The Monthly Water Supply Reliability Indexes in the Parallel Reservoir System

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Abstract

Water supply reliability indexes (WSRI) is estimated for assessment of water supply capacity in the downstream for parallel reservoir system in Nakdong River, South Korea, using allocation rule (AR) according to the water supply capacity of each reservoir and the characteristic of parallel reservoir system. The result of the analyzing parallel reservoir system for Andong and Imha reservoir in Nakdong River does not include evidences available enough to decide whether the results of water supply analysis are excellent in the current reliability evaluation or not. However, AR (C) shows a good result in the water supply capacity for each reservoir based on the connected operation system and the total water supply capacity at the control point of downstream by the average water supply capacity and possible range of water supply capacity suggested by this study. The average water supply capacity is analyzed by the reliability of monthly average water supply capacity. Furthermore, the possible range of water supply capacity is estimated by the standard deviation when water deficit occurs. Therefore, AR (C) is useful to establish and estimate the planning water supply capacity according to the monthly water supply condition and the possible range of water supply capacity when the water supply capacity deficit occurs, South Korea.

Keywords: Parallel reservoir system, Allocation rule, Monthly water supply reliability, Water supply reliability indexes

1. Introduction

The evaluation of reliability and drought indexes has been carried out in the evaluation of water supply capacity for the multi-purpose reservoirs, Republic of Korea. Indexes, however, for the evaluation of water supply capacity have not been established perfectly in the water resources management and planning. The evaluation of water supply capacity for the multi-purpose reservoirs had been carried out by the many literatures and the technical reports such as the published reports of water supply capacity evaluation for the current reservoirs (Han River, 1997; Nakdong River, 1998, MOCT & K-water). In such reports, the evaluation of water supply capacity was accomplished and focused on the frequency reliability and quantity reliability. We consider that the evaluation for the reliability, however, is insufficient to provide the data to understand the water supply capacity deficit and the water supply capacity of multi-purpose reservoirs.

Chang (1984) evaluated the reliability of reservoir water supply capacity using the transition probability matrix method (TPMM). Ko *et al*. (1991) carried out the development of monthly operation rate based on the reliability for the monthly operation of multi-purpose reservoirs. KICT report (1994) used the indexes such as reliability, resiliency and vulnerability to evaluate the water supply capacity of various reservoirs. Shim *et al.* (1997) evaluated the reliability after inflow discharge was generated using the stochastic models for the multi-purpose reservoirs. Park and Lee (2006) evaluated the water supply capacity during the drought period using the average water storage capacity of multi-purpose reservoir as the initial condition, and Park *et al*. (2007) evaluated the water supply capacity of parallel reservoir system using AR focused on the reliability.

In this study, we composed the parallel reservoir system using AR, which is suggested by Revelle (1999), for Andong and Imha reservoir located in the upstream of the Nakdong River basin, and analyzed the water supply capacity for the 192 months from 1992 to 2007. Furthermore, we could suggest the reliable data for the evaluation of water supply capacity using the current reliability evaluation and new evaluation indexes such as monthly average water supply probability (MAWSP), average water deficit probability (AWDP), and standard deviation for water deficit (SDWD), Republic of Korea.

2. Reliability Index

2.1 Reliability Index

In this study, we use the seven types of reliability indexes such as reliability, resiliency, vulnerability, monthly average water supply probability (MAWSP), average water deficit probability (AWDP) and standard deviation for water deficit (SDWD), respectively. First, the reliability is the probability that the system carries out the water supply normally under the given time period. The standard for reliability analysis is generally divided into occurrence-based reliability and quantity-based reliability,

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respectively. Occurrence-based reliability can be expressed as the ratio between the total analysis period and the water supply deficit period. And, quantity-based reliability can be expressed as the ratio between the water supply quantity and the water supply deficit quantity. Resiliency is used as the concept how fast the system can be recovered to the normal condition when the damage occurs. It can be used as the standard evaluation in case the water supply capacity deficit occurs because the water supply capacity does not meet the water demand capacity.

2.2 Parallel Reservoir Operation Rule

In this study, allocation rule (AR) is used to evaluate the methodology of water supply ability with the parallel reservoir system. Furthermore, AR is used to supply the water in the downstream of mutually-independent reservoir with the parallel reservoir system. In the water supply analysis using AR, it is possible to allocate according to the water rate supplied from each reservoir at the control point of the same period, and calculate the allocation rate for each month according to the rate of water supply capacity. In this study, AR allocated the water supply capacity of each reservoir using the storage condition of parallel reservoir system, the inflow discharge, and the current water storage. Furthermore, AR satisfied the water supply capacity in the downstream of each reservoir, and evaluated

3. The Assessment of Water Supply Ability Using AR and Reliability

3.1 Model configuration

In this study, we have to consider the reservoir control and temporal/spatial reservoir condition of each reservoir in monthly unit to develop the parallel reservoir system for applying AR (A), AR (B), and AR (C), respectively. And, we should understand the statistical characteristics using the analysis of the monthly inflow discharge, and the water supply capacity can be accomplished by the calculation of water supply allocation rate in the parallel reservoir system. After the inflow discharge and initial condition should be assumed, we can calculate AR coefficients under the condition of water storage capacity and inflow discharge for the parallel reservoir system, and estimate the reliability indexes under the water supply capacity.

3.2 Study watershed

Andong and Imha reservoir are located in the upstream of the Nakdong River, and have the representative parallel reservoir system, Republic of Korea. The watershed area corresponds to 1,584㎢ for Andong reservoir and 1,361㎢ for Imha reservoir, respectively. And, average annual precipitation corresponds to 950mm for Andong reservoir and 983.4mm for Imha reservoir, respectively. And, average annual inflow discharge corresponds to 819 MCM/yr for Andong reservoir and 762 MCM/yr for Imha reservoir, respectively. Figure 1 shows the study watershed.

3.3 Input data and constrained condition

The results of inflow discharge from 1992 to 2007 show that average monthly inflow discharge is 37.62 CMS for Andong reservoir and 24.04 CMS for Imha reservoir, respectively. The constrained condition is set up to apply AR. The initial condition that is applied to Andong and Imha reservoir shows that initial water storage capacity is assumed to the normal pool storage. The upper constrained condition is set up to the normal pool storage for Andong and Imha reservoir, respectively. If the reservoir water storage capacity may be maintained above the normal pool storage, the quantity for above the normal pool storage should be outflow. The lower constrained condition is set up to the dead storage. The constrained condition of outflow capacity is set up that it is larger than zero at any time, and should supply the water perfectly (100%) in July, August, and September in case of water demand capacity for Andong and Imha reservoir.

4. Application and Results

The results of reliability indexes for water supply capacity analysis of Andong and Imha reservoir using AR (A), AR (B), and AR (C) are summarized on the Table 1. From the Table 1, occurrence-based reliability corresponds to 97, 97, and 97% for Andong reservoir, 94, 95, and 94% for Imha reservoir, and 92, 93, and 93% for the control point in the downstream using AR (A), AR (B), and AR (C), respectively. The reliability evaluation for analysis methods and water supply capacity is not clearly carried out in case that the reliability for the total analysis period is suggested only in the current reliability evaluation. However, the calculating results for monthly water supply reliability using the average water supply capacity show that the evaluation for monthly water supply capacity is much clear and exact than quantity-based reliability.

Figure 2 - 4 show the monthly average reliability for Andong reservoir, Imha reservoir, and the control point in the downstream, respectively. From the Figures, we consider that AR can show the evaluation of monthly water supply capacity

clearly which can not be represented using the current single reliability indexes.

5. Conclusions

In this study, we calculate MAWSP, AWSP, and SDWP to complement the short suggestion in the reliability indexes, which evaluate the current water supply capacity. Furthermore, we evaluate the reliability indexes and water supply capacity analysis using AR for Andong and Imha reservoir with the parallel reservoir system in Nakdong River. AR (C) has the almost same contribution from each reservoir, respectively. Especially, for AR (C), the reliability of total water supply capacity in the downstream is the highest, and the average water supply deficit is the lowest in the evaluation of reliability indexes.

Therefore, we can consider that the reliability of water supply capacity, which can not be suggested in the current occurrence-based reliability and quantity-based reliability, for each month can be clearly evaluated using AR (A), AR (B), and AR (C), respectively.

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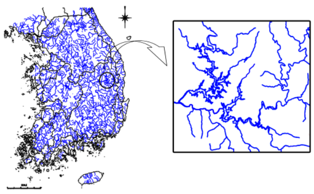
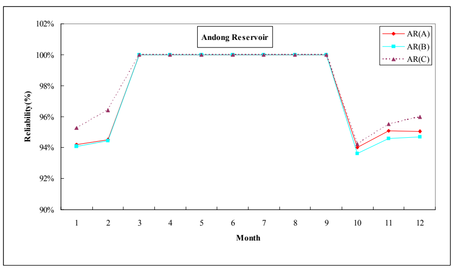


Figure 1. The study watershed



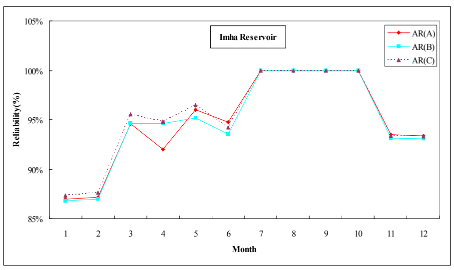


Figure 2. The monthly average reliability for Andong   Figure 3. The monthly average reliability for Imha

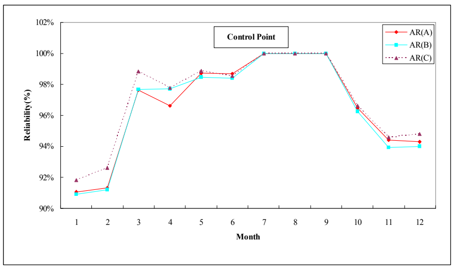


Figure 4. The monthly average reliability for the control point

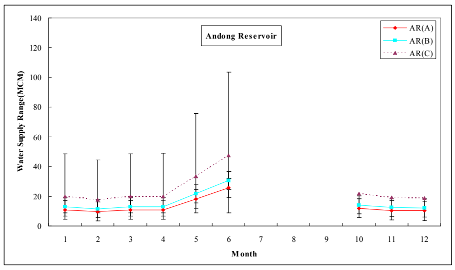


Figure 5. water supply capacity for water deficit of Andong

Table 1. The comparison of reliability analysis results

Classifications		AR(A)	AR(B)	AR(C)
Occurrence-based reliability (%)	Andong	97	97	97
	Imha	94	95	94
	Control point	92	93	93
Quantity-based reliability (%)	Andong	98	98	99
	Imha	94	94	96
	Control point	97	97	98
Resiliency	Andong	0.20	0.20	0.33
	Imha	0.36	0.40	0.36
	Control point	0.29	0.31	0.29
Average water supply capacity for water supply capacity deficit (CMS)	Andong	12.48	10.36	15.81
	Imha	8.74	5.41	10.96
	Control point	56.39	58.23	60.18
Vulnerability	Andong	0.84	0.70	0.74
	Imha	0.71	0.36	0.86
	Control point	4.24	4.07	4.53
Average water supply deficit (CMS)	Andong	40.09	42.21	33.60
	Imha	31.49	31.68	27.27
	Control point	39.06	39.97	34.26
Monthly average reliability (%)	Andong	98	98	98
	Imha	95	95	96
	Control point	97	97	97
Water supply capacity deficit (%)	Andong	24	20	37
	Imha	21	21	27
	Control point	58	55	62
Standard deviation for water deficit	Andong	6.18	6.42	8.91
	Imha	6.19	11.23	9.84
	Control point	17.09	18.97	16.28