Effect of the Peace-Dam Construction on the Flood Discharge and the Flood Stage of the Hwachun-Dam

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ABSTRACT/Because of the Keumkangsan-Dam and the Peace-Dam constructed in recent years, it is expected that the peak flood discharge and the peak flood stage at the Hwachun-Dam site have been changed. In this study, two methods were used to simulate and compare the effects of the upstream dam construction on the change of the discharge and the stage. One is the storage function method widely used for the hydrological routing in this country. The other is the DWOPER(Dynamic Wave Operational Model) package developed by the U. S. NWS for the hydraulic routing. Flood routing simulations have been conducted on four different scenarios: (1) before the construction of the Keumkangsan-Dam and the Peace-Dam; (2) the exclusion of the Keumkangsan-Dam watershed (before the construction of the Peace-Dam); (3) the exclusion of the Keumkangsan-Dam watershed (after the construction of the Peace-Dam); (4) the exclusion of the Peace-Dam watershed. The results of the four test cases from the two methods show that the peak flood discharge and the peak flood stage at the Hwachun-Dam site are reduced due to the construction of the Peace-Dam. From these findings, it is suggested that the operational criteria for the optimal dam-operation of the Hwachun-Dam need to be modified.

1. Introduction

In the upstream of the Hwachun-Dam, there is the Keumkangsan-Dam, which is under construction by the North Korea, and between these two dams there exists the other one called the Peace-Dam, constructed against the Keumkangsan-Dam by the South Korea for a defensive purpose. Most of the past research, aimed at the flood control of the Han River, were to analyze the discharge at the Hwachun-Dam without considering effects caused by these two upstream dams and the regional characteristics of the North Korea. Hence, the expected value of the flood inflow at the Hwachun-

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Dam site showed considerable deviation from field data during recent years, and this is due to the influence of those two dams located in upstream.

In this study the data on both the Peace–Dam, the first stage of its construction was finished in May, 1988, and the Keumkangsan–Dam, which started to be constructed in October, 1986, are applied by analyzing and summarizing in many aspects. Flood discharge and inflow by frequency will be estimated after the whole watershed is divided into a number of subwatersheds instead of assuming the Hwachun–Dam watershed as a single watershed as in the previous research, and flood routing will be performed on the basis of these results. The inflow, discharge, and flood stage at the Hwachun–Dam will also be analyzed for several possible conditions which may take place in this watershed, and this will provide useful information for more effective operation and usage of the Hwachun–Dam in the future.

2. Data Collection and Calibration

In this study, the characteristics of the upstream Hwachun–Dam watershed, the present condition of each dam, and the data on runoff and discharge were analyzed and summarized(Ministry of Construction 1979, 1980, 1989, 1980∼1990, Central Meteorological Office 1982, 1984, 1985, 1986, 1990). Since there were few hydrologic data available such as rainfall record which is essential for research, except the flood inflow into the Hwachun–Dam and the discharge from the Hwachun–Dam, there was difficulty in estimating rainfall and discharge of each subwatershed, and analyzing optimal operation between the Peace–Dam and the Hwachun–Dam.

2.1 Present Condition and Characteristics of the Watershed

The watershed for this study is divided as shown in Figure 2.1 to determine the characteristics of each subwatershed and the results are shown in Table 2.1 (Korea Committee on Construction Promotion 1988, Sunwoo Joong Ho 1986, People's Committee on the Peace–Dam Construction 1987, 1987. 3∼1988. 6, Committee on Academic Research 1986).

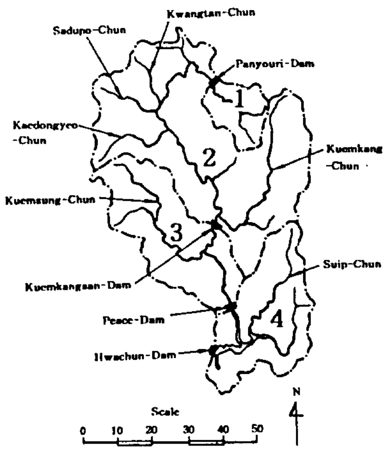


Figure 2.1 Watershed Map for the Hwachun–Dam

Table 2.1 Characteristics of the Watershed (Length of Width : km)

Watershed Name	Classi-fication	Watershed Area A(km²)	Channel Slope S(%)	L (km)	L_c (km)	Width of longer side of water shed	Width of shorter side of watershed	Shape Factor A/L^2
Panyouri-Dam	①	244	–	–	–	–	–	–
Kuemkangsan-Dam	②	2,394 (2,150)	0.45 (0.25)	135 (103.5)	36.5 (43.7)	80.5	54.5	0.13 (0.23)
Peace-Dam	①②③	3,277 (2,983)	0.38 (0.22)	171 (139.5)	68.5 (67.7)	80.6	80.5	0.11 (0.17)
Hwachun-Dam	①②③④	4,092 (3,848)	0.36 (0.18)	195 (163.5)	75.5 (74.4)	89.0	80.5	0.11 (0.16)
Rest of Peace-Dam Watershed	③	833	0.72	90	48.5	55.0	24.3	0.11
Rest of Hwachun-Dam Watershed	④	865	1.27	71	33.0	42.0	39.0	0.18
Present Hwachun-Dam	③④	1,689	0.61	114	36.0	59.5	45.5	0.14

* The number in ( ) is the value when the Panyouri-Dam watershed is excluded.

2.2 Analysis of Watershed Inflow and Discharge Record

a. Average Monthly Inflow and Discharge at the Hwachun Reservoir and the Peace-Dam Site

Average monthly inflow during the recent 10 years(1981～1990) is shown in Table 2.2, and average yearly inflow is 104.2 CMS. But, in case of watershed diversion to the East Sea due to the construction of the Keumkangsan-Dam, it is expected that the average yearly inflow of the Hwachun Reservoir will be reduced to 41.7 CMS by about 58.5% from the estimation based on watershed area ratio, compared with that before the construction of the Keumkangsan-Dam.

Since there were no field data on the average monthly inflow at the Peace-Dam site, the average monthly inflow was estimated by the watershed area ratio as the simplest method. And, on the basis of the Hwachun-Dam discharge record of 10 years since 1981, average monthly discharge has been estimated and discharge record shown in the table is the sum of power plant releases and spillway discharge, mostly occurred during the summer rainy season(KEPCO 1983, 1986, 1988, 1991)

As shown in Table 2.2, the discharge of the 10-year-period is greater than the inflow of the same period. Also, from the stage of 172.5m at the beginning of 1981 and the stage of 174.1m at the end of 1990, it can be concluded that the reservoir's storage has been increased with age. However, since these two facts are not consistent with natural phenomenon, and the data on inflow and discharge during the past 10 years seem to be low in their credibility, considering incoming sediments into the reservoir, which is estimated 1.54 CMS, some extra research and measures are needed to enhance the confidence level of data.

b. Hourly Flood Inflow of Maximum Known Flood

Hourly flood discharge at the Hwachun-Dam site can be estimated by using rainfall distribution and inflow hydrograph. However, since the field data on the rainfall distribution are not available, this study corrected the measured hydrograph of maximum known flood which occurred at the Hwachun-Dam between September 1, 1984 and September 5, 1984, as shown in Figure 2.2 to estimate the time distribution of inflow by applying to the peak flood discharge for each frequency.

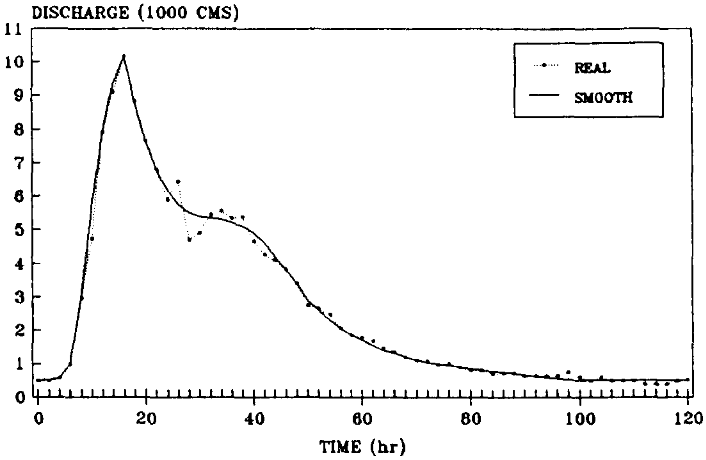


Figure 2.2 Inflow Hydrograph for maximum known flood at the Hwachun-Dam

Table 2.2 Average Monthly inflow of the Hwachun-Dam and the Peace-Dam(CMS)

Classification	Month / Dam		1	2	3	4	5	6	7	8	9	10	11	12	Yearly Average
Inflow	Hwachun		13.7	18.9	38.6	63.1	60.5	79.5	282.8	308.5	267.5	48.7	48.3	20.9	104.2
	Peace	B	10.2	11.9	33.6	78.1	46.4	52.6	241.2	236.3	147.1	35.5	25.0	15.6	78.0
		A	2.9	3.3	9.4	21.8	13.0	14.7	67.3	66.0	41.1	9.9	7.0	4.4	21.8
Discharge	Hwachun		44.8	41.3	40.1	59.4	73.8	95.8	251.9	255.6	267.9	57.7	55.1	49.7	108.2

(B : Before the construction of the Kuemkangsan-Dam
A : After the construction of the Kuemkangsan-Dam)

3. Estimation of Flood Inflow for Each Rainfall Frequency

3.1 Determination of Probable Flood and Maximum Flood Inflow for the Entire Hwachun-Dam Watershed

This study obtained probable flood and maximum flood inflow for the entire Hwachun-Dam watershed by frequency analysis, using measured flood record. In general, for the analysis of annual maximum series, Weibull formula is proved to be the most suitable one by V.T. Chow(1964), and for annual exceedence series, the California plotting position method and the Hazen formula. Thus this study used the Weibull formula to estimate the peak flood, and the California formula for the determination of maximum flood inflow(Ministry of Construction 1980, 1982).

a. Calculation of Probable Flood Discharge

Peak flood discharge was calculated by the frequency analysis, using annual exceedence series between 1954 and 1986(the data after 1987 were not used in order to exclude the influence of the Keumkangsan–Dam construction). The average of the data used was 4,520.76 CMS, the standard deviation, 2,322.2 CMS, skewness coefficient, 0.808, and in logarithmic scale for the same data, average was 3.958, standard deviation, 0.233, skewness coefficient, –0.2668. Using these data, frequency analysis was conducted for the normal distribution, the log–normal distribution, the Pearson Type 붗 distribution, and the Type 붏 extremal distribution(Sunwoo Joongho 1985, Yoon Yongnam 1986). For the results of frequency analysis, Kolmogorov–Smirnov test was carried out. Since maximum difference, Dn for each distribution type has smaller value than critical value for significance level, 빓=5%(95% confidence), $D^{0.05}$=0.235, the distributions considered in this study can be accepted as the representative for the adopted data on annual maximum peak flood. But, since the standard deviation of the normal distribution was the highest among 5 distributions as 0.0987, with exclusion of this, the values by the Log–Pearson Type 붗 distribution, which is known to be the most suitable for the frequency analysis of flood data, Type 붏 extremal distribution(Gumbel distribution), and the log normal distribution, which shows the lowest standard deviation, 0.0462 in this frequency analysis, were averaged to determine the peak flood discharge.

b. Calculation of Maximum Flood Inflow

Since the determination of flood inflow in the design of structure can be generally affected not only by the maximum value occured in a certain year, but by the second biggest value, it is advisable to analyze it, using annual excedence series. Like the estimation of peak flood discharge,

Table 3.1 Probable Flood Inflow(CMS) and Probable Maximum Flood Inflow(10^6m^3/day)

Probability Year	Average of Log–normal, Gumbel, and Log–Pearson	Adopted Probable Flood	Average of Pearson, Gumbel, Log–Pearson	Adopted Flood Inflow
1/500	16,830	16,800	1,414	1,450
1/200	14,658	14,700	1,240	1,250
1/150	13,931	13,900	1,191	1,200
1/100	13,056	13,000	1,117	1,150
1/50	11,483	11,500	998	1,000
1/25	9,932	9,900	882	900
1/10	7,898	7,900	730	750
1/5	6,331	6,300	614	650

subsequent statistical parameters were obtained, using the data which is greater than 20,000 CMS between 1954 and 1986 ; average, 480.00, standard deviation, 180.66, skewness coefficient, 1.18, and in logarithmic scale for the same data, average, 2.655, standard deviation, 0.1488, skewness coefficient, 0.631. Using these values, frequency analysis was carried out by the normal distribution, the lognormal distribution, the Pearson Type Ⅲ distribution, Log Pearson distribution, and Gumbel distribution. To find out a proper distribution type, the Kolmogorov-Smirnov test was conducted and, by the same procedure of determining peak flood discharge, maximum flood inflow was calculated as shown in Table 3.1.

3.2 Probable Flood Discharge and Maximum Flood Inflow by Frequency at Unguaged Site

a. The Determination of Probable Flood Discharge, Occurence Time, and Rainfall Duration

In this study, probable maximum flood discharge and occurence time were determined for 50, 100, and 200-year return period by applying Kajiyama's and Wilbur Smith's peak flood discharge estimation formula, and Wilbur Smith's and Nakayasu's synthetic unit hydrograph method(Ministry of Construction 1981~1990, Korea Institute of Construction Technology 1989). Retention depth due to surface depression, final infiltration capacity in Holton's and Holtan's formula, and rainfall loss by SCS method were considered to calculate effective rainfall for the application of the unit hydrograph method. As a result, the average rainfall loss in the watershed was estimated at about 7.5 mm/hr. Since the values of base flow for the flood of September 1, 1984, known to be maximum peak flood record, was not greater than 480 m^3/sec, 500 m^3/sec was adopted for the base flow of the safety value. However, since there is no field data on base flow during a flood inflow for other subwatersheds, the base flow was estimated by comparing the data of Pyungchang river watershed, where the soil condition is similar and field data were available, and maximum known base flow for the Hwachun-Dam watershed according to area. The resulting relationship between base flow and area ratio estimated that the base flow is approximately proportional to the area ratio raised to the power of 2/3. Using this relatioship, the base flow values for each watershed were estimated as follows : 450 CMS for the Peace-Dam, 350 CMS for the Keumkangsan-Dam, 200 CMS for the rest of the Peace-Dam and the Hwachun-Dam, 300 CMS for the present Hwachun-Dam. The average was calculated by comparing probable flood by frequency for the Hwachun-Dam watershed(calculated by each method) with measured probable flood of the Hwachun-Dam watershed(calculated previously) and adjusting the peak flood of each subwatershed(calculated by each method) to be 100% on the basis of the Hwachun-Dam. The result shows this value is very close to the area ratio raised to the power of 0.6 on the basis of the peak flood of the Hwachun-Dam watershed, where measured data is available. Therefore, adopted peak flood by frequency for each subwatershed was determined by applying the proportion of the area ratio raised to the power of 0.6 to the peak flood by frequency for the Hwachun-Dam watershed.

Table 3.2 Comparison of Peak Flood by Frequency according to Estimating Method

Watershed Name	Return Period	Estimating Method of Peak Flood(CMS)							Rainfall Duration	Peak Flood Occurrence Time
		Kajiyama	W.S.	Snyder	Nakayasu	Average	Value by area ratio	Adopted Value		
Hwachun -Dam	50year	11,559	11,720	11,461	11,467	11,552	–	11,500	15	16
	100year	13,065	13,107	12,949	12,948	13,017	–	13,000		
	200year	14,738	14,833	14,590	14,619	14,695	–	14,700		
Peace-Dam	50year	9,924	10,600	9,474	9,649	9,912	9,870	9,900	15	15
	100year	11,220	11,893	10,692	10,971	11,194	11,158	11,200		
	200year	12,657	13,500	11,974	12,325	12,614	12,617	12,650		
Kuemkangsan -Dam	50year	8,223	9,400	7,750	7,993	8,342	8,110	8,150	10	11
	100year	9,294	10,607	8,718	8,963	9,396	9,168	9,200		
	200year	10,485	12,000	9,782	10,090	10,589	10,367	10,400		
Rest of Peace-Dam Watershed	50year	4,481	6,640	3,124	3,739	4,496	4,591	4,600	8	10
	100year	5,065	7,429	3,490	4,160	5,036	5,190	5,200		
	200year	5,713	8,500	3,872	4,666	5,688	5,869	5,900		
Rest of Hwachun-Dam Watershed	50year	4,664	6,800	3,537	3,872	4,718	4,696	4,700	6	8
	100year	5,272	7,571	3,944	4,274	5,265	5,309	5,350		
	200year	5,947	8,667	4,382	4,775	5,943	6,003	6,060		
(Present) Hwachun-Dam	50year	6,997	8,680	6,347	6,351	7,094	7,039	7,050	13	14
	100year	7,909	9,679	7,064	7,147	7,950	7,957	8,000		
	200year	8,923	11,000	7,872	8,030	8,956	8,998	9,000		

* Flood discharge by area ratio was calculated by the formula, peak flood × $(\text{area ratio})^{0.6}$
* Values for the Hwachun-Dam was adopted from the result of the analysis of field data(Table 3.1)

In the Snyder's method design rainfall duration, which is applied to estimate the design flood for each watershed, is 1.5 ~ 2.5 times as large as Sherman's recommended values(Sunwoo Joongho 1985). In the Nakayasu's method, all the design rainfall durations for watersheds remain in Sherman's suggested range. For the Hwachun-Dam watershed, design rainfall duration by Nakayasu's method was about 15 hours. On the other hand, design rainfall duration by Snyder's method was about 30 hrs. Peak flood occurence time by Snyder's method was 23 ~ 30 hrs ; by Nakayasu's method, it was 8 ~ 18 hrs. Considering that peak flood occurence time of maximum known flood at the Hwachun-Dam watershed(which occured between September 1, 1984 and September 5, 1984) was 16 hours, design rainfall duration and peak flood occurence time by Nakayasu's method is considered to be more suitable for this watershed.

b. Maximum Flood Inflow by Frequency

Since the data on flood inflow are available only for the present Hwachun-Dam site, and the three fourths of the entire watershed is in the North Korean territory, it is difficult to collect the information about the soil type, land usage and other related data of this region. Hence, maximum flood inflow for the unguaged sites within the watershed can only be estimated by a simple area ratio method, which assumes that the entire watershed generally shows similar discharge phenomenon. In this way, maximum flood inflow by frequency for each unguaged subwatershed was estimated by using the probable maximum flood inflow(adopted flood inflow) as shown in Table 3.3.

Table 3.3 Probable Maximum Flood Inflow at the Hwachun-Dam and Unguaged Area(10^6m^3/dya)

Watershed Name	Return Period					
	10year	25year	50year	100year	200year	500year
Hwachun-Dam (Analysis of field data)	750	900	1,000	1,150	1,250	1,450
Peace-Dam	600	700	800	900	1,000	1,100
Kuemkangsan-Dam	450	500	600	650	700	800
Rest of Peace-Dam Watershed	160	200	220	250	270	310
Rest of Hwachun-Dam Watershed	170	200	230	260	280	320
(Present)Hwachun-Dam	350	400	450	500	550	650

3.3 Design Flood Inflow Hydrograph

By considering peak flood, rainfall duration, and peak flood occurence time for each subwatershed, which were determined previously, design flood inflow hydrograph was constructed by frequency. For the Hwachun-Dam, the form of design flood inflow hydrograph is shown in Fig 2. 2 by smoothing the maximum known flood. For other subwatersheds, it is constructed in a way which considers the general trend of the smoothed maximum known flood inflow hydrograph for the Hwachun-Dam, and then sets the probable maximum flood inflow for maximum value.

4. Flood Routing

In this study, the changes of stage, inflow, and discharge in each simulation for the Keumkangsan -Dam, Peace-Dam, and Hwachun-Dam were traced by storage function method(Kimura 1961), which is most popular hydrologic routing method, in Korea, and by DWOPER(Dynamic Wave Operational Model) Package, a nonsteady flood routing model, which is programmed to employ the weighted four point implicit method by U.S. NWS(National Weather Service)'s Hydrologic Research Laboratory as a hydraulic routing.

4.1 Hydrologic Flood Routing

The analysis of flood stage, inflow, and discharge at the Hwachun-Dam site was simulated for the following four different cases : 1) Before the construction of the Keumkangsan-Dam and the Peace -Dam, 2) The exclusion of the Keumkangsan-Dam watershed(before the construction of the Peace-Dam), 3) The exclusion of the Keumkangsan-Dam watershed(after the construction of the Peace-Dam), and 4) The exclusion of the Peace-Dam watershed. Assuming that dam stages are generally maintained to be full, EL. 175.0 m of critical stage at the Hwachun-Dam is used as the initial condition for flood routing, and discharge during flood was based on natural flood control method, which opens all the spillway gates fully. According to the management regulation for hydraulic power plant dam(Korea Electric Power Corporation 1983), when a sudden increase in flood discharge at the upstream is expected, preliminary discharge should be made below the critical stage. As a result this assumption is thought to be reasonable. Table 4.1 and Table 4.2 show the maximum stage and discharge by return period at the Hwachun-Dam and Peace-Dam site by simulating each the special cases respectively. The stage-storage relationship of the Hwachun Reservoir applied for this simulation, was the same as in the safety analysis report on hydraulic power plant dam by KEPCO, 1986.

Table 4.1 Maximum Stage and Discharge at the Hwachun-Dam Site

Watershed Condition	Classi-fication	Return Period		
		50year	100year	200year
Before the Construction of the Kuemkangsan-Dam Before the Construction of the Peace-Dam	Stage Discharge	182.00 7,618	182.66 8,667	83.47 10,017
After the Construction of the Kuemkangsan-Dam Before the Construction of the Peace-Dam	Stage Discharge	179.88 4,551	180.44 5,292	180.96 6,045
Shut-down of the Peace-Dam's Tunnel	Stage Discharge	178.02 2,357	178.40 2,749	178.78 3,184

Table 4.2 Maximum Stage and Discharge at the Peace-Dam Site

Watershed Condition	Classi-fication	Return Period		
		50year	100year	200year
Before the Construction of the Kuemkangsan-Dam	Stage Discharge	205.2 5,000	209.0 5,297	212.9 5,600
After the Construction of the Kuemkangsan-Dam	Stage Discharge	185.6 2,959	187.2 3,170	188.9 3,389

* Stage(EL.m), Discharge(CMS)

Table 4.3 Maximum Stage and Discharge under the Relational Operation between the Hwachun-Dam and the Peace-Dam

Dam Site	Classi-fication	Return Period	Before the Construction of the Kuemkangsan-Dam	Modification of the Kuemkangsan-Dam Watershed
Hwachun-Dam	Maximun Stage (EL.m)	50year	180.08	178.82
		100year	180.35	179.18
		200year	180.63	179.52
	Maximun Stage (CMS)	50year	4,804	3,227
		100year	5,174	3,662
		200year	5,573	4,096
Peace-Dam	Maximun Stage (EL.m)	50year	201.03	184.18
		100year	204.19	185.53
		200year	207.60	187.01
	Maximun Stage (CMS)	50year	4,154	2,182
		100year	4,430	2,344
		200year	4,712	2,517

Table 4.3 shows stages and discharges at the Hwachun–Dam and the Peace–Dam when the effects of the Peace–Dam is considered, assuming the Hwachun–Dam's initial stage to be critical stage of EL. 175.00 m. As shown in this table, for the flood of 200 year frequency at the Peace–Dam, maximum stage is 207.6 m and discharge is 4,712 CMS ; at the Hwachun–Dam, maximum stage is 180.63 m and discharge is 5,573 CMS. Hence, there is no problem in flood control.

4.2 Hydraulic Flood Routing(DWOPER)

To run DWOPER, the entire range was divided into two reaches : one from the Hwachun–Dam to the Peace–Dam, and the other from the Peace–Dam to the Keumkangsan–Dam. For the reach from the Hwachun–Dam to the Peace–Dam, 12 sections were provided(13 input nodes), and for the reach from the Peace–Dam to the Keumkangsan–Dam, 13 sections. Section data at each node were prepared from the Basic Plan for River Modification(Bukhan river, Yangku Seochun) and data provided by KWRC(Korea Water Resources Corporation). Flood inflow from each subwatershed was also assumed to inflow laterally from six equally distanced calculation points between these two dams. The initial condition was automatically calculated by backwater analysis in DWOPER by giving the initial channel discharge and limiting stage at downstream dam, and limiting stage, EL. 175.0 m, was used for the initial stage at the Hwachun–Dam. For the upstream boundary condition, a discharge hydrograph was used at each dam, and for the downstream boundary condition, a rating curve of downstream spillway was used.

The estimated maximum discharge, lag time, and maximum stage of the reservoir are shown in Table 4.4. Here, the difference between the result by reservoir routing and that by DWOPER ranged

Table 4.4 Result of Flood Routing at the Hwachun–Dam Site

Classification	Method	Return Period	Maximum Stage (EL.m)	Maximum Discharge (CMS)	Lag Time (hr)
Before the construction of the Peace–Dam and the Kuemkangsan–Dam	Storage Function	100year 200year	182.66 183.47	8,667 10,017	22.0 21.5
	DWOPER	100year 200year	182.87 183.30	8,622 9,311	25.5 23.5
Exclusion of the Kuemkangsan–Dam Watershed(Before the construction of the Peace–Dam)	Storage Function	100year 200year	180.44 180.96	5,292 6,045	21.0 21.0
	DWOPER	100year 200year	180.31 180.82	4,795 5,516	22.5 22.5
Exclusion of the Kuemkangsan–Dam Watershed(After the construction of the Peace–Dam)	Storage Function	100year 200year	179.18 179.52	3,662 4,096	21.0 20.0
	DWOPER	100year 200year	179.39 179.87	3,632 4,232	17.5 17.5
Shut–down of Peace–Dam's Tunnel	Storage Function	100year 200year	178.40 178.78	2,749 3,184	15.0 15.0
	DWOPER	100year 200year	178.36 178.73	2,463 2,868	16.5 16.5

from 4 to 35 in maximum storage aspect. Since the Hwachun–Dam watershed has a greater storage capacity, which causes lateral inflow, compared to other dam sites, and because the determination of section in Paro Lake, has a great influence on calculation , network analysis and more study on the watershed data are needed to enhance the results by DWOPER. From the calculations of the storage equation method and the DWOPER, with gates fully opened and initial stage maintained to the limiting stage of 175.0 m, the result was that maximum stage for 200 year frequency due to construction of the Keumkangsan–Dam was EL. 180 m, and this shows the Hwachun–Dam has enough freeboard, considering that the flood stage of the Hwachun–Dam is EL. 183 m, and full reservoir level is EL. 181 m.

5. Analysis of the Influence of the Peace–Dam

In the case of before the construction of the Peace–Dam, the backwater effect by the Hwachun–Dam in the site of northern boundary line(entrance of Kuemsungchun) is calculated as follows : 197.83m, 198.75m, and 199.87m for the flood of 50, 100, and 200 year frequency respectively. Hence it can be shown that for the flood of 200 year frequency , the stage can be increased to 8m at the entrance of Kuemsungchun, due to the flow discharged through permanent discharge tunnel. This also means that burdens upon the Hwachun–Dam can be alleviated during flood due to the construction of the Peace–Dam.

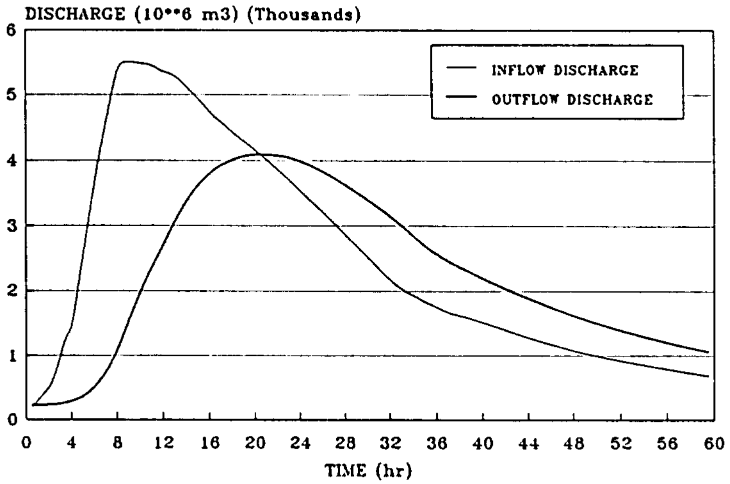
In the northern truce line, Anbu is located at an elevation of 318.0m along with the road which reaches out of the Peace–Dam watershed. If the elevation of the Kuemsungchun exceeds EL. 318.0m at this site, it will flood Kuemhwa, Chulwon, Yeonchun, and Pyungkang region and flow down to Namhan River and Imjin River.

If this kind of overflow occurs, a wide area around the Military Demarcation Line will be flooded. Hence this fact should be considered during military operations. However, when considering the backwater effect and the fact that the crest height of the present Peace–Dam is EL. 225.0m, it can be concluded that Kuemsungchun is not likely to flow into Namhan River or Imjin River through Anbu, even if all permanent discharge tunnels should be shut down.

Since flow detention can be made through the construction of the Peace–Dam, full stage at the Hwachun–Dam also can be increased further in the future. In this case, the storage capacity at the Hwachun–Dam can also be increased, and it can be concluded that this increase can be used for power genration, river maintenance, or other purpose. Since it can be assumed that the stage of dam is generally maintained fully during the summer season, the full stage of the Hwachun–Dam, EL. 175.0m is used as a initial condition for flood routing, and flood routing was carried out to investigate how the Peace–Dam, which is constructed on the basis of natural flood control method, that opens spillway gates fully during flood discharge, influence on the Hwachun–Dam at downstream.

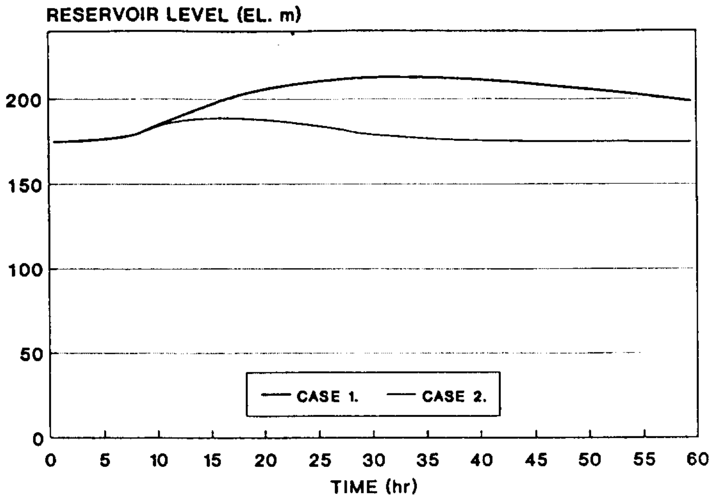
In the case that the Peace–Dam interrupts inflow from upstream, the stage at the Hwachun–Dam is shown to increase by 3.40m and 3.78m for 100 year and 200 year frequency flood, respectively.

Also, while the stage at the Hwachun–Dam is 183.47m without the Peace–Dam and the Keumkangsan–Dam for 200 year frequency flood, if flood is interrupted temporarily by shuting down all the tunnels of the Peace–Dam, the stage becomes 178.78m. As a result, the stage can be reduced by 4.67m. This result shows that further study is needed to take full advantage of the Peace–Dam hydraulically and hydrologically.



∗ Relational Operation, Return Period of 200 year

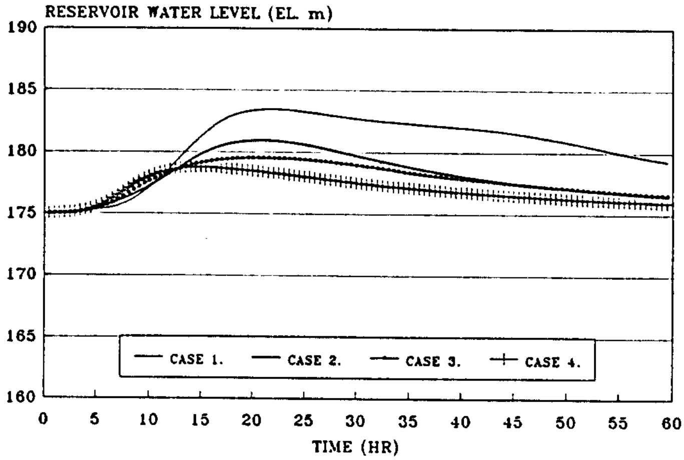
Figure 5.1 Inflow and Discharge Hydrograph at the Hwachun–Dam Site



Case 1 : Before the construction of Kuemkangsan–Dam

Case 2 : After the construction of Kuemkangsan–Dam

Figure 5.2 Stage Variation Graph at the Peace–Dam(Return Period of 200 Year)



Case 1 : Before the construction of the Kuemkangsan–Dam and the Peace–Dam

Case 2 : The exclusion of the Kuemkangsan–Dam watershed

Case 3 : Relational operation of the Peace–Dam

(The exclusion of the Kuemkangsan–Dam watershed)

Case 4 : Shut–down of the Peace-Dam tunnel

Figure 5.3 Stage Variation Graph at the Hwachun–Dam Site(Return Period of 200 Year)

6. Conclusion

This study aimes at analyzing scarce data on the upstream of the Hwachun–Dam watershed, and discharge condition for the upstream Hwachun–Dam due to the construction of the Peace–Dam through the suggestion of reasonable discharge data. As discussed previously, the Peace–Dam construction within the Hwachun–Dam watershed reduced the flood inflow and stage of the Hwachun–Dam. Therefore, by applying and analyzing these results, limiting stage of the Hwachun–Dam(EL. 175.0 m) can be adjusted. Also, through reconsideration of the Hwachun–Dam operation for flood control during rainfall, and various analysis and application on 4 discharge tunnels of the Peace–Dam, optimal operation methodology should be determined. Since there are little hydrologic data, such as rainfall record, which is essential to perform research for the Hwachun–Dam, except flood inflow and discharge data on the Hwachun–Dam, the establishment of the plan for the hydrologic study on watershed, and optimal operation of the Hwachun–Dam and the Peace–Dam becomes difficult. Hence, by installing stage guage and rainfall guage at the Peace–Dam, inflow and discharge should be measured and recorded, and by collecting and measuring rainfall data for unguaged watershed, subsequent study on the relational operation between the Peace–Dam and the Hwachun–Dam should be continued.

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