003_1985_2014(strt_idx:tndays)
T2003 = [dnum_2015_2034 Q2003]

figure(), plot(T2003(:,1), T2003(:,2)), datetick('x','mm/dd/yyyy'), axis
tight, grid on, ylabel('Q (m^3/s)'), title(filename(1:7))

% 2004 basin
filename='sub2004_output.out';
fid = fopen(filename, 'r');
```

```
formatSpec = '%10s%8f%9f%9f%9f%9f%9f%9f%9f';
data = textscan(fid,formatSpec, 'headerLines', 31, 'delimiter', '');
fclose(fid);

date=data{1}
dnum_1985_2014=datenum(date,'mm/dd/yyyy')
Q2004_1985_2014=data{5}

Q2004 = Q2004_1985_2014(strt_idx:tndays)
T2004 = [dnum_2015_2034 Q2004]

figure(), plot(T2004(:,1), T2004(:,2)), datetick('x','mm/dd/yyyy'), axis
tight, grid on, ylabel('Q (m^3/s)'), title(filename(1:7))


% 2005 basin
filename='sub2005_output.out';
fid = fopen(filename, 'r');
formatSpec = '%10s%8f%9f%9f%9f%9f%9f%9f%9f';
data = textscan(fid,formatSpec, 'headerLines', 31, 'delimiter', '');
fclose(fid);

date=data{1}
dnum_1985_2014=datenum(date,'mm/dd/yyyy')
Q2005_1985_2014=data{5}

Q2005 = Q2005_1985_2014(strt_idx:tndays)
T2005 = [dnum_2015_2034 Q2005]

figure(), plot(T2005(:,1), T2005(:,2)), datetick('x','mm/dd/yyyy'), axis
tight, grid on, ylabel('Q (m^3/s)'), title(filename(1:7))

% 2007 basin
filename='sub2007_output.out';
fid = fopen(filename, 'r');
formatSpec = '%10s%8f%9f%9f%9f%9f%9f%9f%9f';
data = textscan(fid,formatSpec, 'headerLines', 31, 'delimiter', '');
fclose(fid);

date=data{1}
dnum_1985_2014=datenum(date,'mm/dd/yyyy')
Q2007_1985_2014=data{5}

Q2007 = Q2007_1985_2014(strt_idx:tndays)
T2007 = [dnum_2015_2034 Q2007]

figure(), plot(T2007(:,1), T2007(:,2)), datetick('x','mm/dd/yyyy'), axis
tight, grid on, ylabel('Q (m^3/s)'), title(filename(1:7))


% Sangju weir basin (summation)
filename='SJweir_output.out';
fid = fopen(filename, 'r');
formatSpec = '%10s%8f%9f%9f%9f%9f%9f%9f%9f';
```

```
data = textscan(fid,formatSpec, 'headerLines', 31, 'delimiter', '');
fclose(fid);

date=data{1}
dnum_1985_2014=datenum(date,'mm/dd/yyyy')
datevec(dnum_1985_2014)
Qsjweir_30yrs=data{5}

Qsjweir = Qsjweir_30yrs(strt_idx:tndays)
Tsjweir = [dnum_2015_2034 Qsjweir]

figure(), plot(Tsjweir(:,1), Tsjweir(:,2)), datetick('x','mm/dd/yyyy'), axis
tight, grid on, ylabel('Q (m^3/s)'), title(filename(1:7))


%% Flow network
AD_in = Q2001
IH_in = Q2002.*0.69
GR_out = Q2002-IH_in
YJ_in = Q2004.*0.28
NS_out = Q2004-YJ_in
YG_out = Q2005
ND1_out = Q2003
ND2_out = Q2007

% making histogram
nbins = 1000;
figure()
hist(AD_in, nbins)
xlabel('Q (cms)'), ylabel('number of data points')
title(['Mean daily discharge, nbins = ' num2str(nbins)]);

find(AD_in<0)
logQ = log10(AD_in)

infinds = find(isinf(logQ)==1);
logQ(infinds) = []

nbinsvec = [10 30 50 100 200];
for i=1:length(nbinsvec)
nbins = nbinsvec(i);
figure
hist(logQ,nbins);
xlabel('log Q (cfs)')
ylabel('number of data points')
title(['Log of mean daily discharge, n = ' num2str(nbins)]);
end

% plot each year of data
datev = datevec(dnum_2015_2034)
dnum = dnum_2015_2034
yearvec =unique(datev(:,1))
prevYear = datenum(datev(:,1) - 1,12,31)
dayofYear = dnum-prevYear
```

```
%% Creating average Flow-Duration Curve

%Sub-basin 2001================================
Q=Q2001;
subbasin_name = 'mbs2001'
%==================================================

figure()
 statement = ['sortQ = [']
for i = 1:length(yearvec)
    inds = find(datev(:,1)==yearvec(i))
    %plot(dayofYear(inds),Q2001(inds))
    eval(['q' num2str(yearvec(i)) '= Q(inds)']) % select yearvec(1)=2015 data
(365ea)
    eval(['[sortQ' num2str(yearvec(i)) ', ~]=sort(q' num2str(yearvec(i)) ',
''descend'')']) % Descending sort for calculation of
    eval(['dayofYear' num2str(yearvec(i)) '= dayofYear(inds)']) % select
yearvec(1)=2015 data (365ea)
    %eval(['semilogy(dayofYear' num2str(yearvec(i)) ',sortQ'
num2str(yearvec(i)) ')'])
    eval(['plot(dayofYear' num2str(yearvec(i)) ', q' num2str(yearvec(i)) ',
dayofYear' num2str(yearvec(i)) ', sortQ' num2str(yearvec(i)) ')'])

    switch i
        case length(yearvec)
           code = ['sortQ' num2str(yearvec(i)) ']']
        otherwise
           code = ['sortQ' num2str(yearvec(i)) ';']
    end
        statement = [statement code]
    hold on
end
%axis tight
xlabel('Day of Year')
ylabel ('Q (cms)')
title(['Sub-basin ' subbasin_name ', '  num2str(yearvec(1)) '-'
num2str(yearvec(end))])

% re-arrangement with descending order
eval([statement])
sortQ
size(sortQ)

figure()
semilogy(dayofYear, sortQ, 'b-'), axis tight, xlabel('Day of year'),
ylabel('Q (cms)'), title(['FD curve for ' subbasin_name])
hold on
% calculation of mean value corresponding day of Year (1 to 365)
avg_sortQ = zeros(max(dayofYear),1);
for i=1:max(dayofYear)
avg_sortQ(i) = mean(sortQ(dayofYear == i)); % computes the average value for
all of the data in sortQ variable that correspond to that dayofYear.
end
semilogy([1:max(dayofYear)], avg_sortQ, 'r', 'LineWidth', 2)

Qdrought=avg_sortQ(355)
```

```
Qlow=avg_sortQ(275)
Qmedian=avg_sortQ(185)
Qabundant=avg_sortQ(95)

semilogy(355, Qdrought, 'ko', 275, Qlow, 'ko', 185, Qmedian, 'ko', 95,
Qabundant, 'ko', 'markerfacecolor', 'k', 'markersize', 10)

eval(['Q355_' subbasin_name '= Qdrought'])
eval(['Q275_' subbasin_name '= Qlow'])
eval(['Q185_' subbasin_name '= Qmedian'])
eval(['Q095_' subbasin_name '= Qabundant'])



%Sub-basin 2002================================
Q=Q2002;
subbasin_name = 'mbs2002'
%==================================================

figure()
 statement = ['sortQ = [']
for i = 1:length(yearvec)
    inds = find(datev(:,1)==yearvec(i))
    %plot(dayofYear(inds),Q2001(inds))
    eval(['q' num2str(yearvec(i)) '= Q(inds)']) % select yearvec(1)=2015 data
(365ea)
    eval(['[sortQ' num2str(yearvec(i)) ', ~]=sort(q' num2str(yearvec(i)) ',
''descend'')']) % Descending sort for calculation of
    eval(['dayofYear' num2str(yearvec(i)) '= dayofYear(inds)']) % select
yearvec(1)=2015 data (365ea)
    %eval(['semilogy(dayofYear' num2str(yearvec(i)) ',sortQ'
num2str(yearvec(i)) ')'])
    eval(['plot(dayofYear' num2str(yearvec(i)) ', q' num2str(yearvec(i)) ',
dayofYear' num2str(yearvec(i)) ', sortQ' num2str(yearvec(i)) ')'])

    switch i
        case length(yearvec)
           code = ['sortQ' num2str(yearvec(i)) ']']
        otherwise
           code = ['sortQ' num2str(yearvec(i)) ';']
    end
        statement = [statement code]
    hold on
end
%axis tight
xlabel('Day of Year')
ylabel ('Q (cms)')
title(['Sub-basin ' subbasin_name ', '  num2str(yearvec(1)) '-'
num2str(yearvec(end))])

% re-arrangement with descending order
eval([statement])
sortQ
size(sortQ)
```

```
figure()
semilogy(dayofYear, sortQ, 'b-'), axis tight, xlabel('Day of year'),
ylabel('Q (cms)'), title(['FD curve for ' subbasin_name])
hold on
% calculation of mean value corresponding day of Year (1 to 365)
avg_sortQ = zeros(max(dayofYear),1);
for i=1:max(dayofYear)
avg_sortQ(i) = mean(sortQ(dayofYear == i)); % computes the average value for
all of the data in sortQ variable that correspond to that dayofYear.
end
semilogy([1:max(dayofYear)], avg_sortQ, 'r', 'LineWidth', 2)

Qdrought=avg_sortQ(355)
Qlow=avg_sortQ(275)
Qmedian=avg_sortQ(185)
Qabundant=avg_sortQ(95)

semilogy(355, Qdrought, 'ko', 275, Qlow, 'ko', 185, Qmedian, 'ko', 95,
Qabundant, 'ko', 'markerfacecolor', 'k', 'markersize', 10)

eval(['Q355_' subbasin_name '= Qdrought'])
eval(['Q275_' subbasin_name '= Qlow'])
eval(['Q185_' subbasin_name '= Qmedian'])
eval(['Q095_' subbasin_name '= Qabundant'])

%Sub-basin 2003================================
Q=Q2003;
subbasin_name = 'mbs2003'
%==================================================

figure()
 statement = ['sortQ = [']
for i = 1:length(yearvec)
    inds = find(datev(:,1)==yearvec(i))
    %plot(dayofYear(inds),Q2001(inds))
    eval(['q' num2str(yearvec(i)) '= Q(inds)']) % select yearvec(1)=2015 data
(365ea)
    eval(['[sortQ' num2str(yearvec(i)) ', ~]=sort(q' num2str(yearvec(i)) ',
''descend'')']) % Descending sort for calculation of
    eval(['dayofYear' num2str(yearvec(i)) '= dayofYear(inds)']) % select
yearvec(1)=2015 data (365ea)
    %eval(['semilogy(dayofYear' num2str(yearvec(i)) ',sortQ'
num2str(yearvec(i)) ')'])
    eval(['plot(dayofYear' num2str(yearvec(i)) ', q' num2str(yearvec(i)) ',
dayofYear' num2str(yearvec(i)) ', sortQ' num2str(yearvec(i)) ')'])

    switch i
        case length(yearvec)
           code = ['sortQ' num2str(yearvec(i)) ']']
        otherwise
           code = ['sortQ' num2str(yearvec(i)) ';']
    end
        statement = [statement code]
    hold on
end
%axis tight
```

```
xlabel('Day of Year')
ylabel ('Q (cms)')
title(['Sub-basin ' subbasin_name ', '  num2str(yearvec(1)) '-'
num2str(yearvec(end))])

% re-arrangement with descending order
eval([statement])
sortQ
size(sortQ)

figure()
semilogy(dayofYear, sortQ, 'b-'), axis tight, xlabel('Day of year'),
ylabel('Q (cms)'), title(['FD curve for ' subbasin_name])
hold on
% calculation of mean value corresponding day of Year (1 to 365)
avg_sortQ = zeros(max(dayofYear),1);
for i=1:max(dayofYear)
avg_sortQ(i) = mean(sortQ(dayofYear == i)); % computes the average value for
all of the data in sortQ variable that correspond to that dayofYear.
end
semilogy([1:max(dayofYear)], avg_sortQ, 'r', 'LineWidth', 2)

Qdrought=avg_sortQ(355)
Qlow=avg_sortQ(275)
Qmedian=avg_sortQ(185)
Qabundant=avg_sortQ(95)

semilogy(355, Qdrought, 'ko', 275, Qlow, 'ko', 185, Qmedian, 'ko', 95,
Qabundant, 'ko', 'markerfacecolor', 'k', 'markersize', 10)

eval(['Q355_' subbasin_name '= Qdrought'])
eval(['Q275_' subbasin_name '= Qlow'])
eval(['Q185_' subbasin_name '= Qmedian'])
eval(['Q095_' subbasin_name '= Qabundant'])

%Sub-basin 2004================================
Q=Q2004;
subbasin_name = 'mbs2004'
%==================================================

figure()
 statement = ['sortQ = [']
for i = 1:length(yearvec)
    inds = find(datev(:,1)==yearvec(i))
    %plot(dayofYear(inds),Q2001(inds))
    eval(['q' num2str(yearvec(i)) '= Q(inds)']) % select yearvec(1)=2015 data
(365ea)
    eval(['[sortQ' num2str(yearvec(i)) ', ~]=sort(q' num2str(yearvec(i)) ',
''descend'')']) % Descending sort for calculation of
    eval(['dayofYear' num2str(yearvec(i)) '= dayofYear(inds)']) % select
yearvec(1)=2015 data (365ea)
    %eval(['semilogy(dayofYear' num2str(yearvec(i)) ',sortQ'
num2str(yearvec(i)) ')'])
    eval(['plot(dayofYear' num2str(yearvec(i)) ', q' num2str(yearvec(i)) ',
dayofYear' num2str(yearvec(i)) ', sortQ' num2str(yearvec(i)) ')'])
```

```
    switch i
        case length(yearvec)
           code = ['sortQ' num2str(yearvec(i)) ']']
        otherwise
           code = ['sortQ' num2str(yearvec(i)) ';']
    end
        statement = [statement code]
    hold on
end
%axis tight
xlabel('Day of Year')
ylabel ('Q (cms)')
title(['Sub-basin ' subbasin_name ', '  num2str(yearvec(1)) '-'
num2str(yearvec(end))])

% re-arrangement with descending order
eval([statement])
sortQ
size(sortQ)

figure()
semilogy(dayofYear, sortQ, 'b-'), axis tight, xlabel('Day of year'),
ylabel('Q (cms)'), title(['FD curve for ' subbasin_name])
hold on
% calculation of mean value corresponding day of Year (1 to 365)
avg_sortQ = zeros(max(dayofYear),1);
for i=1:max(dayofYear)
avg_sortQ(i) = mean(sortQ(dayofYear == i)); % computes the average value for
all of the data in sortQ variable that correspond to that dayofYear.
end
semilogy([1:max(dayofYear)], avg_sortQ, 'r', 'LineWidth', 2)

Qdrought=avg_sortQ(355)
Qlow=avg_sortQ(275)
Qmedian=avg_sortQ(185)
Qabundant=avg_sortQ(95)

semilogy(355, Qdrought, 'ko', 275, Qlow, 'ko', 185, Qmedian, 'ko', 95,
Qabundant, 'ko', 'markerfacecolor', 'k', 'markersize', 10)

eval(['Q355_' subbasin_name '= Qdrought'])
eval(['Q275_' subbasin_name '= Qlow'])
eval(['Q185_' subbasin_name '= Qmedian'])
eval(['Q095_' subbasin_name '= Qabundant'])

%Sub-basin 2005=================================
Q=Q2005;
subbasin_name = 'mbs2005'
%==================================================

figure()
 statement = ['sortQ = [']
for i = 1:length(yearvec)
    inds = find(datev(:,1)==yearvec(i))
    %plot(dayofYear(inds),Q2001(inds))
```

```
    eval(['q' num2str(yearvec(i)) '= Q(inds)']) % select yearvec(1)=2015 data
(365ea)
    eval(['[sortQ' num2str(yearvec(i)) ', ~]=sort(q' num2str(yearvec(i)) ',
''descend'')']) % Descending sort for calculation of
    eval(['dayofYear' num2str(yearvec(i)) '= dayofYear(inds)']) % select
yearvec(1)=2015 data (365ea)
    %eval(['semilogy(dayofYear' num2str(yearvec(i)) ',sortQ'
num2str(yearvec(i)) ')'])
    eval(['plot(dayofYear' num2str(yearvec(i)) ', q' num2str(yearvec(i)) ',
dayofYear' num2str(yearvec(i)) ', sortQ' num2str(yearvec(i)) ')'])

    switch i
        case length(yearvec)
           code = ['sortQ' num2str(yearvec(i)) ']']
        otherwise
           code = ['sortQ' num2str(yearvec(i)) ';']
    end
        statement = [statement code]
    hold on
end
%axis tight
xlabel('Day of Year')
ylabel ('Q (cms)')
title(['Sub-basin ' subbasin_name ', '  num2str(yearvec(1)) '-'
num2str(yearvec(end))])

% re-arrangement with descending order
eval([statement])
sortQ
size(sortQ)

figure()
semilogy(dayofYear, sortQ, 'b-'), axis tight, xlabel('Day of year'),
ylabel('Q (cms)'), title(['FD curve for ' subbasin_name])
hold on
% calculation of mean value corresponding day of Year (1 to 365)
avg_sortQ = zeros(max(dayofYear),1);
for i=1:max(dayofYear)
avg_sortQ(i) = mean(sortQ(dayofYear == i)); % computes the average value for
all of the data in sortQ variable that correspond to that dayofYear.
end
semilogy([1:max(dayofYear)], avg_sortQ, 'r', 'LineWidth', 2)

Qdrought=avg_sortQ(355)
Qlow=avg_sortQ(275)
Qmedian=avg_sortQ(185)
Qabundant=avg_sortQ(95)

semilogy(355, Qdrought, 'ko', 275, Qlow, 'ko', 185, Qmedian, 'ko', 95,
Qabundant, 'ko', 'markerfacecolor', 'k', 'markersize', 10)

eval(['Q355_' subbasin_name '= Qdrought'])
eval(['Q275_' subbasin_name '= Qlow'])
eval(['Q185_' subbasin_name '= Qmedian'])
eval(['Q095_' subbasin_name '= Qabundant'])
```

```
%Sub-basin 2007=================================
Q=Q2007;
subbasin_name = 'mbs2007'
%==================================================

figure()
 statement = ['sortQ = [']
for i = 1:length(yearvec)
    inds = find(datev(:,1)==yearvec(i))
    %plot(dayofYear(inds),Q2001(inds))
    eval(['q' num2str(yearvec(i)) '= Q(inds)']) % select yearvec(1)=2015 data
(365ea)
    eval(['[sortQ' num2str(yearvec(i)) ', ~]=sort(q' num2str(yearvec(i)) ',
''descend'')']) % Descending sort for calculation of
    eval(['dayofYear' num2str(yearvec(i)) '= dayofYear(inds)']) % select
yearvec(1)=2015 data (365ea)
    %eval(['semilogy(dayofYear' num2str(yearvec(i)) ',sortQ'
num2str(yearvec(i)) ')'])
    eval(['plot(dayofYear' num2str(yearvec(i)) ', q' num2str(yearvec(i)) ',
dayofYear' num2str(yearvec(i)) ', sortQ' num2str(yearvec(i)) ')'])

    switch i
        case length(yearvec)
           code = ['sortQ' num2str(yearvec(i)) ']']
        otherwise
           code = ['sortQ' num2str(yearvec(i)) ';']
    end
        statement = [statement code]
    hold on
end
%axis tight
xlabel('Day of Year')
ylabel ('Q (cms)')
title(['Sub-basin ' subbasin_name ', '  num2str(yearvec(1)) '-'
num2str(yearvec(end))])

% re-arrangement with descending order
eval([statement])
sortQ
size(sortQ)

figure()
semilogy(dayofYear, sortQ, 'b-'), axis tight, xlabel('Day of year'),
ylabel('Q (cms)'), title(['FD curve for ' subbasin_name])
hold on
% calculation of mean value corresponding day of Year (1 to 365)
avg_sortQ = zeros(max(dayofYear),1);
for i=1:max(dayofYear)
avg_sortQ(i) = mean(sortQ(dayofYear == i)); % computes the average value for
all of the data in sortQ variable that correspond to that dayofYear.
end
semilogy([1:max(dayofYear)], avg_sortQ, 'r', 'LineWidth', 2)

Qdrought=avg_sortQ(355)
Qlow=avg_sortQ(275)
Qmedian=avg_sortQ(185)
```

```
Qabundant=avg_sortQ(95)

semilogy(355, Qdrought, 'ko', 275, Qlow, 'ko', 185, Qmedian, 'ko', 95,
Qabundant, 'ko', 'markerfacecolor', 'k', 'markersize', 10)

eval(['Q355_' subbasin_name '= Qdrought'])
eval(['Q275_' subbasin_name '= Qlow'])
eval(['Q185_' subbasin_name '= Qmedian'])
eval(['Q095_' subbasin_name '= Qabundant'])


%% calculatio of lagtime
L1=10.9*10^3; % meter, 2002outlet - 2001outlet
A1=731.4*0.3; % m^2, Imha Station Q185
Q1=Q185_mbs2002; %
V1 = Q1/A1;
T1=L1/V1/86400 % day

L2=57383; % meter, 2001outlet - 2003&2004outlet
A2=501.5;  % m^2, Andong Station Q185
Q2=Q1+Q185_mbs2001; %
V2 = Q2/A2;
T2=L2/V2/86400 % day

L3=6991; % meter, 2001outlet - 2003&2004outlet
A3=1369.4%8.7;  % m^2, Dalji Station Q185
Q3=Q2+Q185_mbs2003+Q185_mbs2004; %
V3 = Q3/A3;
T3=L3/V3/86400 % day

L4=12958; % meter, 2004outlet - Sangju Weir
A4=1369.4;  % m^2, Sabeol station area
Q4=Q3+Q185_mbs2005; %
V4 = Q4/A4;
T4=L4/V4/86400 % day

T1=round(T1)
T2=round(T2)
T3=round(T3)
T4=round(T4)

% Lag time adjustment for verification of Tank simulation
%T2=0;  % if do, peak value rapidly increase.
T3=1;
T4=0;

%% Hydrograph Synthesis

% AD_in = Q2001
% IH_in = Q2002.*0.69
% GR_out = Q2002-IH_in
% YJ_in = Q2004.*0.28
% NS_out = Q2004-YJ_in
% YG_out = Q2005
% ND1_out = Q2003
```

```
% ND2_out = Q2007

% A. For historical period(1985-2014)
% case 1) For Sangju Weir considered flow lagtime
Q2002_1985_2014(1:10)
lagged_Q1=circshift(Q2002_1985_2014,T1); % T1 days shift down for time lag
lagged_Q1(1:10)
lagged_Q1(1:T1)=lagged_Q1(T1+1); % replacing the T1 (3days) data with the
next row (row 4)'s data
lagged_Q1(1:10)

Q2 = lagged_Q1 + Q2001_1985_2014;  % confluenced Q subbasin 2001+2002 at
Banbyeon Str. confluence
lagged_Q2 = circshift(Q2, T2);
lagged_Q2(1:T2)=lagged_Q2(T2+1);

Q3 = lagged_Q2+ Q2003_1985_2014 + Q2004_1985_2014 % confluenced Q subbasin
2003 and 2004 (Naeseong Str) at Naeseong Str. confluence
lagged_Q3 = circshift(Q3, T3);
lagged_Q3(1:T3)=lagged_Q3(T3+1);

Q4 = lagged_Q3 + Q2005_1985_2014 % add Yeong Str.
lagged_Q4 = circshift(Q4, T4);
lagged_Q4(1:10)
lagged_Q4(1:T4)=lagged_Q4(T4+1);
lagged_Q4(1:10)

Q5=lagged_Q4 + Q2007_1985_2014 % add Sangju weir subbasin runoff, final
Sangju weir inflow
Qsjweir_1985_2014 = Q5

figure(), plot(dnum_1985_2014, Qsjweir_1985_2014), datetick('x',
'mm/dd/yyyy'), axis tight,
title('Sangju weir discharge with lag time'), ylabel('Q (cms)')

% case 2) For Nakdong Rver considered flow lagtime
Q2002_1985_2014(1:10)
lagged_Q1=circshift(Q2002_1985_2014,T1); % T1 days shift down for time lag
lagged_Q1(1:10)
lagged_Q1(1:T1)=lagged_Q1(T1+1); % replacing the T1 (3days) data with the
next row (row 4)'s data
lagged_Q1(1:10)

Q2 = lagged_Q1 + Q2001_1985_2014;  % confluenced Q subbasin 2001+2002 at
Banbyeon Str. confluence
lagged_Q2 = circshift(Q2, T2);
lagged_Q2(1:T2)=lagged_Q2(T2+1);

Q3 = lagged_Q2+ Q2003_1985_2014 % + Q2004_1985_2014 % confluenced Q subbasin
2003 and 2004 (Naeseong Str) at Naeseong Str. confluence
lagged_Q3 = circshift(Q3, T3);
lagged_Q3(1:T3)=lagged_Q3(T3+1);

Q4 = lagged_Q3 % + Q2005_1985_2014 % add Yeong Str.
lagged_Q4 = circshift(Q4, T4);
```

```
lagged_Q4(1:10)
lagged_Q4(1:T4)=lagged_Q4(T4+1);
lagged_Q4(1:10)

Q5=lagged_Q4 + Q2007_1985_2014 % add Sangju weir subbasin runoff, final
Sangju weir inflow
Qndrvr_1985_2014 = Q5

figure(), plot(dnum_1985_2014, Qndrvr_1985_2014), datetick('x', 'mm/dd/yyyy'),
axis tight,
title('Nakdong Rvr. discharge with lag time'), ylabel('Q (cms)')


% B. For prediction period(2015-2034)
% case 1-a) For Sangju Weir considered flow lagtime
Q2002(1:10)
lagged_Q1=circshift(Q2002,T1); % T1 days shift down for time lag
lagged_Q1(1:10)
lagged_Q1(1:T1)=lagged_Q1(T1+1); % replacing the T1 (3days) data with the
next row (row 4)'s data
lagged_Q1(1:10)

Q2 = lagged_Q1 + Q2001;  % confluenced Q subbasin 2001+2002 at Banbyeon Str.
confluence
lagged_Q2 = circshift(Q2, T2);
lagged_Q2(1:T2)=lagged_Q2(T2+1);

Q3 = lagged_Q2+Q2003+Q2004 % confluenced Q subbasin 2003 and 2004 (Naeseong
Str) at Naeseong Str. confluence
lagged_Q3 = circshift(Q3, T3);
lagged_Q3(1:T3)=lagged_Q3(T3+1);

Q4 = lagged_Q3+Q2005 % add Yeong Str.
lagged_Q4 = circshift(Q4, T4);
lagged_Q4(1:10)
lagged_Q4(1:T4)=lagged_Q4(T4+1);
lagged_Q4(1:10)

Q5=lagged_Q4+Q2007 % add Sangju weir subbasin runoff, final Sangju weir
inflow
Qsjweir_2015_2034 = Q5

figure(), plot(dnum_2015_2034, Qsjweir_2015_2034), datetick('x',
'mm/dd/yyyy') ,axis tight,
title('Sangju weir discharge with lag time'), ylabel('Q (cms)')

% case 1-b) For Nakdong Rvr considered flow lagtime
Q2002(1:10)
lagged_Q1=circshift(Q2002,T1); % T1 days shift down for time lag
lagged_Q1(1:10)
lagged_Q1(1:T1)=lagged_Q1(T1+1); % replacing the T1 (3days) data with the
next row (row 4)'s data
lagged_Q1(1:10)
```

```
Q2 = lagged_Q1 + Q2001;  % confluenced Q subbasin 2001+2002 at Banbyeon Str.
confluence
lagged_Q2 = circshift(Q2, T2);
lagged_Q2(1:T2)=lagged_Q2(T2+1);

Q3 = lagged_Q2+Q2003%+Q2004 % confluenced Q subbasin 2003 and 2004 (Naeseong
Str) at Naeseong Str. confluence
lagged_Q3 = circshift(Q3, T3);
lagged_Q3(1:T3)=lagged_Q3(T3+1);

Q4 = lagged_Q3%+Q2005 % add Yeong Str.
lagged_Q4 = circshift(Q4, T4);
lagged_Q4(1:10)
lagged_Q4(1:T4)=lagged_Q4(T4+1);
lagged_Q4(1:10)

Q5=lagged_Q4+Q2007 % add Sangju weir subbasin runoff, final Sangju weir
inflow
Qndrvr_2015_2034 = Q5

figure(), plot(dnum_2015_2034, Qndrvr_2015_2034), datetick('x',
'mm/dd/yyyy') ,axis tight,
title('Sangju weir discharge with lag time'), ylabel('Q (cms)')


% case 2) without lagtime
Q_sjweir = Q2001 + Q2002 + Q2003 + Q2004 + Q2005 + Q2007
figure(), plot(dnum_2015_2034, Q_sjweir), datetick('x', 'mm/dd/yyyy') , axis
tight,
title('Sangju weir discharge without lag time'), ylabel('Q (cms)')

Q_sjweir_2013_2014=Q_sjweir(end-729:end) % choose last 730 days data
corresponding data of 2013-2014
size(Q_sjweir_2013_2014)
Q5_2013_2014=Q5(end-729:end) % choose last 730 days data corresponding data
of 2013-2014
size(Q5_2013_2014)


% comparison of Sangju weir hydrograph
figure()
subplot(2,1,1), plot(dnum, Q_sjweir), datetick('x', 'mm/dd/yyyy') , axis
tight, title('Sangju Weir hydrograph Synthesis without lag time')
subplot(2,1,2), plot(dnum, Q5), datetick('x', 'mm/dd/yyyy') , axis tight,
title('Sangju Weir hydrograph Synthesis with lag time')

figure(), plot(dnum, Q_sjweir, 'b:', dnum, Q5, 'r-'), datetick('x',
'mm/dd/yyyy'),
          axis tight, title('Sangju Weir hydrograph with vs. without lag
time'),
          legend('Synthesized hydrograph without lag time', 'Synthesized
hydrograph with lag time')

% conclusion
% Oct. 25th, 2015
```

```
% Simulated inflow data considering lag time are more appropriate than
% without lag time data, because the maximum inflow is similar to observed
% real data of 2013 and 2014 as well as the respond pattern is very similar.
%
% Q5 is the finally simulated data set for 20yrs (2015-2034) which
% correspond to the historical data of 1995 through 2014.
%
% Q5 has to inserted to Sep11th2015_Func_MCDA_v6a_......m to run final
% results for the dissertation.
%




% % comparison of statistics inflow during two years
% a=cumsum(observed_SJ_inflow)
% b=cumsum(Q_sjweir_2013_2014)
% c=cumsum(Q5_2013_2014)
% figure(), plot(date2013_2014, a, 'k-', date2013_2014, b, 'b:',
date2013_2014, c, 'r-'), datetick('x', 'mm/dd/yyyy') , axis tight,
title('Verification of Sangju Weir Inflow (2013-2014)'), legend('Observed
Sangju Weir Inflow', 'Synthesized hydrograph without lag time', 'Synthesized
hydrograph with lag time')
%
% e=max(observed_SJ_inflow)
% f=max(Q_sjweir_2013_2014)
% g=max(Q5_2013_2014)


%% verification with observed data
%
%(1) Andong Dam inflow, 1977-2014
%    (a) obserbed data vs. (b) Tank simulation
%
%
% (a) Andong dam observed data (1977-2014)
filename = 'ADdam_operational_information_1977_2014_En.txt';
delimiter = '\t';
formatSpec =
'%s%s%s%s%s%s%s%s%s%s%s%s%s%f%s%s%s%s%f%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s
%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%[^\n\r
]';

fileID = fopen(filename,'r');
dataArray = textscan(fileID, formatSpec, 'Delimiter', delimiter,
'ReturnOnError', false, 'headerlines', 1);
fclose(fileID);

date=dataArray{3}  % 1977-2014
ob_dnum=datenum(date, 'yyyy-mm-dd')

ob_AD_inflow=dataArray{14} % this is the total inflow from watershed / this
column was used for comparision inflow with simulation
ind=find(ob_AD_inflow<0)
%ob_inflow(ind)=0;  % replace all data with
```

```
ob_inflow2=dataArray{19} % this column was generated for water budget
analysis
find(ob_inflow2<0)

figure()
subplot(2,1,1), plot(ob_dnum, ob_AD_inflow), datetick('x', 'mm/dd/yyyy'),
title('Total Andong dam inflow'), xlim([datenum('1/1/2014', 'mm/dd/yyyy')
datenum('12/31/2014', 'mm/dd/yyyy')])
subplot(2,1,2), plot(ob_dnum, ob_inflow2), datetick('x', 'mm/dd/yyyy'),
title('Andong dam Inflow generated for water budget'),
xlim([datenum('1/1/2014', 'mm/dd/yyyy') datenum('12/31/2014', 'mm/dd/yyyy')])

figure()
g=[]
g(1)=datenum('1/1/1985', 'mm/dd/yyyy')
g(2)=datenum('1/1/1990', 'mm/dd/yyyy')
g(3)=datenum('1/1/1995', 'mm/dd/yyyy')
g(4)=datenum('1/1/2000', 'mm/dd/yyyy')
g(5)=datenum('1/1/2005', 'mm/dd/yyyy')
g(6)=datenum('1/1/2010', 'mm/dd/yyyy')
g(7)=datenum('12/31/2014', 'mm/dd/yyyy')
plot(ob_dnum, ob_AD_inflow, 'ro-', ob_dnum, ob_inflow2, 'bo-'),...
set(gca, 'XTick', g)
datetick('x', 'mm/dd/yyyy', 'keepticks'), title('Andong dam Total inflow vs.
inflow generated for water budget (K-water DB)'),...
%xlim([datenum('12/1/2012', 'mm/dd/yyyy') datenum('12/31/2012',
'mm/dd/yyyy')]),...
grid on, legend('Total inflow (column 14)', 'Inflow for water budget (column
19)')
xticklabel_rotate

% (b) Tank simulation (1985-2014)
simulated_AD_Q30yrs
simulated_AD_dnum30yrs

% Graph comparison Tank vs. Observation
figure()
subplot(2,1,1), plot(simulated_AD_dnum30yrs, simulated_AD_Q30yrs), set(gca,
'XTick', g), datetick('x', 'mm/dd/yyyy', 'keepticks'),...
                xlim([datenum('1/1/1985', 'mm/dd/yyyy') datenum('12/31/2014',
'mm/dd/yyyy')]),...
                ylim([0 4000]), title('AD inflow Tank simulation')
subplot(2,1,2), plot(ob_dnum, ob_AD_inflow), set(gca, 'XTick', g),
datetick('x', 'mm/dd/yyyy', 'keepticks'),...
                xlim([datenum('1/1/1985', 'mm/dd/yyyy') datenum('12/31/2014',
'mm/dd/yyyy')]),...
                ylim([0 4000]), title('AD inflow Observation')

figure()
plot(simulated_AD_dnum30yrs, simulated_AD_Q30yrs, 'bo-',ob_dnum, ob_AD_inflow,
'ko:' )
set(gca, 'XTick', [datenum('1/1/2013', 'mm/dd/yyyy') datenum('12/31/2014',
'mm/dd/yyyy')])
datetick('x', 'mm/dd/yyyy', 'keepticks'), xticklabel_rotate
xlim([datenum('1/1/2013', 'mm/dd/yyyy') datenum('12/31/2014', 'mm/dd/yyyy')])
title('Tank simulation vs. Observation (Andong Dam Inflow)')
```

```
legend('Simulation result', 'Observed data')
%===========================================================================
==================================================
%---------------------------------------------------------------------------
%
%(2) Sangju weir inflow, 2013-2014
%   (a) observed data vs. (b) Tank simulation vs. (c) proportional method
%
%---------------------------------------------------------------------------
% (a-1) observed data (2013-2014) from hourly data
%
filename='20120716_20150301_operation.txt';  % dimliter must be tab.
fid = fopen(filename, 'r');
data =
textscan(fid,'%s %f32 %f32 %f32 %f32 %f %f %f %f %f %f %f %f %f %f %f %f %f',
'headerLines', 1, 'delimiter', '\t');
fclose(fid);

% getting datevector from text type date&time
dates = data{1};
datev = datevec(dates,'yyyymmddHHMM');
daten = datenum(datev);

% filtering with certain period
%ini_date = input('Enter starting date, ex)20120718:');
ini_date = datenum(datevec('201301010000','yyyymmddHHMM'));
end_date = datenum(datevec('201412312350','yyyymmddHHMM'));
% giving conditions
ind = find(daten >= ini_date & daten <= end_date);

ind_date = datev(ind,1:6);
s_date=datenum(ind_date) % filtered date and time vector

d_date=reshape(s_date, 144, []); % reshape the table into one column with 144
records length
d_dnum=d_date(1,:)' % choose the first row and transpose
d_dvec= datevec(d_dnum) % convert datenum into date vector

hwl = double(data{2}); % get head water level and converte cell into double
s_hwl=hwl(ind);        % filter hwl with certain datecondition
twl = double(data{3});  % get head water level and converte cell into double
s_twl=twl(ind);
inf = double(data{6}); % inflow
s_inf=inf(ind);
outf = double(data{7}); % outflow
s_outf=outf(ind);

dat = [s_hwl s_twl s_inf s_outf];

[row col] = size(dat); % dat_daily is quearyied matrix with condition
for i = 1:col
d(:,i)  = mean(reshape(dat(:,i), 144, []))';  % average all data
end

% fill nan value with previous data
```

```
for k = find(isnan(d))
    d(k)=d(k-1);
end

s_t = [d_dvec d]; % selected table; filtered table

nday = datenum(d_dvec);

t_final = [nday d];
size(t_final)

date2013_2014 = nday
observed_SJ_inflow = d(:,3);
figure(), plot(date2013_2014, observed_SJ_inflow), datetick('x',
'mm/dd/yyyy'),
          title('Observed Sangju Weir inflow'), ylabel('Inflow (cms)')

% (a-2) Sangju Weir observed data (2013-2014), from daily data
% (hdims.kwater.or,kr)
filename = 'SJweir_operational_information_2013_2014_En.txt';
delimiter = '\t';
formatSpec =
'%s%s%s%s%s%s%s%s%s%s%s%s%s%s%f%s%s%s%s%f%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s
%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%[^\n\r
]';

fileID = fopen(filename,'r');
dataArray = textscan(fileID, formatSpec, 'Delimiter', delimiter,
'ReturnOnError', false, 'headerlines', 1);
fclose(fileID);

date=dataArray{3}  % 2013-2014
ob_SJweir_dnum2013_2014=datenum(date, 'yyyy-mm-dd')

ob_SJweir_inflow_Hdims=dataArray{14} % this is the total inflow from
watershed / this column was used for comparision inflow with simulation
ind=find(ob_SJweir_inflow_Hdims<0)
%ob_inflow(ind)=0;  % replace all data with



figure()
g=[]
g(1)=datenum('1/1/2013', 'mm/dd/yyyy')
g(2)=datenum('7/1/2013', 'mm/dd/yyyy')
g(3)=datenum('1/1/2014', 'mm/dd/yyyy')
g(4)=datenum('7/1/2014', 'mm/dd/yyyy')
g(5)=datenum('12/31/2014', 'mm/dd/yyyy')
subplot(3,1,1), plot(date2013_2014, observed_SJ_inflow),set(gca, 'XTick',
g),datetick('x', 'mm/dd/yyyy', 'keepticks'),...
                title('SJ inflow from hourly data')
subplot(3,1,2),  plot(ob_SJweir_dnum2013_2014, ob_SJweir_inflow_Hdims),set(gca,
'XTick', g),datetick('x', 'mm/dd/yyyy', 'keepticks'),...
                title('SJ inflow from daily data (HDIMS)')
```

```
subplot(3,1,3), plot(date2013_2014, observed_SJ_inflow, 'b-',
ob_SJweir_dnum2013_2014, ob_SJweir_inflow_Hdims, 'r-'),set(gca, 'XTick',
g),datetick('x', 'mm/dd/yyyy', 'keepticks'),...
                title('hourly vs. daily'), legend('hourly based', 'daily
based (HDIMS)')
% Thus, Sangju weir's inflow is correct because inflows from HDIMS based on
% daily data is the same as the inflows calculated 10 minutes data from
% Seonghun Kim (Oct. 28th, 2015, Hwa Y. Kim)
%
%
% (b) Tank simulation and simple channel routing
%
dnum1995_2014_for_verification
size(dnum1995_2014_for_verification)
simulated_SJ_inflow=Qsjweir_2015_2034
size(simulated_SJ_inflow)
figure(), plot(dnum1995_2014_for_verification, simulated_SJ_inflow),
datetick('x', 'mm/dd/yyyy'),
          title('Simulated Sangju Weir inflow'), ylabel('Inflow (cms)')
%
%
% (c) proportional method
%
A_2001 = 1628.7;
A_2002 = 1975.7;
A_2003 =  980.4;
A_2004 = 1816.0;
A_2005 =  914.4;
A_2007 =   90.8;

A_ND_Rvr = A_2003 + A_2007
A_YJ_Dam = 500
A_SJ_Weir = A_2001 + A_2002 + A_2003 + A_2004 + A_2005 + A_2007
A_AD_Dam = 1584.0; % catchment Area (km^2)
A_IH_Dam = 1361.0; % catchment Area (km^2)

                        % Converting to Naesung/Yeong/Nakdong stream
fac_2001 = A_2001/A_AD_Dam
fac_2002 = A_2002/A_AD_Dam
fac_2003 = A_2003/A_AD_Dam
fac_2004 = A_2004/A_AD_Dam % converting factor
fac_2005 = A_2005/A_AD_Dam
fac_2007 = A_2007/A_AD_Dam
fac_SJ_Weir = A_SJ_Weir/A_AD_Dam

fac_ADvsSub2001=A_AD_Dam/A_2001
fac_IHvsSub2002=A_IH_Dam/A_2002

% convertted inflow
prop_Q2001=ob_AD_inflow.*fac_2001; % 1977-2014, proportional method
prop_Q2002=ob_AD_inflow.*fac_2002;
prop_Q2003=ob_AD_inflow.*fac_2003;
prop_Q2004=ob_AD_inflow.*fac_2004;
prop_Q2005=ob_AD_inflow.*fac_2005;
prop_Q2007=ob_AD_inflow.*fac_2007;
prop_unlagged_Q_SJ_Weir=ob_AD_inflow.*fac_SJ_Weir;
```

```
size(prop_unlagged_Q_SJ_Weir)

% considering time lag
lagged_Q1=circshift(prop_Q2002,T1); % T1 days shift down for time lag
lagged_Q1(1:10)
lagged_Q1(1:T1)=lagged_Q1(T1+1); % replacing the T1 (3days) data with the
next row (row 4)'s data
lagged_Q1(1:10)

Q2 = lagged_Q1 + prop_Q2001;  % confluenced Q subbasin 2001+2002 at Banbyeon
Str. confluence
lagged_Q2 = circshift(Q2, T2);
lagged_Q2(1:T2)=lagged_Q2(T2+1);

Q3 = lagged_Q2+prop_Q2003+prop_Q2004 % confluenced Q subbasin 2003 and 2004
(Naeseong Str) at Naeseong Str. confluence
lagged_Q3 = circshift(Q3, T3);
lagged_Q3(1:T3)=lagged_Q3(T3+1);

Q4 = lagged_Q3+prop_Q2005 % add Yeong Str.
lagged_Q4 = circshift(Q4, T4);
lagged_Q4(1:10)
lagged_Q4(1:T4)=lagged_Q4(T4+1);
lagged_Q4(1:10)

Q5=lagged_Q4+prop_Q2007 % add Sangju weir subbasin runoff, final Sangju weir
inflow
figure(), plot(ob_dnum, Q5), datetick('x', 'mm/dd/yyyy') ,axis tight,
title('Sangju weir discharge using proportional method with lag time'),
ylabel('Q (cms)')

prop_lagged_SJ_inflow = Q5
prop_lagged_SJ_dnum = ob_dnum
datevec(ob_dnum)


% graph comparison
figure()
subplot(5,1,1), plot(date2013_2014, observed_SJ_inflow),set(gca,
'XTick',[datenum('1/1/2013', 'mm/dd/yyyy') datenum('12/31/2014',
'mm/dd/yyyy')]),
                datetick('x', 'mm/dd/yyyy', 'keepticks'),...
                xlim([datenum('1/1/2013', 'mm/dd/yyyy') datenum('12/31/2014',
'mm/dd/yyyy')]),...
                ylim([0 4000]), title('SJ inflow Observed data')
subplot(5,1,2), plot(dnum1995_2014_for_verification,
simulated_SJ_inflow),set(gca, 'XTick',[datenum('1/1/2013', 'mm/dd/yyyy')
datenum('12/31/2014', 'mm/dd/yyyy')]),
                datetick('x', 'mm/dd/yyyy', 'keepticks'),...
                xlim([datenum('1/1/2013', 'mm/dd/yyyy') datenum('12/31/2014',
'mm/dd/yyyy')]),...
                ylim([0 4000]), title('SJ inflow Simulated data by Tank with
time lag')
```

```
subplot(5,1,3), plot(prop_lagged_SJ_dnum, prop_lagged_SJ_inflow),set(gca,
'XTick',[datenum('1/1/2013', 'mm/dd/yyyy') datenum('12/31/2014',
'mm/dd/yyyy')]),
                datetick('x', 'mm/dd/yyyy', 'keepticks'),...
                xlim([datenum('1/1/2013', 'mm/dd/yyyy') datenum('12/31/2014',
'mm/dd/yyyy')]),...
                ylim([0 4000]), title('SJ inflow Simulated data by
Proportional method with time lag')
subplot(5,1,4), plot(prop_lagged_SJ_dnum, prop_unlagged_Q_SJ_Weir),set(gca,
'XTick',[datenum('1/1/2013', 'mm/dd/yyyy') datenum('12/31/2014',
'mm/dd/yyyy')]),
                datetick('x', 'mm/dd/yyyy', 'keepticks'),...
                xlim([datenum('1/1/2013', 'mm/dd/yyyy') datenum('12/31/2014',
'mm/dd/yyyy')]),...
                ylim([0 4000]), title('SJ inflow Simulated data by
Proportional method without time lag')
subplot(5,1,5), plot(dnum1995_2014_for_verification, Qsjweir),set(gca,
'XTick',[datenum('1/1/2013', 'mm/dd/yyyy') datenum('12/31/2014',
'mm/dd/yyyy')]),
                datetick('x', 'mm/dd/yyyy', 'keepticks'),...
                xlim([datenum('1/1/2013', 'mm/dd/yyyy') datenum('12/31/2014',
'mm/dd/yyyy')]),...
                ylim([0 4000]), title('SJ inflow Simulated data by Tank using
SJ watershed')


figure()
plot(date2013_2014, observed_SJ_inflow, 'ko-',dnum1995_2014_for_verification,
simulated_SJ_inflow, 'r-',dnum1995_2014_for_verification, Qsjweir, 'g-',...
     prop_lagged_SJ_dnum, prop_lagged_SJ_inflow, 'b-', prop_lagged_SJ_dnum,
prop_unlagged_Q_SJ_Weir, 'b:')
set(gca, 'XTick', [datenum('1/1/2013', 'mm/dd/yyyy') datenum('1/1/2014',
'mm/dd/yyyy') datenum('12/31/2014', 'mm/dd/yyyy')])
datetick('x', 'mm/dd/yyyy', 'keepticks'), xticklabel_rotate
xlim([datenum('1/1/2013', 'mm/dd/yyyy') datenum('12/31/2014', 'mm/dd/yyyy')])
ylabel('Q (cms)')
title('SJ inflow comparison, Observation vs. Tank simulation vs. Proportional
method')
legend('Observation', 'Tank simulation with time lag', 'Tank simulation using
SJ watershed', 'Proportional method simulation with time lag', 'Proportional
to SJ Weir without time lag')

figure()
plot(date2013_2014, observed_SJ_inflow, 'ko-',dnum1995_2014_for_verification,
simulated_SJ_inflow, 'r-',...
     prop_lagged_SJ_dnum, prop_unlagged_Q_SJ_Weir, 'b:')
set(gca, 'XTick', [datenum('1/1/2013', 'mm/dd/yyyy') datenum('1/1/2014',
'mm/dd/yyyy') datenum('12/31/2014', 'mm/dd/yyyy')])
datetick('x', 'mm/dd/yyyy', 'keepticks'), xticklabel_rotate
xlim([datenum('1/1/2013', 'mm/dd/yyyy') datenum('12/31/2014', 'mm/dd/yyyy')])
ylabel('Q (cms)')
title('SJ inflow comparison, Observation vs. Tank simulation vs. Proportional
method')
legend('Observation', 'Tank simulation with time lag', 'Proportional to SJ
Weir without time lag')
```

```
figure()
plot(date2013_2014, observed_SJ_inflow, 'ko-',dnum1995_2014_for_verification,
simulated_SJ_inflow, 'r-')
set(gca, 'XTick', [datenum('1/1/2013', 'mm/dd/yyyy') datenum('1/1/2014',
'mm/dd/yyyy') datenum('12/31/2014', 'mm/dd/yyyy')])
datetick('x', 'mm/dd/yyyy', 'keepticks'), xticklabel_rotate
xlim([datenum('1/1/2013', 'mm/dd/yyyy') datenum('12/31/2014', 'mm/dd/yyyy')])
ylabel('Q (cms)')
title('SJ inflow comparison, Observation vs. Tank simulation')
legend('Observation', 'Tank simulation')

%% comparison of specific discharge

% (1) Observed data
% loading Imha observed data (HDIMS)
filename = 'IHdam_operational_information_1992_2014_En.txt';
delimiter = '\t';
formatSpec =
'%s%s%s%s%s%s%s%s%s%s%s%s%s%s%f%s%s%s%s%f%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s
%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%s%[^\n\r
]';

fileID = fopen(filename,'r');
dataArray = textscan(fileID, formatSpec, 'Delimiter', delimiter,
'ReturnOnError', false, 'headerlines', 1);
fclose(fileID);

date=dataArray{3}  % 1992-2014
ob_IHdam_dnum1992_2014=datenum(date, 'yyyy-mm-dd')

ob_IHdam_inflow_Hdims=dataArray{14} % this is the total inflow from watershed
/ this column was used for comparision inflow with simulation
ind=find(ob_IHdam_inflow_Hdims<0)
%ob_inflow(ind)=0;  % replace all data with

s_Q_IH_Dam = ob_IHdam_inflow_Hdims./A_IH_Dam

s_Q_AD_Dam = ob_AD_inflow./A_AD_Dam
s_Q_SJ_Weir = observed_SJ_inflow./A_SJ_Weir

figure()
subplot(4,1,1), plot(ob_dnum, s_Q_AD_Dam), ylim([0 1]), title('Specific Q in
Andong Dam'), grid on,
                set(gca, 'XTick', [datenum('1/1/2013', 'mm/dd/yyyy')
datenum('1/1/2014', 'mm/dd/yyyy') datenum('12/31/2014', 'mm/dd/yyyy')])
                datetick('x', 'mm/dd/yyyy', 'keepticks')
subplot(4,1,2), plot(ob_IHdam_dnum1992_2014, s_Q_IH_Dam), ylim([0 1]),
title('Specific Q in Imha Dam'), grid on,
                set(gca, 'XTick', [datenum('1/1/2013', 'mm/dd/yyyy')
datenum('1/1/2014', 'mm/dd/yyyy') datenum('12/31/2014', 'mm/dd/yyyy')])
                datetick('x', 'mm/dd/yyyy', 'keepticks')
subplot(4,1,3), plot(date2013_2014, s_Q_SJ_Weir), ylim([0 1]),
title('Specific Q in Sangju Weir'), grid on,
                set(gca, 'XTick', [datenum('1/1/2013', 'mm/dd/yyyy')
datenum('1/1/2014', 'mm/dd/yyyy') datenum('12/31/2014', 'mm/dd/yyyy')])
```

```
                datetick('x', 'mm/dd/yyyy', 'keepticks')
ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'\bf Specific discharge (Observed
data)','HorizontalAlignment','center','VerticalAlignment', 'top')

% (2) Tank Simulation
s_Q2001 = Q2001./A_2001
s_Q2002 = Q2002./A_2002
s_Q2003 = Q2003./A_2003
s_Q2004 = Q2004./A_2004
s_Q2005 = Q2005./A_2005
s_Q2007 = Q2007./A_2007
s_Q_simulated_SJ_inflow =simulated_SJ_inflow/A_SJ_Weir
s_Qsjweir_wSJwatershed = Qsjweir/A_SJ_Weir
dnum_2015_2034

Q_AD_Tank = Q2001.*fac_ADvsSub2001 % getting Andong Dam watershed inflow
generated by Tank
Q_IH_Tank = Q2002.*fac_IHvsSub2002 %         Imha

s_Q_AD_Tank = Q_AD_Tank./A_AD_Dam  % getting specific discharge of Andong Dam
inflow
s_Q_IH_Tank = Q_IH_Tank./A_IH_Dam


figure()
subplot(4,2,1), plot(dnum_2015_2034, s_Q2001), ylim([0 3]), title('Specific Q
in bsn2001'), grid on, datetick('x', 'mm/dd/yyyy')
subplot(4,2,2), plot(dnum_2015_2034, s_Q2002), ylim([0 3]), title('Specific Q
in bsn2002'), grid on, datetick('x', 'mm/dd/yyyy')
subplot(4,2,3), plot(dnum_2015_2034, s_Q2003), ylim([0 3]), title('Specific Q
in bsn2003'), grid on, datetick('x', 'mm/dd/yyyy')
subplot(4,2,4), plot(dnum_2015_2034, s_Q2004), ylim([0 3]), title('Specific Q
in bsn2004'), grid on, datetick('x', 'mm/dd/yyyy')
subplot(4,2,5), plot(dnum_2015_2034, s_Q2005), ylim([0 3]), title('Specific Q
in bsn2005'), grid on, datetick('x', 'mm/dd/yyyy')
subplot(4,2,6), plot(dnum_2015_2034, s_Q2007), ylim([0 3]), title('Specific Q
in bsn2007'), grid on, datetick('x', 'mm/dd/yyyy')
subplot(4,2,7), plot(dnum_2015_2034, s_Q_simulated_SJ_inflow), ylim([0 3]),
title('Specific Q in Sangju Weir'), grid on, datetick('x', 'mm/dd/yyyy')
subplot(4,2,8), plot(dnum_2015_2034, s_Qsjweir_wSJwatershed), ylim([0 3]),
title('Specific Q in Sangju Weir using SJ watershed'), grid on, datetick('x',
'mm/dd/yyyy')
% subplot(5,2,9), plot(dnum_2015_2034, s_Q_AD_Tank), ylim([0 3]),
title('Specific Q of Andong Dam (Tank)'), grid on, datetick('x', 'mm/dd/yyyy')
% subplot(5,2,10), plot(dnum_2015_2034, s_Q_IH_Tank), ylim([0 3]),
title('Specific Q of Imha Dam (Tank)'), grid on, datetick('x', 'mm/dd/yyyy')

ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'\bf Specific discharge (Tank
simulation)','HorizontalAlignment','center','VerticalAlignment', 'top')

figure()
```

```
subplot(4,1,1), plot(dnum_2015_2034, s_Q_AD_Tank), ylim([0 1]),
title('Specific Q of Andong Dam (Tank)'), grid on,...
                set(gca, 'XTick', [datenum('1/1/2033', 'mm/dd/yyyy')
datenum('1/1/2034', 'mm/dd/yyyy') datenum('12/31/2034', 'mm/dd/yyyy')])
                datetick('x', 'mm/dd/yyyy', 'keepticks')
subplot(4,1,2), plot(dnum_2015_2034, s_Q_IH_Tank), ylim([0 1]),
title('Specific Q of Imha Dam (Tank)'), grid on,...
                set(gca, 'XTick', [datenum('1/1/2033', 'mm/dd/yyyy')
datenum('1/1/2034', 'mm/dd/yyyy') datenum('12/31/2034', 'mm/dd/yyyy')])
                datetick('x', 'mm/dd/yyyy', 'keepticks')
subplot(4,1,3), plot(dnum_2015_2034, s_Q_simulated_SJ_inflow), ylim([0 1]),
title('Specific Q of Sangju Weir (Tank, lagged)'), grid on,...
                set(gca, 'XTick', [datenum('1/1/2033', 'mm/dd/yyyy')
datenum('1/1/2034', 'mm/dd/yyyy') datenum('12/31/2034', 'mm/dd/yyyy')])
                datetick('x', 'mm/dd/yyyy', 'keepticks')
subplot(4,1,4), plot(dnum_2015_2034, s_Qsjweir_wSJwatershed), ylim([0 1]),
title('Specific Q of Sangju Weir (Tank, one-basin simulation)'), grid on,...
                set(gca, 'XTick', [datenum('1/1/2033', 'mm/dd/yyyy')
datenum('1/1/2034', 'mm/dd/yyyy') datenum('12/31/2034', 'mm/dd/yyyy')])
                datetick('x', 'mm/dd/yyyy', 'keepticks')

ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'\bf Specific discharge (Tank
simulation)','HorizontalAlignment','center','VerticalAlignment', 'top')



% (3) Proportional method
s_prop_Q2001 = prop_Q2001./A_2001
s_prop_Q2002 = prop_Q2002./A_2002
s_prop_Q2003 = prop_Q2003./A_2003
s_prop_Q2004 = prop_Q2004./A_2004
s_prop_Q2005 = prop_Q2005./A_2005
s_prop_Q2007 = prop_Q2007./A_2007
s_prop_lagged_Q_SJ_Weir = prop_lagged_SJ_inflow./A_SJ_Weir
s_prop_unlagged_Q_SJ_Weir = prop_unlagged_Q_SJ_Weir./A_SJ_Weir

prop_Q_AD = ob_AD_inflow.*(A_AD_Dam/A_AD_Dam)
prop_Q_IH = ob_AD_inflow.*(A_IH_Dam/A_AD_Dam)

s_prop_Q_AD = prop_Q_AD./A_AD_Dam  % getting specific discharge of Andong Dam
inflow
s_prop_Q_IH = prop_Q_IH./A_IH_Dam


figure()
subplot(4,2,1), plot(prop_lagged_SJ_dnum, s_prop_Q2001), ylim([0 3]),
title('Specific Q in bsn2001'), grid on, datetick('x', 'mm/dd/yyyy')
subplot(4,2,2), plot(prop_lagged_SJ_dnum, s_prop_Q2002), ylim([0 3]),
title('Specific Q in bsn2002'), grid on, datetick('x', 'mm/dd/yyyy')
subplot(4,2,3), plot(prop_lagged_SJ_dnum, s_prop_Q2003), ylim([0 3]),
title('Specific Q in bsn2003'), grid on, datetick('x', 'mm/dd/yyyy')
subplot(4,2,4), plot(prop_lagged_SJ_dnum, s_prop_Q2004), ylim([0 3]),
title('Specific Q in bsn2004'), grid on, datetick('x', 'mm/dd/yyyy')
```

```
subplot(4,2,5), plot(prop_lagged_SJ_dnum, s_prop_Q2005), ylim([0 3]),
title('Specific Q in bsn2005'), grid on, datetick('x', 'mm/dd/yyyy')
subplot(4,2,6), plot(prop_lagged_SJ_dnum, s_prop_Q2007), ylim([0 3]),
title('Specific Q in bsn2007'), grid on, datetick('x', 'mm/dd/yyyy')
subplot(4,2,7), plot(prop_lagged_SJ_dnum, s_prop_lagged_Q_SJ_Weir), ylim([0
3]), title('Specific Q in Sangju Weir with time lag'), grid on, datetick('x',
'mm/dd/yyyy')
subplot(4,2,8), plot(prop_lagged_SJ_dnum, s_prop_unlagged_Q_SJ_Weir), ylim([0
3]), title('Specific Q in Sangju Weir without time lag'), grid on,
datetick('x', 'mm/dd/yyyy')

ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'\bf Specific discharge (Proportional method
simulation)','HorizontalAlignment','center','VerticalAlignment', 'top')

figure()
subplot(4,1,1), plot(prop_lagged_SJ_dnum, s_prop_Q_AD), ylim([0 1]),
title('Specific Q of Andong Dam (Prop.)'), grid on,...
                set(gca, 'XTick', [datenum('1/1/2013', 'mm/dd/yyyy')
datenum('1/1/2014', 'mm/dd/yyyy') datenum('12/31/2014', 'mm/dd/yyyy')])
                datetick('x', 'mm/dd/yyyy', 'keepticks')
subplot(4,1,2), plot(prop_lagged_SJ_dnum, s_prop_Q_IH), ylim([0 1]),
title('Specific Q of Imha Dam (Prop.)'), grid on,...
                set(gca, 'XTick', [datenum('1/1/2013', 'mm/dd/yyyy')
datenum('1/1/2014', 'mm/dd/yyyy') datenum('12/31/2014', 'mm/dd/yyyy')])
                datetick('x', 'mm/dd/yyyy', 'keepticks')
subplot(4,1,3), plot(prop_lagged_SJ_dnum, s_prop_lagged_Q_SJ_Weir), ylim([0
1]), title('Specific Q of Sangju Weir (Prop., lagged)'), grid on,...
                set(gca, 'XTick', [datenum('1/1/2013', 'mm/dd/yyyy')
datenum('1/1/2014', 'mm/dd/yyyy') datenum('12/31/2014', 'mm/dd/yyyy')])
                datetick('x', 'mm/dd/yyyy', 'keepticks')
subplot(4,1,4), plot(prop_lagged_SJ_dnum, s_prop_unlagged_Q_SJ_Weir), ylim([0
1]), title('Specific Q of Sangju Weir (Prop., one-basin simulation)'), grid
on,...
                set(gca, 'XTick', [datenum('1/1/2013', 'mm/dd/yyyy')
datenum('1/1/2014', 'mm/dd/yyyy') datenum('12/31/2014', 'mm/dd/yyyy')])
                datetick('x', 'mm/dd/yyyy', 'keepticks')

ha = axes('Position',[0 0 1 1],'Xlim',[0 1],'Ylim',[0
1],'Box','off','Visible','off','Units','normalized', 'clipping' , 'off');
text(0.5, 1,'\bf Specific discharge (Proportional
method)','HorizontalAlignment','center','VerticalAlignment', 'top')

%%

g=[]
g(1)=datenum('1/1/1985', 'mm/dd/yyyy')
g(2)=datenum('1/1/1990', 'mm/dd/yyyy')
g(3)=datenum('1/1/1995', 'mm/dd/yyyy')
g(4)=datenum('1/1/2000', 'mm/dd/yyyy')
g(5)=datenum('1/1/2005', 'mm/dd/yyyy')
g(6)=datenum('1/1/2010', 'mm/dd/yyyy')
g(7)=datenum('1/1/2015', 'mm/dd/yyyy')
g(8)=datenum('1/1/2020', 'mm/dd/yyyy')
g(9)=datenum('1/1/2025', 'mm/dd/yyyy')
```

```
g(10)=datenum('1/1/2030', 'mm/dd/yyyy')
g(11)=datenum('1/1/2035', 'mm/dd/yyyy')

%(1) Naeseong Stream Watershed
dnum_1985_2034= [dnum_1985_2014; dnum_2015_2034]
datevec(dnum_1985_2034)
size(dnum_1985_2034)

Q2004_1985_2014=circshift(Q2004_1985_2014,T3) % 1day lag
Q2004_1985_2014(1)=Q2004_1985_2014(2)        % lagged data fill with next
data

Q2004=circshift(Q2004,T3) % 1day lag
Q2004(1)=Q2004(2)        % lagged data fill with next data

Q2004_1985_2034=[Q2004_1985_2014; Q2004]


size(Q2004_1985_2034)
size(dnum_1985_2034)
figure()
plot(dnum_1985_2034,Q2004_1985_2034), ylabel('Inflow (cms)')
set(gca, 'XTick', g), datetick('x', 'mm/dd/yyyy', 'keepticks')
title('Naeseong Stream Inflow (1985-2034)')

%(2) Yeong Stream Watershed
Q2005_1985_2034=[Q2005_1985_2014; Q2005]
figure()
plot(dnum_1985_2034,Q2005_1985_2034), ylabel('Inflow (cms)')
set(gca, 'XTick', g), datetick('x', 'mm/dd/yyyy', 'keepticks')
title('Yeong Stream Inflow (1985-2034)')

%(3) Nakdong River Watershed
Qndrvr_1985_2034=[Qndrvr_1985_2014; Qndrvr_2015_2034]
figure()
plot(dnum_1985_2034,Qndrvr_1985_2034), ylabel('Inflow (cms)')
set(gca, 'XTick', g), datetick('x', 'mm/dd/yyyy', 'keepticks')
title('Nakdong River Inflow (1985-2034)')

%(4) Sangju Watershed
Qsjweir_1985_2014_sum = Qndrvr_1985_2014 + Q2004_1985_2014 + Q2005_1985_2014
Qsjweir_2015_2034_sum = Qndrvr_2015_2034 + Q2004 + Q2005
Qsjweir_1985_2034_sum = [Qsjweir_1985_2014_sum; Qsjweir_2015_2034_sum] %
summation of three watershed inflow

Qsjweir_1985_2034=[Qsjweir_1985_2014; Qsjweir_2015_2034] % Synthesized inflow
hydrograph using all subbasins and travel time (T1~T4)

size(Qsjweir_1985_2034)
figure()
subplot(3,1,1), plot(dnum_1985_2034,Qsjweir_1985_2034), ylabel('Inflow (cms)')
set(gca, 'XTick', g), datetick('x', 'mm/dd/yyyy', 'keepticks')
title('Sangju Weir Watershed Inflow (1985-2034)')
subplot(3,1,2), plot(dnum_1985_2034,Qsjweir_1985_2034_sum), ylabel('Inflow
(cms)')
```

```
set(gca, 'XTick', g), datetick('x', 'mm/dd/yyyy', 'keepticks')
title('Sangju Weir Watershed Inflow (1985-2034), Summation of three
watershed')
subplot(3,1,3), plot(dnum_1985_2034,Qsjweir_1985_2034-Qsjweir_1985_2034_sum),
ylabel('Inflow (cms)')
set(gca, 'XTick', g), datetick('x', 'mm/dd/yyyy', 'keepticks')
title('Sangju Weir Watershed Inflow (1985-2034), Summation of three
watershed')

round(max(Qsjweir_1985_2034-Qsjweir_1985_2034_sum))
% two data is almost same, thus there is no problem to use inflows by
watershed respectively, NS, YG, ND or as an one watershed, SJ.

figure(), plot(dnum_1985_2034, cumsum(Qsjweir_1985_2034),'b-',...
               dnum_1985_2034, cumsum(Qsjweir_1985_2034_sum),'r-')



%%
t_final_to_add = [dnum_2015_2034 Qsjweir_2015_2034_sum]
period = 20
lastdate = '2034-12-31'
no_of_day = length(t_final_to_add)

dnum_1985_2014
dnum_2015_2034
dnum_1985_2034
dnum_2013_2014 = nday
dnum_2013_2034 = [dnum_2013_2014; dnum_2015_2034]

Qns_historical = Q2004_1985_2014
Qns_prediction = Q2004
Qns_wholeperiod = Q2004_1985_2034

Qyg_historical = Q2005_1985_2014
Qyg_prediction = Q2005
Qyg_wholeperiod = Q2005_1985_2034

Qnd_historical = Qndrvr_1985_2014
Qnd_prediction = Qndrvr_2015_2034
Qnd_wholeperiod = Qndrvr_1985_2034

Qsj_historical = Qsjweir_1985_2014_sum
Qsj_prediction = Qsjweir_2015_2034_sum
Qsj_wholeperiod = Qsjweir_1985_2034_sum

Qsj_observation = observed_SJ_inflow
Qsj_obs_n_prediction = [Qsj_observation; Qsj_prediction]



end
```

Sep11th2015_Func_catch_vol_surf_area.m

```
function [stored_vol, surf_area, XSarea] =
Sep11th2015_Func_catch_vol_surf_area(WS)
% This function returns reservoir volume corresponding certain water stage
% (WS)

filename = 'Aug07th2015_WS_SurfArea_Volume_v2.xlsx';
sheet = 'summary';
[v, T, vT] = xlsread(filename, sheet);

ws4vol=v(:,1);
vol=v(:,2);

ws4area=v(1:17,3);
surfarea=v(1:17,4);

% WS=45
stored_vol = interp1(ws4vol,vol,WS);
surf_area = interp1(ws4area,surfarea,WS);

filename = 'Aug07th2015_WS_SurfArea_Volume_v2.xlsx';
sheet = 'Xsection_SJweir';
[v, T, vT] = xlsread(filename, sheet);

ws4XS=v(:,1);
accXSarea=v(:,5);

% WS=45.5
XSarea = interp1(ws4XS,accXSarea,WS);

end
```

Sep11th2015_Func_flow_width_ratio_calculation.m

```
function [ good_view_station_ratio ] =
Sep11th2015_Func_flow_width_ratio_calculation( manage_WS )
% This is for calculation of flow width ratio

%clear all;
%close all; clc;

filename = 'Aug07th2015_WS_SurfArea_Volume_v2.xlsx';
sheet = 'flow_width';
[v, T, vT] = xlsread(filename, sheet);

ws=v(:,2);
width=v(:,3);

%filename = 'Aug07th2015_WS_SurfArea_Volume_v2.xlsx';
sheet = 'flow_width_index';
```

```
[v, T, vT] = xlsread(filename, sheet);

id=v(:,1);
sta_no = v(:,2);
strt_rn = v(:,3);
end_rn = v(:,4);

[rn, cn]=size(id);

max_width = v(:,5); % Maximum width corresponding to Station No.

for i = 1:rn;
eval(['ws_' num2str(i) '= ' 'ws(' num2str(strt_rn(i)-1) ':'
num2str(end_rn(i)-1) ');']);
eval(['width_' num2str(i) '= ' 'width(' num2str(strt_rn(i)-1) ':'
num2str(end_rn(i)-1) ');']);
end


ratio_t=[]; % for summary of the result

% for manage_WS=37:52

manage_WS;

d=[];


flow_width_ratio=zeros(rn,1);
for i = 1:rn
eval(['cur_flow_width(' num2str(i) ')= ' 'interp1(ws_' num2str(i) ', width_'
num2str(i) ',' num2str(manage_WS) ');']);
eval(['flow_width_ratio(' num2str(i) ')= ' 'cur_flow_width(' num2str(i)
')./max_width(' num2str(i) ');']);
end

%flow_width_ratio=flow_width_ratio
%idx=~isnan(flow_width_ratio)
flow_width_ratio(isnan(flow_width_ratio))=0; % Replace NaN values with zero

final_flow_width_ratio = flow_width_ratio;

avg_width_ratio=mean(final_flow_width_ratio);

cur_flow_width=cur_flow_width';
cur_flow_width(isnan(cur_flow_width))=0;
max_width;

idxx=find(final_flow_width_ratio<0.5 | final_flow_width_ratio>0.7);
[non_amenity_rn,~] = size(idxx);
[total_rn,~] = size(final_flow_width_ratio);
amenity_rn = total_rn - non_amenity_rn;
```

```
% for drawing graphs
pos_max_width=max_width./2;
neg_max_width=pos_max_width.*(-1);
pos_cur_width=cur_flow_width./2;
neg_cur_width=pos_cur_width.*(-1);

%% When the figure is needed, realease the comment sign, %.
% July 23rd, 2015 revised by Hwa Y. Kim
%
% figure()
% subplot(4,1,1)
% tname = strcat('When the manage stage is El.', num2str(manage_WS), 'm')
% plot(id, max_width, 'k-', id, cur_flow_width, 'b--')
% title(tname)
% xlabel('Station No.')
% ylabel('River width and flow width (m)')
% set(gca,'XTick',[1:2:63])
% New_XTickLable = sta_no(1:2:63)
% set(gca, 'XTickLabel', New_XTickLable);
% legend('Maximum river width', 'Flow width')
% hold on
% text(1,100, '\downarrow Sangju Weir')
% %xticklabel_rotate
%
% subplot(4,1,2)
% plot(id, pos_max_width, 'k-', id, pos_cur_width, 'b--', id, neg_max_width,
'k-', id, neg_cur_width, 'b--')
% xlabel('Station No.')
% ylabel('River width and flow width (m)')
% set(gca,'XTick',[1:2:63])
% New_XTickLable = sta_no(1:2:63)
% set(gca, 'XTickLabel', New_XTickLable);
% %xticklabel_rotate
% legend('Maximum river width', 'Flow width')
%
% subplot(4,1,3)
% plot(id, flow_width_ratio, 'bo-')
% hold on
ratio_limit1 = ones(63,1).*0.5;
ratio_limit2 = ones(63,1).*0.7;
% plot(id, ratio_limit1, 'r-', id, ratio_limit2, 'r-')
% xlabel('Station No.')
% ylabel('flow width ratio')
% ylim([0 1])
% set(gca,'XTick',[1:2:63])
% New_XTickLable = sta_no(1:2:63)
% set(gca, 'XTickLabel', New_XTickLable);
% legend('Flow width ratio','Preference levels')
% %xticklabel_rotate
%
% subplot(4,1,4)
x=[{'Total cross section'} {'Between preference levels'} {'Ratio (%)'}];
good_view_station_ratio=amenity_rn/total_rn*100;
y= [total_rn amenity_rn good_view_station_ratio];
% bar(y, 0.1);
% New_XTickLable = x
% set(gca, 'XTickLabel', New_XTickLable);
```

```
% ylabel ('No. of cross sections / Ratio (%)')
% hold on
% text(1,total_rn+5,num2str(total_rn))
% text(2,amenity_rn+5,num2str(amenity_rn))
% diground = @(x,d) round(x*10^d)/10^d; % built-in function
%
text(3,amenity_rn/total_rn*100+5,num2str(diground(good_view_station_ratio,2)))
%
d=[manage_WS avg_width_ratio total_rn amenity_rn good_view_station_ratio];
ratio_t = [ratio_t; d];


end
```

Aug07th2015_Func_eta_interpolation.m

```
function [ eta_for_dHdQ ] = Aug07th2015_Func_eta_interpolation( netH, possQ );
%UNTITLED2 Summary of this function goes here
%   Detailed explanation goes here

% clear all; close all; clc
netH;% =6.6
possQ;% = 25

if (possQ<=0) || (netH<3.0)
    eta_for_dHdQ =0;
elseif netH>10.5
    eta_for_dHdQ = 0;
else
%disp('ok');

% % filename = 'Aug07th2015_eta.xlsx';
% % sheet = 'eta';
% % [v, T, vT] = xlsread(filename, sheet, 'A2:S9' );
% %
% % Qper = v(:,1);
% % Qaa = v(:,2);
% % eta300 = v(:,3);
% % eta350 = v(:,4);
% % eta400 = v(:,5);
% % eta450 = v(:,6);
% % eta500 = v(:,7);
% % eta550 = v(:,8);
% % eta600 = v(:,9);
% % eta650 = v(:,10);
% % eta675 = v(:,11);
% % eta700 = v(:,12);
% % eta750 = v(:,13);
% % eta800 = v(:,14);
% % eta850 = v(:,15);
% % eta900 = v(:,16);
```

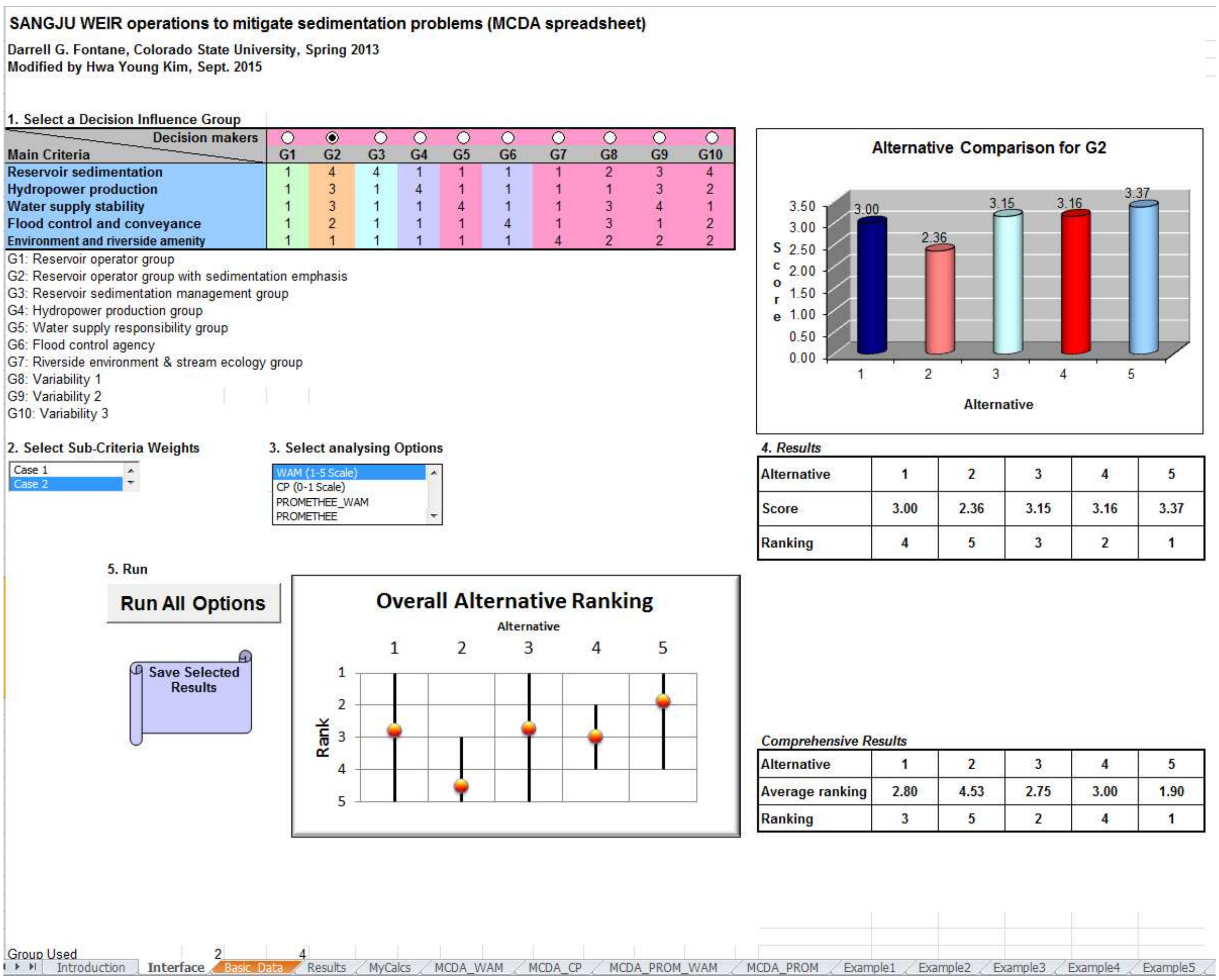
```
% % eta950 = v(:,17);
% % eta1000 = v(:,18);
% % eta1050 = v(:,19);
% %
% % % making eta table combined all together according to H.. from Hill chart
% % eta = [eta300 eta350 eta400 eta450 eta500 eta550 eta600 eta650 eta675...
% %        eta700 eta750 eta800 eta850 eta900 eta950 eta1000 eta1050];
% %
% % % 1cm  H slice
% % H = [3:0.5:6.5 6.75 7:0.5:10.5];
ddH = linspace(3.0,10.5,751);
%ddH = num2str(ddH);
%ddH = str2num(ddH);
%diground = @(x,d) round(x*10^d)/10^d;
%ddH = diground(ddH,2);

% interpolation using dH
% for i = 1:length(Qaa)
% intrp_eta(i,:) = interp1(H, eta(i,:), ddH);
% end
%
% % transpose for interpolation using dQ
% intrp_eta_t = intrp_eta';
%
% 0.01 cms Q slice
%Q=Qaa';
%dQ = [10.4:0.01:11 11.01:0.01:27];
dQ = linspace(10.4,27,1661);
%dQ = [0.01:0.01:11 11.01:0.01:27];

% interpolation using dQ
% for i = 1:length(intrp_eta_t)
% intrp_eta_final(i,:) = interp1(Q, intrp_eta_t(i, :), dQ);
% end
% size(intrp_eta_final);

% write as txt file.
%dlmwrite('intrp_eta_final.txt',intrp_eta_final,'delimiter','\t','precision',
4)

% read the file already saved.....
intrp_eta_final=dlmread('intrp_eta_final.txt');

switch netH<3.0
        case 1
            eta_for_dHdQ = 0;
        case 0
            %id = find(ddH'==netH); % find the col/row number corresponding
'net Head'
            %eta_orderby_dQ=intrp_eta_final(90,:)'; % transpose eta
corresponding...
            %x=dQ';
            ind_H = find(ddH>netH-0.009 & ddH<netH+0.009);
            ind_Q = find(dQ>possQ-0.009 & dQ<possQ+0.009);

                switch possQ<10.4
```

```
                    case 1
                        eta_for_dHdQ = 0;
                    case 0
                        %eta_for_dHdQ = interp1(x, eta_orderby_dQ, possQ);
                        %eta_for_dHdQ = eta_orderby_dQ(id)
                        eta_for_dHdQ = intrp_eta_final(ind_H, ind_Q);
                end % for switch possQ<3.0

    end % for switch netH<3.0

end % for if i statement


% p_ini_kW = 9.81*netH*possQ*eta_for_dHdQ/100;
%
% Pini =[1500; 1125; 750; 375];
% eta_g =[0.985; 0.984; 0.98;0.97];
%
% if p_ini_kW > 1500
%     eta_gear=0.985;
% elseif p_ini_kW < 375
%     eta_gear=0.97;
% else
%     eta_gear = interp1(Pini, eta_g, p_ini_kW);
% end
%
% pkW = p_ini_kW * eta_gear;


end % for function
```

PART 3: MCDA MODELING

Apr29th2016_MCDA_v5.xlsm

Interface page



Module 1

```
Function Interpolate(x, x1, x2, y1, y2)
'This custom function performs linear interpolation
'Developed by D.G. Fontane, January 2001
If x = x1 Then
Interpolate = y1
ElseIf x = x2 Then
Interpolate = y2
Else
Interpolate = y1 + ((y2 - y1) / (x2 - x1)) * (x - x1)
End If
End Function
Sub Splash()
UserForm1.Show
End Sub
Sub Store()
' It is need to change because I moved some cells and graphs by H.Y. Kim, September,
2015

' This custom macro saves results to another worksheet
' Developed by D.G. Fontane, March 2001
Dim row As Integer
Application.ScreenUpdating = False
Sheets("Interface").Select
x1 = Range("M24").Value
x2 = Range("N24").Value
x3 = Range("O24").Value
x4 = Range("P24").Value
x5 = Range("Q24").Value
x6 = Range("M25").Value
x7 = Range("N25").Value
```

```
x8 = Range("O25").Value
x9 = Range("P25").Value
x10 = Range("Q25").Value
x11 = Range("D40").Value
x12 = Range("D41").Value
x13 = Range("D42").Value
x14 = Range("D43").Value
x15 = Range("D44").Value
x16 = Range("A57").Value
x17 = Range("A53").Value
lang = Sheets("Language").Range("B3").Value
If lang = 1 Then
Sheets("Results").Select
ElseIf lang = 2 Then
Sheets("Resultados").Select
End If
row = 15
Do Until (Cells(row, 1).Value = "")
row = row + 1
Loop
Cells(row, 1).Value = x1
Cells(row, 2).Value = x2
Cells(row, 3).Value = x3
Cells(row, 4).Value = x4
Cells(row, 5).Value = x5
Cells(row, 6).Value = x6
Cells(row, 7).Value = x7
Cells(row, 8).Value = x8
Cells(row, 9).Value = x9
Cells(row, 10).Value = x10
Cells(row, 11).Value = x11
Cells(row, 12).Value = x12
```

```
Cells(row, 13).Value = x13
Cells(row, 14).Value = x14
Cells(row, 15).Value = x15
Cells(row, 16).Value = x16
Cells(row, 17).Value = x17
Sheets("Interface").Select
Application.ScreenUpdating = True
End Sub
Sub Cleartable()
Dim row As Integer
Application.ScreenUpdating = False
lang = Sheets("Language").Range("B3").Value
If lang = 1 Then
Sheets("Results").Select
ElseIf lang = 2 Then
Sheets("Resultados").Select
End If
' Erase the Results
Range("A15:Q15").Select
Range(Selection, Selection.End(xlDown)).Select
Selection.ClearContents
Range("A1").Select
End Sub
```

Module 2

```
Dim langold As Integer
Dim langnew As Integer
Sub Change_Lang1()
' Macro Developed 5/02/2002 by  Darrell G. Fontane
' This macro changes the language of the spreadsheet to English
    Application.ScreenUpdating = False
```

```
    Sheets("Interface").Select
    langold = Range("Z2").Value
    If langold = 1 Then GoTo LastLine
    langnew = 1
    Range("Z2").Value = langnew
' Change the page names
    Rename_Pages
'
    Sheets("Interface").Select
    Range("A1").Select
LastLine:
    Application.ScreenUpdating = True
End Sub
Sub Change_Lang2()
' Macro Developed 5/02/2002 by  Darrell G. Fontane
' This macro changes the language of the spreadsheet to Portuguese
    Application.ScreenUpdating = False
'
    Sheets("Interface").Select
    langold = Range("Z2").Value
    If langold = 2 Then GoTo LastLine
    langnew = 2
    Range("Z2").Value = langnew
' Change the page names
    Rename_Pages
'
    Sheets("Interface").Select
    Range("A1").Select
LastLine:
    Application.ScreenUpdating = True
End Sub
Sub Change_Lang3()
```

```
' Macro Developed 5/02/2002 by  Darrell G. Fontane
' This macro changes the language of the spreadsheet to French

    Application.ScreenUpdating = False
'
    Sheets("Interface").Select
    langold = Range("Z2").Value
    If langold = 3 Then GoTo LastLine
    langnew = 3
    Range("Z2").Value = langnew
' Change the page names
    Rename_Pages
'
    Sheets("Interface").Select
    Range("A1").Select
LastLine:
    Application.ScreenUpdating = True
End Sub
Sub Rename_Pages()
Select Case langold
Case 1
    Select Case langnew
        Case 2
            Sheets("Results").Select
            Sheets("Results").Name = "Resultados"
            Sheets("Basic_Data").Select
            Sheets("Basic_Data").Name = "Dados_Básicos"
        Case 3
            Sheets("Results").Select
            Sheets("Results").Name = "Résultats"
    End Select
Case 2
```

```
    Select Case langnew
        Case 1
            Sheets("Resultados").Select
            Sheets("Resultados").Name = "Results"
            Sheets("Dados_Básicos").Select
            Sheets("Dados_Básicos").Name = "Basic_Data"

        Case 3
            Sheets("Resultados").Select
            Sheets("Resultados").Name = "Résultats"
            Sheets("Dados_Básicos").Select
            Sheets("Dados_Básicos").Name = "Basic_Data"

    End Select
Case 3
    Select Case langnew
        Case 1
            Sheets("Résultats").Select
            Sheets("Résultats").Name = "Results"
        Case 2
            Sheets("Résultats").Select
            Sheets("Résultats").Name = "Resultados"
            Sheets("Basic_Data").Select
            Sheets("Basic_Data").Name = "Dados_Básicos"

    End Select
End Select
End Sub
```

Module 3

```
Sub LoadExample()
```

```
Sheets("Basic_Data").Select
ctr = Range("AG1").Value
Select Case ctr
Case 1
Call Example1_Load
Case 2
Call Example2_Load
Case 3
Call Example3_Load
Case 4
Call Example4_Load
Case 5
Call Example5_Load
Case 6
Call Example6_Load
Case 7
Call Example7_Load
End Select
End Sub
Sub Example1_Load()
'
' Example1_Load Macro
' Load Example 1
'
Application.ScreenUpdating = False
'
    Sheets("Example1").Select
    Range("A1").Select
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("A1").Select
    ActiveSheet.Paste
```

```
    Sheets("Example1").Select
    Range("A6:H35").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("A6").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Range("I7:J32").Value = ""
    Sheets("Example1").Select
    Range("I7:J19").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("I7").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Sheets("Example1").Select
    Range("M6:X35").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("M6").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Range("A1").Select
    Sheets("Example1").Select
    Range("A1").Select
    Application.CutCopyMode = False
    Sheets("Basic_Data").Select
    Range("A1").Select
End Sub
```

```
Sub Example2_Load()
'
' Example2_Load Macro
' Load Example 2
'
Application.ScreenUpdating = False
'
    Sheets("Example2").Select
    Range("A1").Select
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("A1").Select
    ActiveSheet.Paste
    Sheets("Example2").Select
    Range("A6:H35").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("A6").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Range("I7:J32").Value = ""
    Sheets("Example2").Select
    Range("I7:J19").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("I7").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Sheets("Example2").Select
    Range("M6:X35").Select
```

```
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("M6").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Range("A1").Select
    Sheets("Example2").Select
    Range("A1").Select
    Application.CutCopyMode = False
    Sheets("Basic_Data").Select
    Range("A1").Select
End Sub
Sub Example3_Load()
'
' Example3_Load Macro
' Load Example 3
'
Application.ScreenUpdating = False
'
    Sheets("Example3").Select
    Range("A1").Select
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("A1").Select
    ActiveSheet.Paste
    Sheets("Example3").Select
    Range("A6:H35").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("A6").Select
```

```
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Range("I7:J32").Value = ""
    Sheets("Example3").Select
    Range("I7:J19").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("I7").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Sheets("Example3").Select
    Range("M6:X35").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("M6").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Range("A1").Select
    Sheets("Example3").Select
    Range("A1").Select
    Application.CutCopyMode = False
    Sheets("Basic_Data").Select
    Range("A1").Select
End Sub
Sub Example4_Load()
'
' Example4_Load Macro
' Load Example 4
'
Application.ScreenUpdating = False
```

```
'
    Sheets("Example4").Select
    Range("A1").Select
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("A1").Select
    ActiveSheet.Paste
    Sheets("Example4").Select
    Range("A6:H35").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("A6").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Range("I7:J32").Value = ""
    Sheets("Example4").Select
    Range("I7:J19").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("I7").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Sheets("Example4").Select
    Range("M6:X35").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("M6").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
```

```
    Range("A1").Select
    Sheets("Example4").Select
    Range("A1").Select
    Application.CutCopyMode = False
    Sheets("Basic_Data").Select
    Range("A1").Select
End Sub
Sub Example5_Load()
'
' Example5_Load Macro
' Load Example 5
'
Application.ScreenUpdating = False
'
    Sheets("Example5").Select
    Range("A1").Select
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("A1").Select
    ActiveSheet.Paste
    Sheets("Example5").Select
    Range("A6:H35").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("A6").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Range("I7:J32").Value = ""
    Sheets("Example5").Select
    Range("I7:J32").Select
    Application.CutCopyMode = False
```

```
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("I7").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Sheets("Example5").Select
    Range("M6:X35").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("M6").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Range("A1").Select
    Sheets("Example5").Select
    Range("A1").Select
    Application.CutCopyMode = False
    Sheets("Basic_Data").Select
    Range("A1").Select
End Sub
Sub Example6_Load()
'
' Example6_Load Macro
' Load Example 6
'
Application.ScreenUpdating = False
'
    Sheets("Example6").Select
    Range("A1").Select
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("A1").Select
```

```
ActiveSheet.Paste
Sheets("Example6").Select
Range("A6:H35").Select
Application.CutCopyMode = False
Selection.Copy
Sheets("Basic_Data").Select
Range("A6").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False
Range("I7:J32").Value = ""
Sheets("Example6").Select
Range("I7:J32").Select
Application.CutCopyMode = False
Selection.Copy
Sheets("Basic_Data").Select
Range("I7").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False
Sheets("Example6").Select
Range("M6:X35").Select
Application.CutCopyMode = False
Selection.Copy
Sheets("Basic_Data").Select
Range("M6").Select
Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
    :=False, Transpose:=False
Range("A1").Select
Sheets("Example6").Select
Range("A1").Select
Application.CutCopyMode = False
Sheets("Basic_Data").Select
Range("A1").Select
```

```
End Sub

Sub Example7_Load()

'

' Example7_Load Macro

' Load Example 7

'

Application.ScreenUpdating = False

'

    Sheets("Example7").Select

    Range("A1").Select

    Selection.Copy

    Sheets("Basic_Data").Select

    Range("A1").Select

    ActiveSheet.Paste

    Sheets("Example7").Select

    Range("A6:H35").Select

    Application.CutCopyMode = False

    Selection.Copy

    Sheets("Basic_Data").Select

    Range("A6").Select

    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _

        :=False, Transpose:=False

    Range("I7:J32").Value = ""

    Sheets("Example7").Select

    Range("I7:J32").Select

    Application.CutCopyMode = False

    Selection.Copy

    Sheets("Basic_Data").Select

    Range("I7").Select

    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _

        :=False, Transpose:=False

    Sheets("Example7").Select
```

```
    Range("M6:Z35").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Basic_Data").Select
    Range("M6").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Range("A1").Select
    Sheets("Example7").Select
    Range("A1").Select
    Application.CutCopyMode = False
    Sheets("Basic_Data").Select
    Range("A1").Select
End Sub
```

Module 4

```
Sub RunAll()
Call Cleartable
Sheets("Interface").Select
ctype = 1
Range("A52").Value = ctype
For ctr1 = 1 To 2
    Range("A56").Value = ctr1
    For ctr2 = 1 To 7
        Range("B40").Value = ctr2
        Call Store
    Next
Next
ctype = 2
Range("A52").Value = ctype
For pwr = 1 To 3
```

```
Sheets("MCDA_CP").Range("Z2").Value = pwr
    For ctr1 = 1 To 2
        Range("A56").Value = ctr1
        For ctr2 = 1 To 7
            Range("B40").Value = ctr2
            Call Store
        Next
    Next
Next
For ctype = 3 To 4
Range("A52").Value = ctype
    For ctr1 = 1 To 2
        Range("A56").Value = ctr1
        For ctr2 = 1 To 7
            Range("B40").Value = ctr2
            Call Store
        Next
    Next
Next
End Sub
```