ESTIMATION OF THE MINIMUM INSTREAM FLOWS FOR THE RIVERLINE AESTHETICS ON THE KEUM RIVER

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Abstract: The method for estimating the minimum instream flows required for the riverline aesthetics, proposed by the Kim et al.(1996), has been applied to the main channel reach of the Keum river basin in Korea. To determine the minimum instream flows for eight main reaches at Keum river basin, six representative stations have been selected. This paper provides an analysis of influence on the riverline aesthetics, which is affected by change of physical components of river, by using the survey-based quantification method. The developed questionnaire based on the literature, and submitted to the 326 people who visited an each representative station. This surveying had been implemented in three times at each representative station and we had been selected a different flowrate at each implementation.

The results of this analysis and survey have produced the relationship between the variation of physical components and riverline aesthetics. Survey results about the flow comparison are summarized as follows. At the view of riverline aesthetics, most of the respondents are sensitive at the change of the flow velocity and they prefer high water level to low water level. Morcover whole respondents prefer to abundant stream flows and moderate flow velocity. The minimum instream flows for riverline aesthetics is estimated at each representative station by using the survey-based quantification method and the estimated results of some representative station are greater than mean monthly flow at each station. The result of the analysis appears that establishing minimum instream flows for riverline aesthetics is not only a technical problem but a legal problem. Therefore in the case of establishing the instream flows in the river, the estimated results have to be considered as relative standard.

Key words: Instream flows, Keum river basin, Riverline aesthetics

1. INTRODUCTION

Guidelines for River Facility Design (Ministry of Construction & Transportation, 1993) defines "instream flow" as "certain quantity of river flow required to maintain normal state and functions of a river at significant sites in river preservation and maintenance". In general, in-

stream flow is the minimum flow required for navigation, water quality preservation, recreation, and riverline aesthetics/ecosystem preservation. Thus the desirable instream flow must be established to satisfy most of the demands in implementation of both natural and artificial functions of river as mentioned above.

Determination of instream flow requires the estimation of minimum instream flow for navigation, fishery, riverline aesthetics, salt damage prevention, water quality, and ecosystem preservation. Among those components, this research will consider the methods for establishment of minimum instream flow in terms of riverline aesthetics.

Generally, determination of instream flow in Korea have depended upon low flows of the river, and the researchers thought of instream flow as water for dilution considering the water quality. Recently, however, researchers developed and suggested a method and its procedures for assessing instream flow considering synthetically all the components such as low flow, water quality, aquatic ecosystem, recreation, and riverline aesthetics(Kim et al., 1996). Then the developed method applied to their survey on the Keum river to assess each minimum instream flow in terms of low flow, water quality, fishery, and riverline aesthetics. Also, other researches developed and suggested methods for establishing instream flow in terms of the presevation aquatic life habitats in Korea(Woo et al., 1998).

Thus this research is an approach to suggest developed method and procedures for instream flow establishment, applying the previously suggested method especially in terms of riverline aesthetics to Keum river basin.

2. APPLICATION OF MINIMUM INSTREAM FLOW ESTIMATING METHOD

2.1 Evaluation of the methods for minimum instrem flow estimation

So far the reference to the method for establishment of instream flow in terms of riverline aesthetics in Korea could be found in the publication of Korean Water Resources Corporation(1995), whose suggestions were based on the methods of Ministry of Construction in Japan. This method depends on simple and easy questionnaire for establishment of minimum instream flow in terms of riverline aesthetics, and the standard for the estimation of minimum instream flow is that the ratio of water surface / river width within 5 degrees of downward look must be more than 0.2 degrees, with an appropriate flow velocity in terms of the type, feature, and local need of respective rivers. Also, the depth of water must be kept in compliance with a standard to keep the river bed materials hidden under the flow lest it should bring a sudden scenic variation to the riverline.

For the assessment of aesthetic scenery, they asked the tourists visiting the spot to answer the questionnaire and analyzed their satisfaction level about the flow rate, surface width, flow velocity, water quality, and so on to evaluate the effect of each component and they estimated the minimum instream flow required for maintaining the scenery.

In this research, to reflect the respondents' satisfaction level in more active and direct way, we measured the discharge and sampled river water for water quality test at the same time the respondents were answering our questionnaire. Also, we implemented this inquiry three times for each scenery station, each time with different

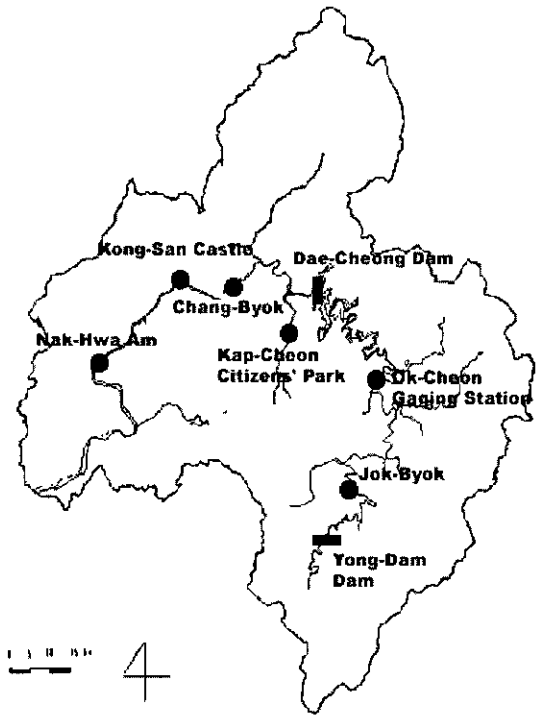

Fig. 1. Location of Each Scenery Station

river flows to analyze the influence of the changing river components.

2.2 Selection of scenery station

The scenery station around Keum river basin which we chose for minimum instream flow estimation in terms of riverline aesthetics were the Keum river downstream main channel reach ranging from Dae-Cheong Dam to Kang-Kyeong and upstream main channel reach ranging from Dae-Cheong Dam to Yong-Dam Dam. About the downstream area, we divided the main channel into five channel reaches as follows:

① Dae-Cheong Dam to Kap stream confluence

② Kap stream confluence to Mi-Ho stream confluence

③ Mi-Ho stream confluence to Kong-Ju

④ Kong-Ju to Kyu-Am

⑤ Kyu-Am to Kang-Kyeung

Also, we divided the upstream main channel into three channel reaches as follows:

① Ok-Chon to Ho-Tan

② Ho-Tan to Su-Tong

③ Su-Tong to Yong-Dam Dam

In the eight channel reaches mentioned above, we picked up ten scenery stations. Each selected stations were historic and scenic places where there were many visitors and where the river flow variation seemed to affect the scenery of the place. Then, through the first investigation on the scene in which we considered the accessibility to the place and possibility of questionnaire implementation, four of them fell out of the list. Therefore, as the Fig. 1 shows, we de

Table 1. Summaries and specific scenic features of the scenery stations

Sites	Scenic Points	Summary	Adjacent Stage Gaging Station
Jok-Byok	Cliffs, Sands, River water	An ideal summer resort whose natural sceneries have been well preserved. The fog and falls coming down from the cliffs in the rain are spectacular. Many tourists come to visit to enjoy fishing and camping.	Su-Tong Gaging Station
Ok-Cheon Station Site	Aquatic lives, Bridge, White sands	10 minutes' distance from Keum River Resting Place. Natural white sands are placed in an open space and many people visit here to enjoy camping on weekends. A bridge goes under the water surface in times of rainfall makes the scenery very spectacle.	Ok-Cheon Gaging Station
Kap Stream Citizens' Park	Bridge, Woods, Bank, Recreation activity	A high level berm is well organized in the riversides and the EXPO park and EXPO bridge provide such a scenery. This is the only urban river in this research.	Hwae-Dok Gaging Station
Chang-Byok	Aquatic lives, River water, Bridge	The scene of rough cliffs with quiet river water is very beautiful. The Forestry Museum is a favorite place for many of the young and the old to visit.	Keum-Nam Gaging Station
Kong-Ju Kong-San Castle	River water, White sands	The capital city of Baekje Dynasty. The scenery seen from the Kongsan castle along with its various historic relics are so great.	Kong-Ju Gaging Station
Nak-Hwa Am	Liner, River water, White sands	A rural river which has an open riverline scenery. This place has a little backwater effect by the Keum river estuary barrage. The banks provide nice scenery as well.	Kyu-Am Gaging Station

cided to estimate the minimum instream flow for six sites in terms of aesthetic riverline scenery and Table 1 shows the summaries and specific scenic features of the scenery stations.

2.3 Scenery Stations Investigation on the Scene

In this research, three investigations at each scenery stations were implemented to establish the minimum instream flow in terms of riverline aesthetics. The first investigation on the scene was made for three days, from Apr. 28 to Apr. 30, 1999 when Keum river basin had their low flows with few rainfalls before our investigation. On the other hand, the second investigation was made for three days from Jun. 25 to Jun. 27, 1999 when a seasonal rain front was moving up to the North. We had a localized torrential downpour of 140 mm in Keum river basin on Jun. 23, which enriched the river flow rates.

The third investigation was made for three days from Aug. 27 to Aug. 29 and we still had relatively much rainfall affected by the seasonal rain front.

In the three investigations we made during the period, we surveyed at each site for the river width and water surface width, and made inquiries over the local citizens of respective area and surveyed their satisfaction level with various hydraulic properties such as the aesthetic scenery seen from the scenery stations, water level, flow velocity, flow rate, and water quality

Table 2. Flow rate status

Stage Gaging Station	Date of Measurement			Discharge (m^3/sec)		
	1st	2nd	3rd	1st	2nd	3rd
Su-Tong	'99. 4. 29	'99. 6. 25	'99. 8. 28	5.3	17.0	51.1
Ok-Cheon	'99. 4. 29	'99. 6. 25	'99. 8. 28	5.4	42.1	126.7
Hwae-Dok	'99. 4. 29	'99. 6. 25	'99. 8. 28	2.7	39.6	20.6
Keum-Nam	'99. 4. 30	'99. 6. 25	'99. 8. 28	131.0	121.0	38.7
Kong-Ju	'99. 5. 1	'99. 6. 27	'99. 8. 29	179.1	190.3	118.7
Kyu-Am	'99. 4. 30	'99. 6. 27	'99. 8. 29	335.5	352.3	223.4

Table 3. Water quality status

Topic / Station	Temperature(℃)			PH			DO(mg/ℓ)		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Jok-Byok	13.5	24.3	21.2	7.6	6.8	6.5	10.7	8.4	7.1
Ok-Cheon Station	13.0	24.2	24.1	7.4	7.4	6.4	11.0	9.0	6.4
Kap Stream Citizens' Park	21.0	26.8	22.9	7.5	6.9	6.7	10.8	8.3	6.0
Chang-Byok	10.0	22.9	24.3	7.6	7.0	6.8	10.9	7.8	5.2
Kong-Ju Kong-San Castle	13.0	24.0	24.5	7.5	7.0	7.1	10.6	7.6	4.3
Nak-Hwa Am	13.0	24.2	24.6	7.5	7.1	7.3	10.7	8.1	4.5
Topic / Station	BOD(mg/ℓ)			COD(mg/ℓ)			SS(mg/ℓ)		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Jok-Byok	1.0	0.8	0.7	2.7	8.0	6.1	5.0	3.5	10.0
Ok-Cheon Station	2.3	1.7	0.9	2.5	9.0	5.8	6.0	9.1	15.0
Kap Stream Citizens' Park	3.2	0.9	1.1	8.3	10.0	5.4	12.0	32.0	23.0
Chang-Byok	3.1	2.2	1.6	6.1	10.5	6.7	13.0	14.0	7.0
Kong-Ju Kong-San Castle	3.3	1.8	1.7	5.3	3.0	6.1	15.0	28.0	10.0
Nak-Hwa Am	3.1	1.7	1.6	5.7	6.0	7.9	23.0	30.0	16.5

to make an intensive analysis on the influence of these components.

Especially, we measured the flow velocity of the day when our inquiry was made with propeller flow meter (Valeport, BFM 001, England). The discharge of the each scenery stations was estimated by the mean velocity, water level, and stream cross section at the adjacent stage gaging station. Table 2 shows the result of our measurement on each sites. Also, Table 3 is the summary of the water quality status measured at each sites.

According to an analysis on the result listed in Table 2, Su-Tong and Hwae-Dok sites showed the influence of rainfalls very clearly with much more discharge in the second and third measurement compared with the discharge we got from the first investigation. On the other

Table 4. Inquiry results for each scenery station

Station	Period	Water level		Flow rate		Flow Velocity		Water Quality
		EL.m	Satisfaction level (%)	m^3/sec	Satisfaction level (%)	m/sec	Satisfaction level (%)	Satisfaction level (%)
Jok-Byok	1st	0.70	60	5.3	47	1.021	80	93
	2nd	1.06	60	17.0	70	0.451	65	60
	3rd	1.34	85	51.1	75	0.365	60	70
Ok-Cheon Gaging Station	1st	0.65	80	5.4	67	1.193	53	67
	2nd	0.80	75	42.1	65	0.684	50	35
	3rd	1.34	70	126.7	50	0.665	85	30
Kap Stream Citizens' Park	1st	0.75	60	2.7	60	0.077	60	30
	2nd	1.04	50	39.6	60	0.473	65	25
	3rd	0.84	70	20.6	85	0.330	40	10
Chang-Byok	1st	0.70	69	131.0	75	0.618	69	68
	2nd	1.06	35	121.0	15	1.319	40	70
	3rd	0.15	65	38.7	60	0.881	45	60
Kong-Ju Kong-San Castle	1st	-1.89	27	179.1	27	0.889	40	34
	2nd	-1.50	50	190.3	55	0.947	35	80
	3rd	-2.05	60	118.7	40	0.877	55	80
Nak-Wha Am	1st	1.35	60	335.5	67	0.342	73	87
	2nd	1.38	35	352.3	35	0.368	30	35
	3rd	0.94	50	233.4	55	0.196	65	25

hand, Keum-Nam, Kong-Ju, and Kyu-Am sites showed somewhat different results; because all these three sites were located in the Dae-Cheong Dam downstream, their discharge were controled by the discharge of Dae-Cheong Dam.

Table 3 shows the water quality level at each scenery stations. About the temperature of the river water, all the sites in the list indicated almost the same temperature except Kap Stream Citizens' Park where we got a somewhat higher temperature compared with that of others. Also, in general, the temperature in the second and the third investigation were higher than that of the first investigation. About pH, all investigated sites satisfied the class I water conditions in the water quality standard, showing almost identical level of pH throughout all the sites.

DO result of all the sites were class I quality in the first and second investigation, but Kong-San castle and Nak-Hwa Am showed class IV quality in the third investigation. Notably, DO results were inversely proportional to the water temperature. The higher water temperature had lower DO values. Also, BOD showed its close correlation with flow rate. As the flow rate increased BOD results decreased in general. About SS, all the sites satisfied class I conditions. But in the second investigation, Keum river basin, where we had a torrential downpour during the investigation, had relatively higher SS rates.

2.4 Analysis on the inquiry results

We implemented inquiry three times over the tourists and citizens visiting the scenery stations. In this survey we made with inquiries, we asked the respondents of their satisfaction with flow level, flow rate, flow velocity, and water quality of the rivers seen from the scenery stations. About the satisfaction level, we prepared five answers in our inquiry: (the water level/flow rate/flow velocity is) too high/much/rapid(in relation with the scenery), high/much/rapid, satisfactory(fair), low/little/slow, too low/little/slow. The percentages for satisfaction levels listed below are the ratio of the respondents who chose "satisfactory(fair)". We had 86 respondents in the first inquiry, 120 respondents respectively for the second and third. Table 4 shows the satisfaction level of the respondents.

According to the analysis of the results, Jok-Byok which is located in the top of Keum river had the highest satisfaction level with all the hydraulic properties including water level, flow rate, flow velocity and water quality due to its excellent natural sceneries and water quality. About the satisfaction level of water quality, Kap Stream Citizens' Park, the only urban river in this research, scored the lowest, and Nak-Hwa Am downstream of the Keum river showed low satisfaction level in the second and third investigation. When we take the result in Table 3 into consideration, we can understand that the increase and decrease of SS rate is closely correlated with water quality.

Besides, other hydraulic properties such as water level, flow velocity, and flow rate didn't show any specific tendency for each scenery stations. This is mainly because respondents who answered our inquiry questionnaire during the survey were different ones each time and the standard in deciding satisfaction level about those components can vary from person to person. Most of the respondents seems to have not been able to show a consistent inclination because they lack the knowledge in hydraulic properties such as flow velocity and flow rate.

Another reason is that our investigation was made from April to August. So the seasonal change of riverline vegetations can cause a change to the aesthetic scenery of a river. As a result, the same flow rate at different season could have cause the different satisfaction level that it gave to the respondents.

3. DETERMINATION OF MINIMUM INSTREAM FLOW

This research tried to analyze the influence of hydraulic property variation on the aesthetic sceneries through inquiries. The respondents answered "satisfactory" in the inquiries for each hydraulic properties which were in harmony with the given sceneries, and this study tried to reflect the respondents' satisfaction level as much as possible. In the process of minimum instream flow determination, the satisfaction level for water quality was excluded because it was SS rate which decided water quality more than any other factors. Thus, the formula we employed for minimum instream flow determination in accordance with the satisfaction level of each hydraulic properties such as water level, flow rate, and flow velocity will be described as follows:

$$Q_{ra} = \frac{\sum_{i=1}^{N} \{[P(h_i)+P(v_i)+P(Q_i)]\times(Q_i)\}}{\sum_{i=1}^{N} [P(h_i)+P(v_i)+P(Q_i)]} \quad (1)$$

In this formula, Q_{ra} is the minimum instream flow(m^3/sec) for riverline aesthetic scenery.

Table 5. Minimum instream flow rate required for riverline aesthetics

Channel	Scenery Station	Minimum instream flow for riverline aesthetics (m^3/sec)	Annual mean flow, 1999 (m^3/sec)
Dae-Cheong Dam Upstream	Jok-Byok	34.9	11.7
	Ok-Cheon Station	58.9	56.1
Dae-Cheong Dam Downstream	Kap Stream Citizens' Park	20.7	14.2
	Chang-Byok	93.4	96.7
	Kong-Ju Kong-San Castle	161.7	127.3
	Nak-Hwa Am	301.1	223.8

Then, $P(h_i)$ is the satisfaction level of water level, $P(v_i)$ is the satisfaction level of flow velocity, $P(Q_i)$ is the satisfaction level of flow rate, and Q_i is the flow rate measured at each site during our investigation (m^3/sec). Thus the minimum instream flows for each site in terms of riveline aesthetic sceneries are shown in Table 5, along with mean yearly flows in 1999.

Table 5 shows that the estimated minimum instream flow for each site is greater in general than the mean yearly rate in 1999. This indicates that people usually feel satisfied with the riverline sceneries abound in flow rates.

In this research, especially, one of the three investigations was implemented when the water level is relatively low(April), and the other two, when the water level is relatively high(June and August). This means that the flow rates we gained might be relatively greater. Therefore, if we apply more detailed flow rate with more inquiries in a research, different result may be drawn. Moreover, where there are four clearly distinctive seasons, such as Korea, the riverline scenery may change by seasons and months and this indicates that the minimum instream flow of a scenery station may change in accordance with the conditions of its surroundings.

4. CONCLUSIONS

In this research, the method for minimum instream flow determination using inquiries (Kim et al., 1996) was employed to assess the minimum instream flow required for the reservation of riverline aesthetics in Keum river basin. The conclusions derived from this research will be surmarized as follows:

The minimum instream flow determination for the six sites around Keum river basin showed similar or somewhat greater compared with the mean yearly flow rate in general indicating that people usually prefer the rivers abound in flows.

About the survey result of the inquiries we have implemented, respondents' satisfaction level in accordance with the variation of various hydraulic properties didn't show any clear inclination. In determining the minimum instream flow using inquiry method, the structure of riverline scenery may vary according to the change of seasons or months. Therefore, to find out a consistent inclination in general about the flow rate, it seems necessary to have more detailed flow rates for each season or month combinated with more inquiries.

As a result, the term "minimum instream flow for riverline aesthetics" is somewhat misleading

because there can be no single value of minimum flow for riverline aesthetic scenery. So, the further investigation on the minimum instream flow for riverline aesthetics for each season or month is required.

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