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Simulating Daily Runoff in Hydrologic Standard Basin Considering Agricultural Reservoir Operation

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The amounts of streamlow in the downstream are influenced from the operation of agricultural reservoirs upstream. To simulate daily streamflow by considering the operation of irrigation reservoirs upstream located in the standard basins, a system was constructed to simulate the amount of streamflow in order from upstream to downstream standard basins. The DAWAST model was selected to daily hydrologic runoff model, and daily reservoir water balance model was constructed. These two basic models were coupled to the system to simulate the downstream streamflow amount by considering the operation of reservoirs upstream. The Gemho river basin with watershed area of 2,092km^2 was selected to study basin, in which this basin was separated to 20 standard basins and has 21 reservoirs with total water storage above 1 Mm^3. Using the system with runoff and reservoir water balance modules, daily streamflows at each junction were simulated and compared with each other in cases of considering and no considering upstream reservoir operations. And using the above daily simulated streamflows, flow duration curves were drawn and compared with each other. The streamflow amounts of standard basins considering reservoir operations were shown to less than those of no considering reservoir operations in case of agricultural reservoir with low storage capacity. But the Youngcheon dam with high water storage capacity of 81 Mm^3 had a great influence on the downstream stream flow amount according to reservoir operation. The daily runoff modeling of considering upstream reservoir operation resulted more accurately than those of no considering reservoir operation.

Key words: *agricultural reservoir, daily runoff, flow duration*

INTRODUCTION

The operation of upstream dams and reservoirs in the riverbasin has a significant impact on the downstream flow in time. Factors affecting river flow vary not only with the existence of dams and reservoirs but also with reservoir connections, sewage treatment reuse, adjustment of water rights, and with water transfer to other watershed (MOLIT, 2009; Choi, 2010; Ko, 2015). Hydraulic structures in Korea are divided into multipurpose dams, domestic and industrial water dams, hydroelectric dams, and agricultural reservoirs depending on the purpose of supplying water. Of these, the number of agricultural reservoirs is the largest with 17,477 sites nationwide, and the number of reservoirs over 300,000 m^3 is 1,209, accounting for 7% (Kim, 2015). Kim *et al*. (2002) analyzed the change of flow durations in the dam downstream due to the construction of Daecheong dam, and Lee and Kim (2011) analyzed the change of water resources environment due to dam construction. In addition, Kim and Lee (2009) applied the SWAT model to the Soyanggang dam and Chungju dam, and Yeo (2012) applied the SWAT model to the Chungju dam to compare the changes of river flow with and without operation of the multi–purpose dam. Most of the researches in Korea and abroad have been carried out with a large scale hydraulic structure such as multi–purpose dams (Kim *et al*., 2002; Kim, 2007; Shin *et al*., 2007; Mwamila *et al*., 2008; Wellmeyer *et al*.). However, some studies on agricultural reservoirs are limited to some reservoirs in the watershed (Jee *et al*., 2012; Lee and Noh, 2015). It is necessary to determine the impact of agricultural reservoirs on the overall watershed flow for reasonable water resources planning.

Agricultural reservoirs are located in the upstream watersheds nationwide and have a significant impact on the flow of tributary streams. In order to analyze the river flow through an arbitrary boundary point, it is necessary to divide the watershed appropriately for the purpose of analysis considering the reservoir location. The Ministry of Land, Transport and Maritime Affairs has divided the watershed by standardizing the whole country to 21 major regions, 117 central regions, and 840 standard watersheds in order to efficiently implement the national water resources planning and management (http:/ /www.wasis.go.kr).

In the long–term comprehensive plan for water resources (MOCT, 2006), the runoff analysis was carried out by the middle sized regions and the operation of

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agricultural reservoirs and dams was not considered. In order to further study the water resources planning in consideration of tributary streams, it is necessary to consider the operation of agricultural reservoirs and to make reference to the standard hydrologic watershed, which is the minimum watershed unit. As a result of changes in the water environment due to the 4 Rivers Rehabilitation Project, the standard watershed of the water unit map was re–established as Ver. 3.0 (MOLIT, 2010) considering the location of the newly constructed multifunctional weirs and the location of the raised agricultural reservoirs. Therefore, in this study, we considered the operation of the reservoir for the runoff analysis of the standard watershed unit, and constructed a model to quantitatively analyze the flow rate change of the downstream river considering the upstream agricultural reservoirs and dams and to evaluate its usefulness.

MATERIALS AND METHODS

Study areas

The study river basin was selected to the Geumho river basin with watershed area of 2,092 km^2, which is tributary basin of the Nakdong river with watershed area of 23,702 km^2. Land uses of Geumho river basin consist of upland 220.56 km^2 (10.5%), paddy field 382.05 km^2 (18.3%), forest 1,390.46 km^2 (66.5%), urban area 75.91 km^2 (3.6%), and water area 21.25 km^2 (1.0%) as shown in Fig.1.

Geumho river basin has the elevation range from 1,192 meters at the top of mount Palbong to 14.3 meters in the outlet of the Geumho river (reach length 118.4 km), which is located in 206 km from the estuary. Elevation is distributed with 520.85 km^2 below 100 m (24.9%), 618.54 km^2 less than 200 m (29.6%), 340.46 km^2 less than 300 m (16.3%), 239.15 km^2 less than 400 m (11.4%), 170.26 km^2 less than 500 m (8.1%), 102.39 km^2 less than 600 m (4.9%), 54.25 km^2 less than 700 m (2.6%), 28.37 km^2 less than 800 m (1.4%), 12.03 km^2 less than 900 m (0.6%), and 6.04 km^2 over 900 m (0.3%) as shown in Fig. 2.

There are 18 agricultural reservoirs and 2 domestic dams, and one multipurposed dams with effective water storage over 1 Mm^3 within the Geumho river basin as

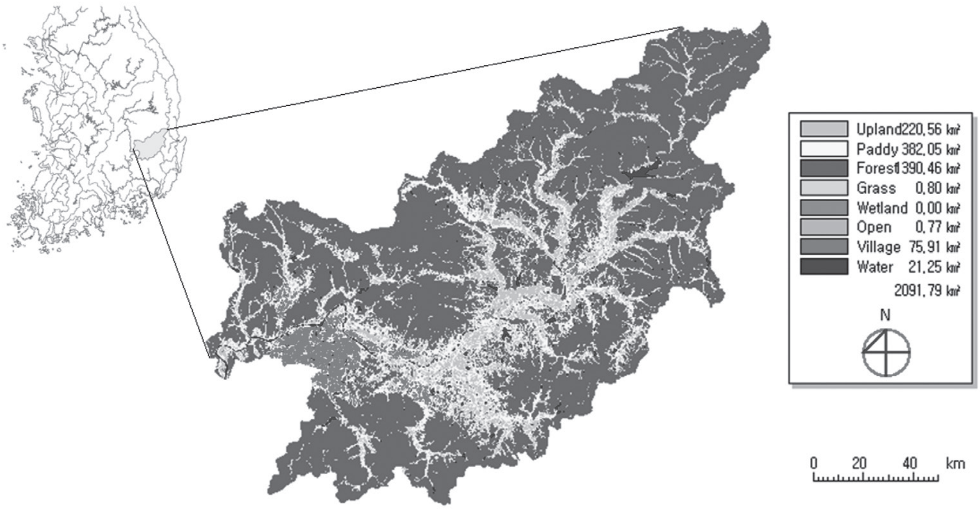

Fig. 1. Location and land uses of Geumho river watershed.

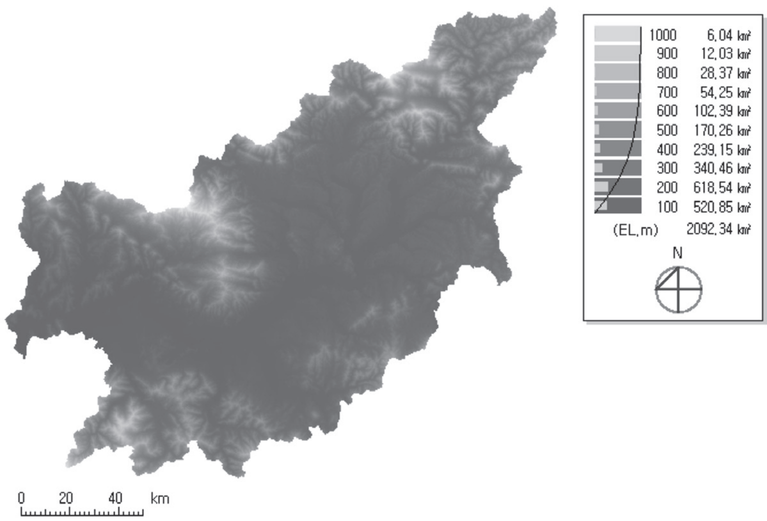

Fig. 2. DEM of Geumho river watershed.

shown in Fig. 3 and Table 1.

The study flow and content include selection of river basin, separation of standard hydrologic basin, data collection, modeling at stream network considering upstream reservoir operation, and comparison of streamflows in cases with and without upstream reservoirs as shown in Fig. 4.

Fig. 3. Separation of standard watershed and location of reservoir and dam within Geumho river watershed.

Table 1. Characteristics reservoirs and dams over 1 Mm^3 within Geumho riverbasin

Reservoir name	Watershed area (km^2)	Effective water storage (10^3m^3)	Irrigated area (ha)	Remark
Total	587.03	120,952.6	4,103	
Youngcheon dam	235	81,400	–	IW[a]: 400,000 m^3/d
Imgo	26.84	1,515	206	
Gogyeong	13.45	1,345.5	215	
Hwasan	3.95	1,009.2	117	
Dangju	8.4	1,028	115	
Pungrak	9.8	2,143.1	235	
Daeseung	7.15	1,619	190	
Soweol	15.17	2,066.3	155	
Muncheon	25.33	2,533.2	1900	
Songrim	11.53	1,199	183	
Yongseong	7.38	1,943	47	
Songnae	5.3	1,087	47	
Hado	4.55	1,199	52	
Songbaek	3.45	1,463	124	
Nammae	0.8	1,120	100	
Dansan	60.88	2,253	59	
Gongsan	60.3	4,500	–	DW[b]: 40000 m^3/d
Gachang	43	8,100	–	DW: 60000 m^3/d
Dongmyeong	26.6	1,451.3	82	
Jicheon	18.15	1,978	276	

[a] IW means industrial water supplied to Pohang area.
[b] DW means domestic water supplied to Daegu city.

Table 2. Watershed area, population, and industry works by sub-watershed within Geumho river basin

Juction No.	Sub-watershed		Population	Industry works
	Name	Area (km^2)		
J01	Youngcheon	234.15	3,055	1,026
	Imgo	25.84	1,313	441
	J01-Youncheon-Imgo	63.33	3,553	1,194
J02	Gogyeong	16.99	996	335
	J02-Gogyeong	100.71	17,007	5,714
J03	Hwasan	3.89	229	77
	Dangji	8.35	597	201
	J03-Hwasan-Dangji	83.63	5,102	1,714
J04	J04	365.32	56,997	19,151
J05	Pungrak	9.80	754	253
	J05-Pungrak	15.33	3,681	1,237
J06	Daeseung	7.00	1,744	586
	J06-Daeseung	58.56	5,904	449
J07	Soweol	1.82	303	23
	J07-Soweol	109.82	24,658	1,874
J08	Muncheon	15.96	11,814	898
	J08-Muncheon	34.44	24,467	1,859
J09	Yongseong	7.53	366	28
	Songrim	11.23	545	41
	J09-Yongseong-Songrim	26.82	1,325	100
J10	Songnae	4.93	550	42
	J10-Songnae	81.19	32,007	2,433
J11	J11	67.54	80,407	6,111
J12	Hado	4.35	235	18
	Songbaek	3.40	184	14
	J12-Hado-Songbaek	69.62	30,443	2,313
J13	Nammae	1.07	2,617	199
	J13-Nammae	36.06	163,154	12,400
J14	J14	1.45	2,742	99
J15	J15	68.27	228,530	8,227
J16	Dansan	0.97	1,829	66
	J16-Dansan	25.82	48,693	1,753
J17	Gongsan	58.86	110,843	8,424
	J17-Gongsan	62.48	228,022	8,436
J18	Gachang	42.14	18,520	667
	J18-Gachang	125.82	409,313	15,144
J19	Dongmyeong	19.73	1,889	70
	J19-Dongmyeong	92.58	397,539	14,709
J20	Jicheon	17.93	1,075	40
	J20-Jicheon	73.41	41,362	1,530

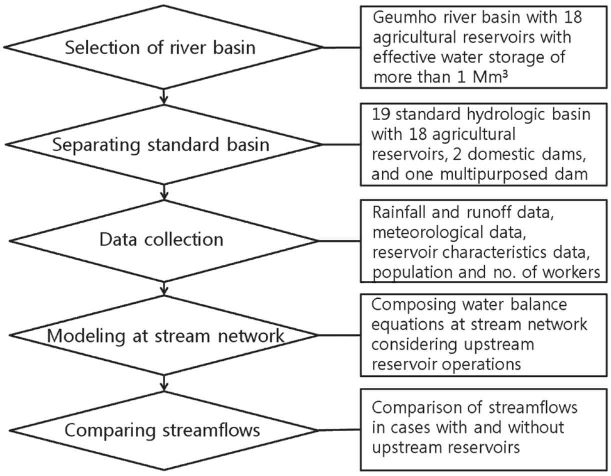

Fig. 4. Study flow an contents.

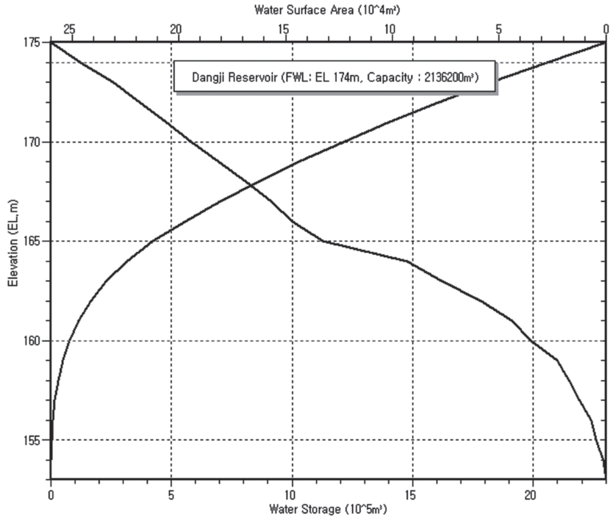

Fig. 5. The example of area capacity curve of Dangji reservoir.

Data sources

Data needed for simulating streamflows considering the operation of reservoirs are rainfall, evapotranspiration, and reservoir water storages on a daily basis. Rainfall and streamflow data were collected from Korea Meteorological Administration (http://www.kma.go.kr), and water management information system called WAMIS (http://www.wamis.go.kr). Meteorological data such as relative humidity, wind speed, sunshine hour were collected from Meteorological Information Portal Service System_ Disaster Prevention (http://afso.kma.go.kr) on a daily basis to estimate evapotransipiration. And reservoir water storages were arranged on a daily basis from effective reservoir water storage ratio data in the Rural Infrastructure Managing System (http://rims.ekr.or.kr). The relationship between elevation and water storage called area capacity curve were collected by reservoir and dam to simulate downstream streamflows by considering water balancing in each reservoir and dam as shown in the example of Fig. 5 and Fig. 6.

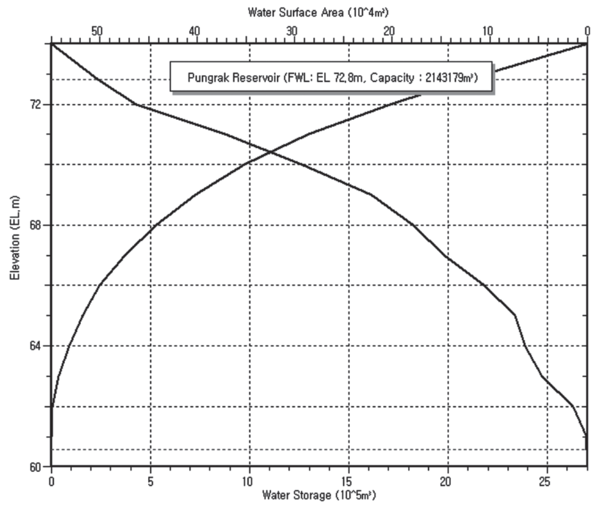

Fig. 6. The example of area capacity curve of Pungrak reservoir.

Analyzing daily streamflows by considering operation of reservoir and dams

To analyze daily streamflows at the outlet streams of standard hydrologic watershed by considering operation of reservoir and dams, stream network of Geumho river was prepared by considering the location of reservoirs and dams as shown in Fig. 7. The amount of streamflows at the junction nodes in Fig. 7 needs to simulate by considering the operation condition of reservoirs located at upstream. To simulate streamflows at the junction nodes of stream network, analysis combination set was classified into 10 cases as shown in Fig. 8, and the equations for analyzing water balance at the junction nodes were composed as equation (1) to equation (10). For example, the streamflow at the junction J01 in Fig. 7 is the case 5 in Fig. 6 and is simulated as equation (5) in which flow at stream (QS) is consisted of outflow from upstream reservoir 1 (SQ_{up1}), overflow from upstream reservoir 1 (OV_{up1}), outflow from upstream reservoir 2 (SQ_{up2}), overflow from upstream reservoir 2 (OV_{up2}), and lateral flow (QL). The streamflow at the junction J04 in Fig. 7 is the case 8 in Fig. 8 and is simulated as equation (8) in which flow at stream (QS) is consisted of flow from upstream 1 (QS_{up1}), flow from upstream 2 (QS_{up2}), and lateral flow (QL). The streamflow at the junction J08 in Fig. 7 is the case 7 in Fig. 8 and is simulated as equation (7) in which flow at stream (QS) is consisted of flow from upstream reservoir (SQ_{up}), overflow from upstream reservoir (OV_{up}), flow from upstream (QS_{up}), and lateral flow (QL).

The reservoir water balance equation is composed of reservoir inflow (QI), evaporation at reservoir water surface (EW), and reservoir outflow for water supply (SQ) in which reservoir water storage (S) is added by reservoir inflow (QI), and is reduced by evaporation at reservoir water surface (EW) and reservoir outflow for water supply (SQ).

$$QS_{down}(i) = SQ_{up}(i) + OV_{up}(i) + QL(i) \tag{1}$$

$$QI_{down}(i) = SQ_{up}(i) + OV_{up}(i) + QL(i) \tag{2}$$

$$QS_{down}(i) = SQ_{up}(i) + QL(i) \quad (3)$$

$$QI_{down}(i) = SQ_{up}(i) + QL(i) \quad (4)$$

$$QS_{down}(i) = SQ_{up1}(i) + OV_{up1}(i) + SQ_{up2}(i) + OV_{up2}(i) + QL(i) \quad (5)$$

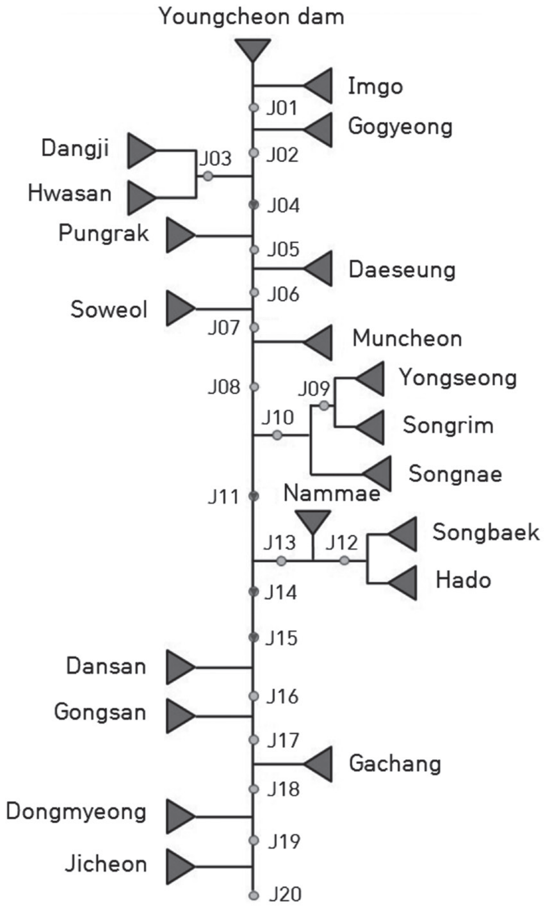

Fig. 7. Stream network of Geumho river by considering the location of reservoirs and dams.

$$QI_{down}(i) = SQ_{up1}(i) + OV_{up1}(i) + SQ_{up2}(i) + OV_{up2}(i) + QL(i) \quad (6)$$

$$QS_{down}(i) = SQ_{up}(i) + OV_{up}(i) + QS_{up}(i) + QL(i) \quad (7)$$

$$QS_{down}(i) = QS_{up1}(i) + QS_{up2}(i) + QL(i) \quad (8)$$

$$QI_{down}(i) = SQ_{up}(i) + OV_{up}(i) + QS_{up}(i) + QL(i) \quad (9)$$

$$QI_{dow}n(i) = SQ_{up}(i) + QS_{up}(i) + QL(i) \quad (10)$$

$$S(i) = S(i\text{-}1) + QI(i) - EW(i) - SQ(i) \quad (11)$$

$$OV(i) = S(i) - FS, \text{ if } H(i) > FH \quad (12)$$

The runoff model called DAWAST model (Noh, 2001) as shown in Fig. 9 was selected to simulate reservoir inflow and lateral flow on a daily basis, in which return flows from paddy fields (35%) and domestic and industrial areas (65%) were added to natural flow by DAWAST model. The DAWAST model is conceptual lumped hydrologic model with 5 parameters such as UMAX (unsaturated maximum soil depth), LMAX (saturated maximum soil depth), FC (field capacity), CP (coefficient of deep percolation), and CE (coefficient of watershed evapotranspiration).

Comparing streamflows at stream junction nodes with and without considering upstream reservoir operations

From upstream to downstream, reservoir inflows are simulated using equation (11) on a daily basis. Reservoir outflow for water supply (SQ) is paddy irrigation water and is estimated on a daily basis based on paddy water requirements composing of evapotranspiration by Penman Monteith equation, infiltration rate (here applied to 5 mm/day), hydraulic facility management loss rate (15%), and cultivation management loss rate (20%). The amount of water supplied to the paddy field is calculated by the amount of irrigated area multiplied by pond-

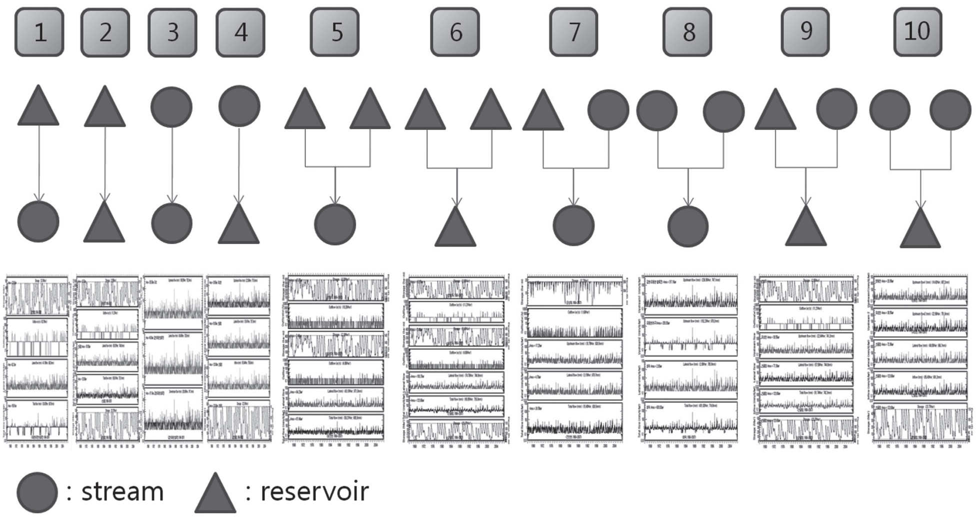

Fig. 8. Classification of stream network for stream water balancing by considering the location of reservoir.

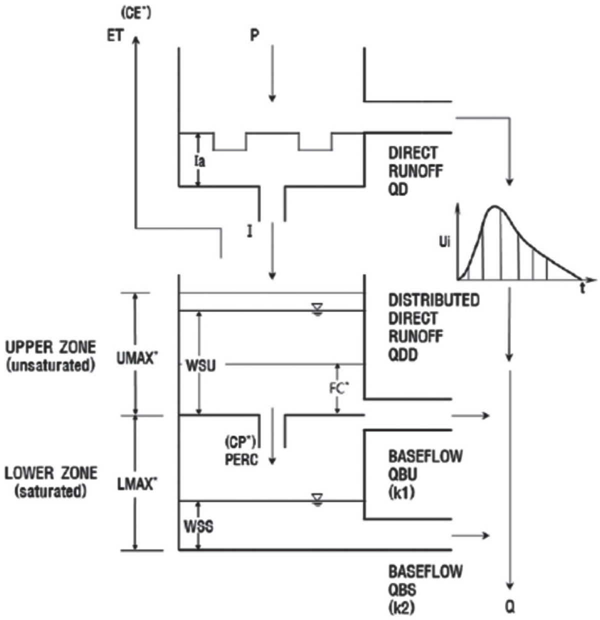

Fig. 9. chematic diagram of DAWAST model.

ing depth required in each cultivation periods (maximum 60 mm). An effective rainfall is considered in calculating ponding depth. The streamflows at the junction nodes of standard hydrologic basin are simulated by considering the operation of upstream reservoirs on a daily basin. And then assuming that there are no reservoirs upstream, the streamflows at the junction nodes of standard hydrologic basin are also simulated in the same method. Using the above result, two simulated streamflows are compared by drawing flow duration curve (FDC). Streamflows at the junction nodes are simulated from 1966 to 2016 on a daily basis, annual averaged daily streamflows are sorted from high to low, and the 1st, 95th, 185th, 275th, 355th flows, and annual sums are compared.

RESULTS

Simulating daily reservoir storages

Using observed reservoir water storages from 1991 to 2015, parameters of DAWAST model were determined and reservoir inflows were simulated on a daily basis. And paddy water requirements to the irrigated paddy area were estimated on a daily basis. Using the above data, the reservoir water storages were simulated by equation (11). And the reservoir simulated water storages were compared with the observed through equal value line (EVL). The above process was performed on all selected reservoirs and dams within the Geumho river basin.

Fig. 10 and Fig. 12 show examples of daily reservoir simulated water storages in Dangji and Pungrak reservoirs, respectively. And Fig. 11 and Fig. 13 show examples of EVLs on Dangju and Pungrak reservoirs, respectively. The simulated result of reservoir water storages on Dangji reservoir showed annual mean rainfall 1,106.2 mm (9.28 Mm^3), reservoir inflow 436.6 mm (3.66 Mm^3), runoff ratio 39.5%, water surface evapora-

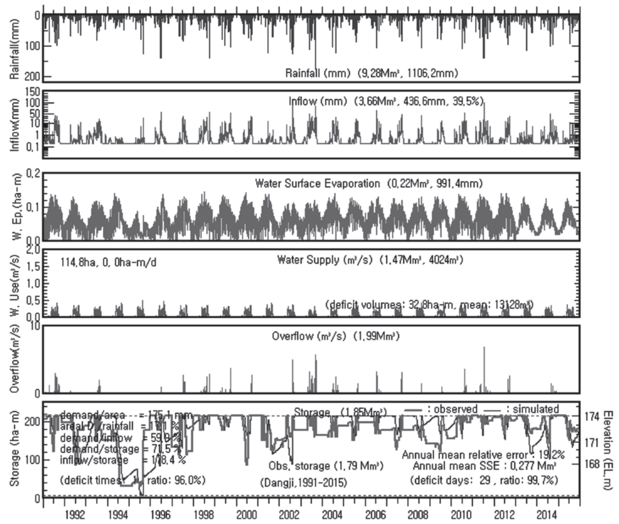

Fig. 10. Comparison of daily reservoir water storages by equation (10) (Dangji, 1991~2015).

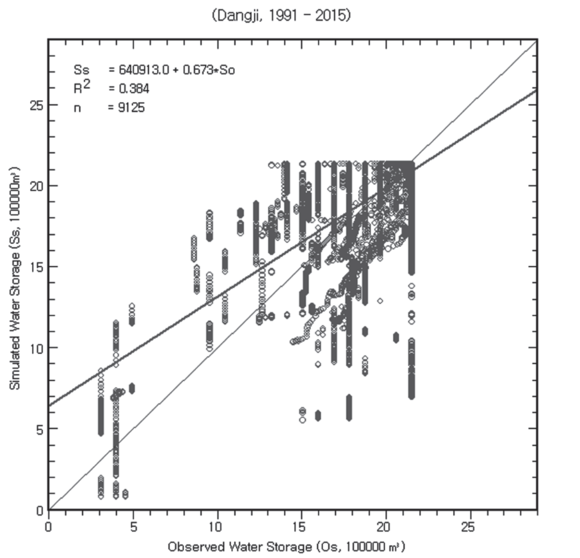

Fig. 11. Equal value line between observed and simulated daily reservoir water storage (Dangji, 1991~2015).

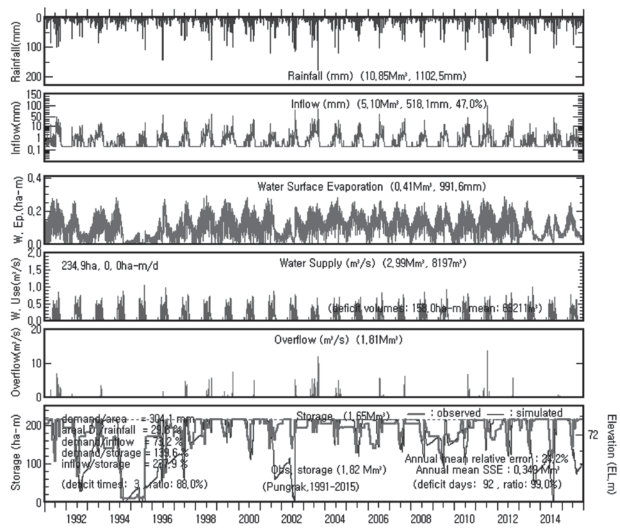

Fig. 12. Comparison of daily reservoir water storages by equation (10) (Pungrak, 1991~2015).

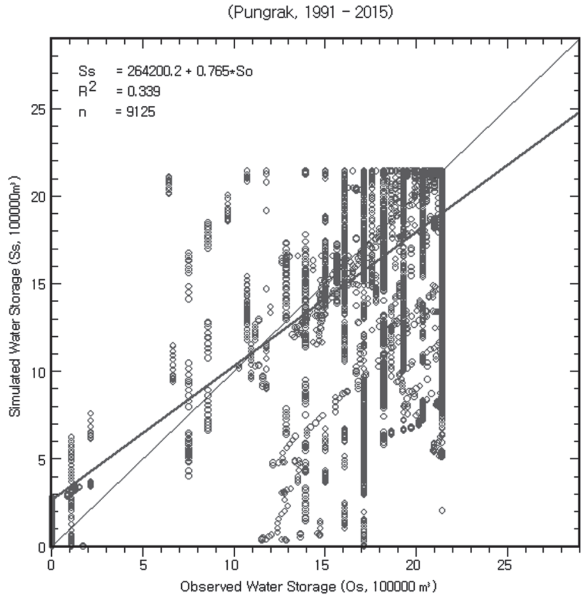

Fig. 13. Equal value line between observed and simulated daily reservoir water storage (Pungrak, 1991~2015).

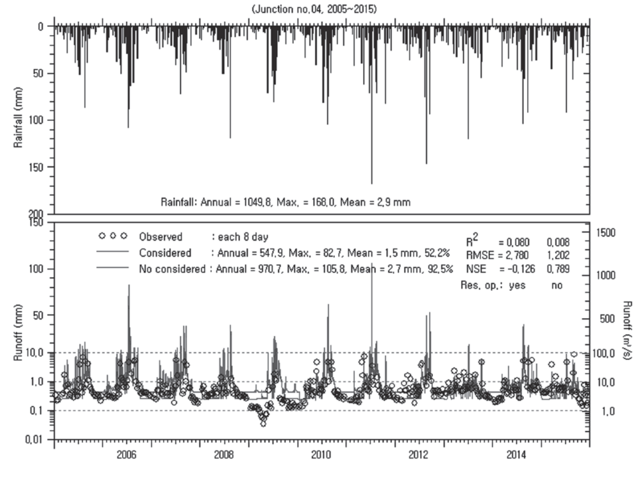

Fig. 15. Comparison of streamflows simulated at the junction node J04 in cases with and without considering upstream reservoir operation, and each 8 day observed streamflows.

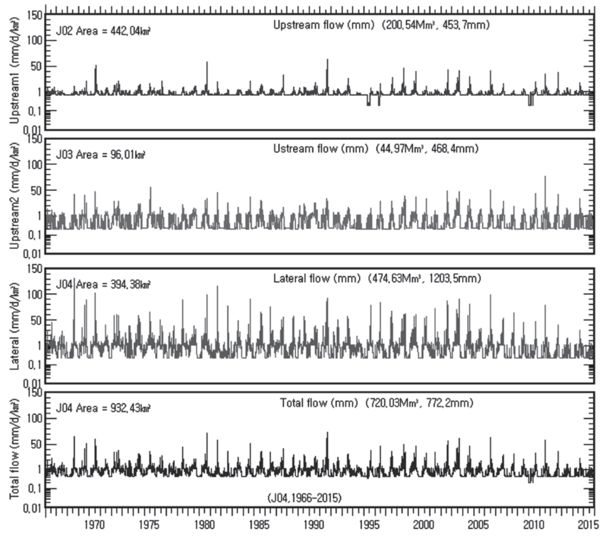

Fig. 14. Daily streamflow simulated at the junction node J04 in case considering upstream reservoir operation.

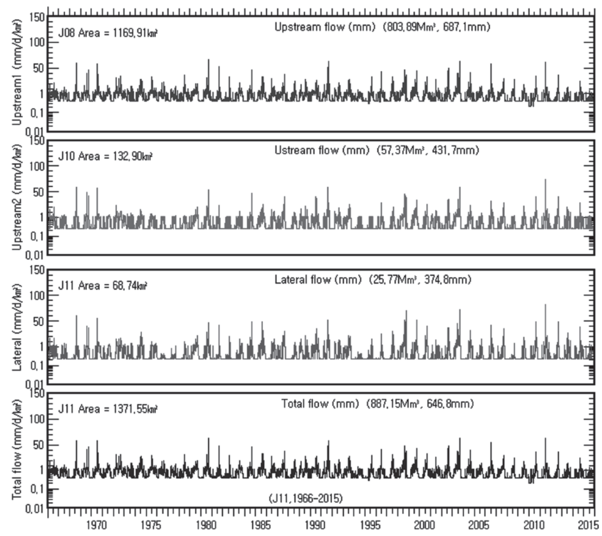

Fig. 16. Daily streamflow simulated at the junction node J11 in case considering upstream reservoir operation.

tion 0.22 Mm³ (991.4 mm), supplied irrigation water 1.47 Mm³ (irrigated area 114.8 ha), overflow 1.99 Mm³, and reservoir mean water storage 1.85 Mm³ (observed 1.79 Mm³). And the result of Pungrak reservoir annual mean rainfall 1,102.5 mm (10.85 Mm³), reservoir inflow 518.1 mm (5.10 Mm³), runoff ratio 47.0%, water surface evaporation 0.41 Mm³ (991.6 mm), supplied irrigation water 2.99 Mm³ (irrigated area 234.9 ha), overflow 1.81 Mm³, and reservoir mean water storage 1.65 Mm³ (observed 1.82 Mm³). Equal value lines were scattered in 45 degrees but simulated water storages were evaluated to be allowable taking into account the past occasionaly observing environment based on the eyes of observer.

Simulating streamflow at the junction nodes of hydrologic standard basin

Streamflows at the junction nodes of each hydrologic standard basin were simulated in cases with and without considering upstream reservoir operations on a daily basis. Simulation results at the junction nodes such as J04, J11, J14, J15, and J20 with observed data were shown as examples in Fig. 14 (J04), Fig. 16 (J11), Fig. 18 (J14), Fig. 20 (J15), and Fig. 22 (J20). And simulation results were compared with each other in cases with and without considering upstream reservoir operations, and were compared with observed streamflow data. Fig. 15, Fig. 19, and Fig. 22 showed examples of comparing with each 8 day observed data. And Fig. 17 and Fig.

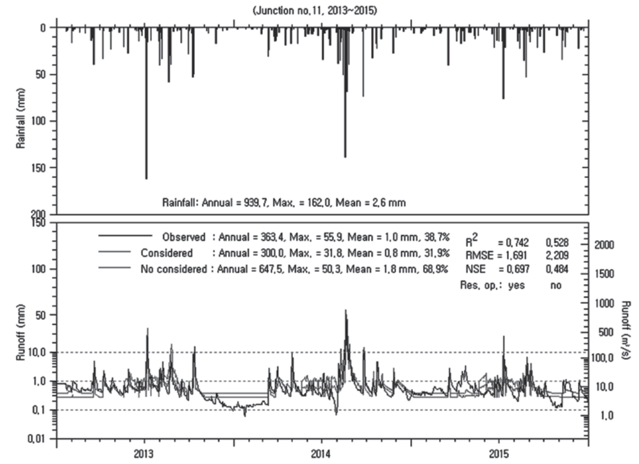

Fig. 17. Comparison of streamflows simulated at the junction node J04 in cases with and without considering upstream reservoir operation, and observed streamflows.

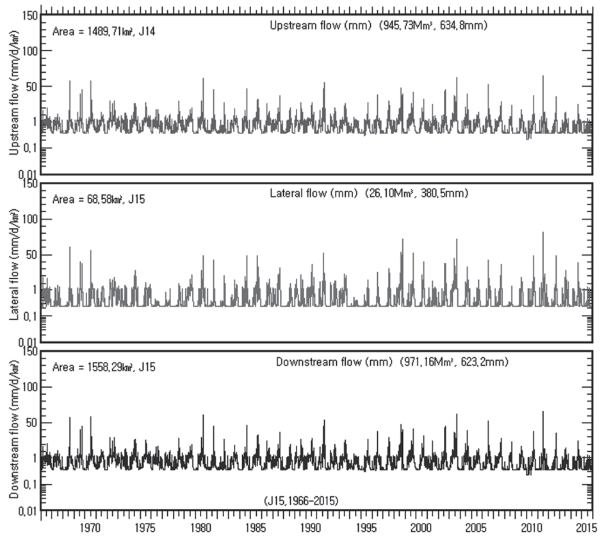

Fig. 20. Daily streamflow simulated at the junction node J15 in case considering upstream reservoir operation.

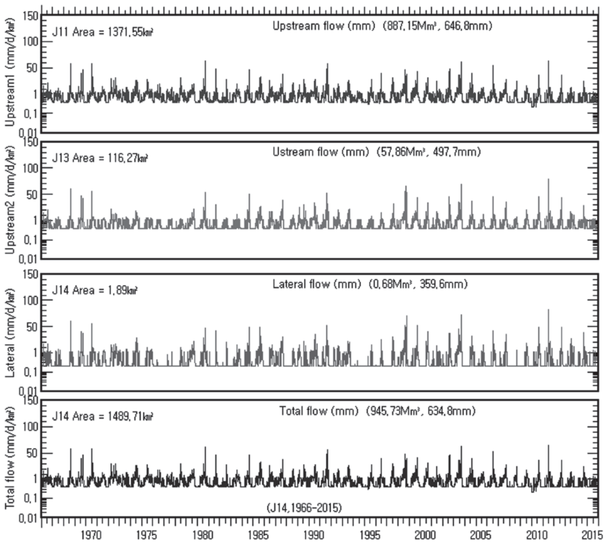

Fig. 18. Daily streamflow simulated at the junction node J14 in case considering upstream reservoir operation.

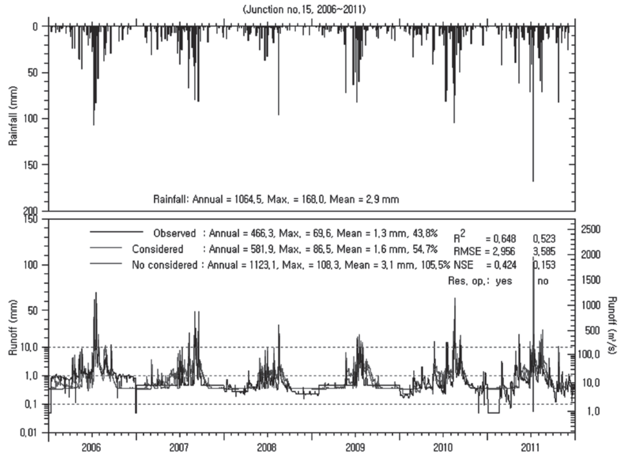

Fig. 21. Comparison of streamflows simulated at the junction node J15 in cases with and without considering upstream reservoir operation, and observed streamflows.

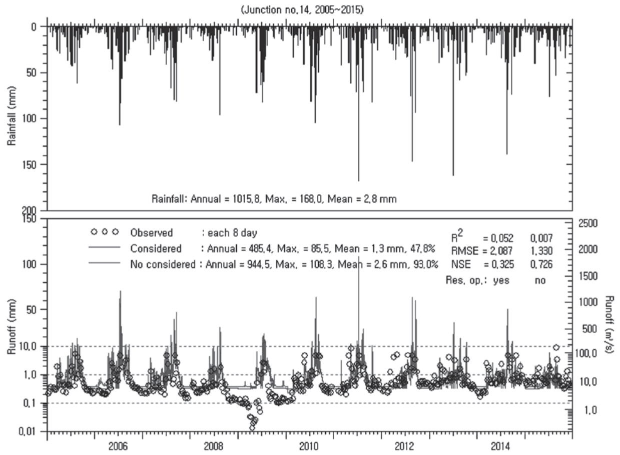

Fig. 19. Comparison of streamflows simulated at the junction node J14 in cases with and without considering upstream reservoir operation, and each 8 day observed streamflows.

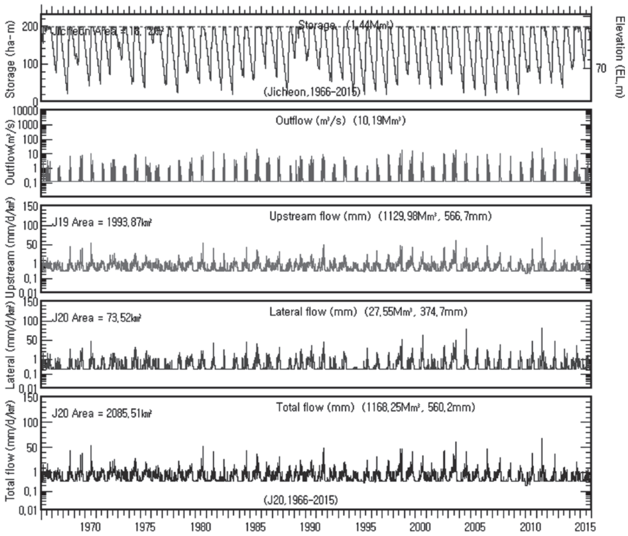

Fig. 22. Daily streamflow simulated at the junction node J20 in case considering upstream reservoir operation.

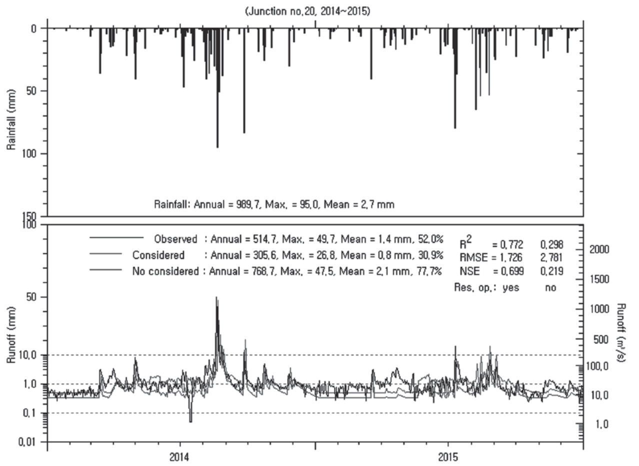

Fig. 23. Comparison of streamflows simulated at the junction node J20 in cases with and without considering upstream reservoir operation, and observed streamflows.

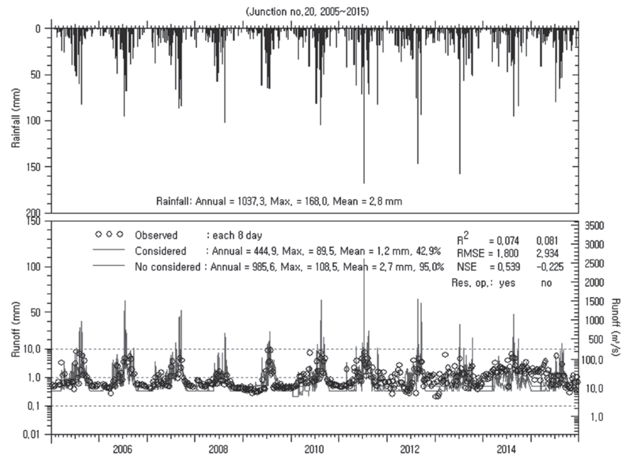

Fig. 24. Comparison of streamflows simulated at the junction node J20 in cases with and without considering upstream reservoir operation, and each 8 day observed streamflow.

Table 3. The results of flow duration analyses in the junction nodes of hydrologic standard basin with and without considering the upstream reservoir operations

Junction no.	1st flow (mm)		95th flow (mm)		185th flow (mm)		275th flow (mm)		355th flow (mm)		Annual flow (mm)	
	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no
J01	24.12	32.58	0.98	0.81	0.88	0.35	0.86	0.23	0.82	0.22	479.5	427.6
J02	24.64	32.62	0.89	0.89	0.73	0.38	0.69	0.25	0.66	0.24	453.5	434.0
J03	34.52	38.83	1.13	1.28	0.39	0.43	0.23	0.25	0.21	0.24	468.3	514.6
J04	47.31	32.75	1.32	0.90	0.74	0.37	0.51	0.26	0.44	0.24	772.2	431.9
J05	46.94	32.76	1.31	0.92	0.73	0.38	0.50	0.26	0.44	0.25	766.0	435.9
J06	45.79	39.19	1.26	0.94	0.70	0.38	0.48	0.26	0.42	0.25	739.9	439.9
J07	44.50	41.26	1.20	1.02	0.67	0.40	0.46	0.26	0.40	0.25	704.1	469.5
J08	43.80	41.27	1.17	1.07	0.65	0.41	0.45	0.27	0.39	0.26	687.1	477.5
J09	27.65	38.22	0.65	0.89	0.29	0.35	0.20	0.23	0.20	0.22	344.5	434.1
J10	32.66	38.39	0.97	1.31	0.39	0.46	0.26	0.30	0.25	0.28	431.5	507.5
J11	41.67	38.12	1.13	1.07	0.62	0.41	0.42	0.28	0.37	0.28	646.9	458.6
J12	34.92	38.49	0.95	1.01	0.36	0.39	0.24	0.25	0.22	0.24	439.0	471.1
J13	36.09	39.34	1.08	1.73	0.52	0.89	0.39	0.73	0.36	0.69	497.2	678.2
J14	40.63	38.16	1.13	1.12	0.62	0.45	0.42	0.32	0.37	0.31	634.9	473.1
J15	40.32	38.20	1.11	1.17	0.61	0.48	0.41	0.36	0.36	0.34	623.1	489.6
J16	40.13	40.02	1.10	1.19	0.60	0.48	0.41	0.37	0.36	0.35	618.8	496.2
J17	39.25	38.63	1.07	1.27	0.58	0.53	0.39	0.41	0.34	0.40	598.9	519.2
J18	38.19	40.61	1.03	1.33	0.55	0.61	0.37	0.46	0.33	0.44	578.3	566.3
J19	37.68	39.21	1.00	1.33	0.54	0.62	0.37	0.50	0.33	0.48	566.7	554.9
J20	37.39	37.76	0.99	1.35	0.54	0.61	0.37	0.49	0.33	0.47	560.1	549.0

21 showed examples of comparing with daily observed data. The simulation results in case with considering upstream reservoir operation were better than that in case without considering reservoir in determination coefficient (R^2), root mean square error (RMSE), and Nash–Schcliffe model efficiency (NSE) without the result in Fig. 15.

Flow duration analysis

Using the above simulated streamflow results at the junction nodes of hydrologic standard basin within Geumho river basin in cases with and without considering upstream reservoir operations, flow duration curves were derived and compared each other as shown in Table 3. FDCs at major junction nodes were shown in Fig. 25. From the above flow duration analyses at the junction nodes, it was concluded that the amount of streamflow was affected from the upstream reservoir operations in more or less according to the reservoir capacity, and its effects were decreased less along the river reach downstream. Youngcheon dam with high water storage capacity of 81 Mm^3 had a great influence

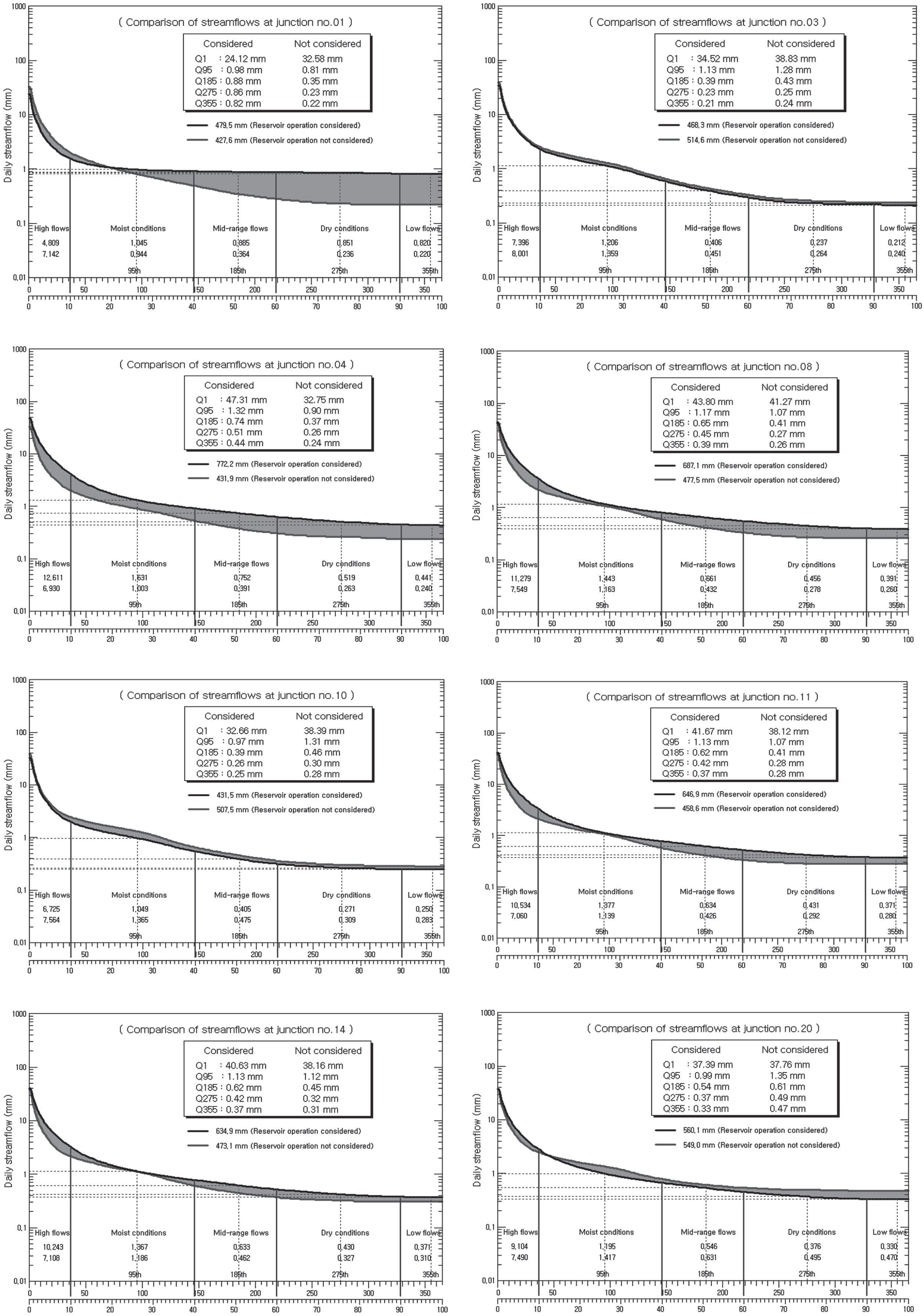

Fig. 25. Comparison of flow duration curves at major junction nodes of hydrologic standard basin in cases with and without upstream reservoir operations

on the downstream stream flow amount according to reservoir operation from the result of junction node, J01. But the amount of streamflows was more affected from the return flows in the domestic and industrial areas within the watershed.

DISCUSSION

To verify the possibility of modeling streamflows by hydrologic standard basin considering the upstream agricultural reservoir operation, the Geumho river basin watershed area of 2,092 km^2 with 18 agricultural reservoirs with over 1Mm^3 was selected to test watershed. And 2 dams are located within the basin to supply domestic water, and one multipurpose dam. Hydrologic standard basin was separated into 20 basins which located one or two reservoirs, or have no reservoirs. Stream network was constructed, and the water balance equations at the junction nodes in hydrologic standard basin were composed of 10 cases for simulating daily streamflows considering stream network. The amount of streamflows was simulated on a daily basis in cases with and without upstream reservoir operations. FDCs were drawn and compared with each other. The results obtained are as follows;

First, the streamflows considering upstream reservoir operations were better simulated than that in case of no considering upstream reservoirs.

Second, the amount of streamflow in hydrologic standard basin with large water storage reservoir affected more than that with small water storage reservoir.

Third, return flows from urban areas with many population showed to the amount of stream flows to a great extent

AUTHOR CONTRIBUTIONS

Jaekyoung NOH carried out substantial contribution to the concept and design on this paper. Jaenam LEE supervised the project, analyzed the data and wrote the paper. Yoshiyuki SHINOGI commented the possibility to apply to the Japanese watershed. Taek–Keun OH carried out analysis and interpretation of data. All authors commented on the manuscript.

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