Integrated Water Resources Management for Disaster Prevention in the Face of Climate Change ; focusing on the Chungju Dam

By

YANG, Kyoung Jun

CAPSTONE

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

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Committee in charge:

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- Abstract -

According to the Intergovernmental Panel on Climate Change (IPCC), the temperature of the entire Earth's surface has risen faster since 1970 than any other period (50 years) in the past 2,000 years, and in many respects, the current climate system is on a scale that has not been experienced for thousands of years.

Recently, climate change and dams have a strong correlation. This is because it is the most efficient facility to prepare for droughts and floods due to climate change, and at the same time, downstream areas can suffer great damage in the event of dam problems and extreme discharge due to climate change. Recently, climate change and dams have a strong correlation. This is because it is the most efficient facility to prepare for droughts and floods due to climate change, and at the same time, downstream areas can suffer great damage in the event of dam problems and extreme discharge due to climate change.

recent climate change is causing many difficulties in dam water management measures. In the case of Chungju Dam, there is a significant difference between the climate at the time of design in 1978 and the current climate change. It appears that there is a limit to the dam's capacity due to the changed climate. If extreme rainfall may occur in the area and floods are difficult to accommodate at the Chungju Dam, the dam will overflow, which is highly likely to lead to dam collapse and secondary damage. The problem of the Chungju Dam is not just a facility problem, but a serious matter that can cause massive flood damage throughout the metropolitan area and even lead to a national disaster, such as water supply and power production being stopped if the freshwater function is lost. It is important to prepare proactive measures.

- Contents -

- Table List -

- Figure List -

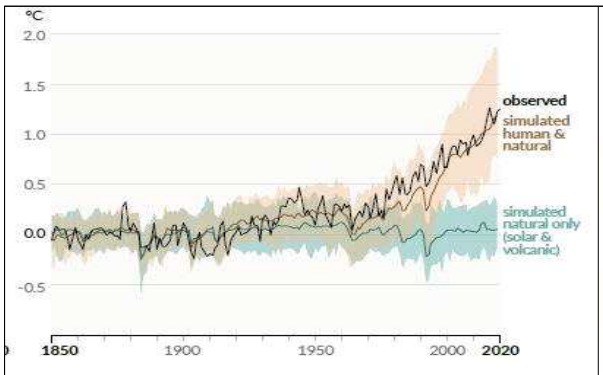
1. Introduction

1.1 Climate Change

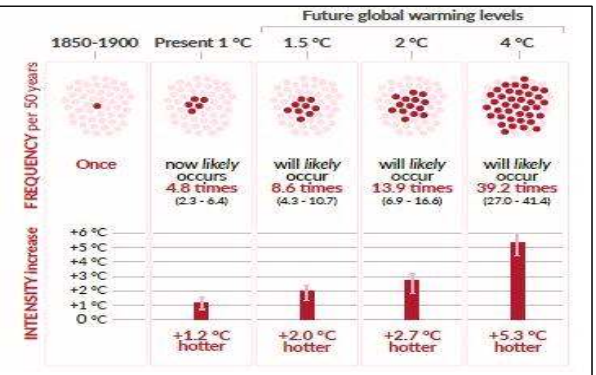
Climate change is a change in the climate system caused by human activities that results in changes in greenhouse gas concentrations that are in addition to natural climate variability that has been observed for a considerable period of time. Climate crisis refers to a state where climate change not only leads to extreme weather conditions but also poses irreversible risks to human civilization, such as water scarcity, food shortages, ocean acidification, sea-level rise, and ecosystem collapse. It signifies a critical need for drastic reduction of greenhouse gas emissions to address a situation with potentially irreparable consequences.

According to the Intergovernmental panel on climate change, the global surface temperature increased by 1.09°C from 2011 to 2020 compared to pre-industrial times (1850-1900), Human-induced climate change is contributing to an increase in tropical cyclone-related heavy rainfall, and there is a growing likelihood of compound extreme events worldwide since the 1950s (such as simultaneous heatwaves and droughts). Furthermore, in 2019, the atmospheric CO2 concentration reached the highest level in the past two million years. Since the 1970s, the rise in global surface temperatures has been faster during certain 50-year periods than at any time over the past thousand years, indicating unprecedented changes in the climate system across various aspects over the span of several hundred to several thousand years.(IPCC,2021)

Table 1 Current status of global warming increase



Global temperature increase (since 1850)



Increased frequency and intensity of temperature extremes

In South Korea, a country with distinct four seasons, it is believed that the public's perception of climate change is relatively significant. Recently, there have been frequent occurrences of climate change phenomena, with particular attention to the notable impacts observed in the year 2020 in South Korea.

According to the 2020 Abnormal Climate Report, the 2020 rainy season started on June 10 and ended on July 28 (49 days) in Jeju, and the longest rainy season started on June 24 and ended on August 16 (54 days) in Central region. It wasn't just a long rainy season. In 2020, the national rainfall during the rainy season was 693.4 mm, nearly twice as much as normal (356.1 mm), and the second highest since 1973 (the first was 699.1 mm in 2006), and the number of very strong rains (torrential downpours) of 80 to 100 mm or more increased dramatically compared to previous years. (Joint Government Departments, 2020)

Recent climate change trends show a clear intensification of precipitation, with rainfall becoming more concentrated and notably stronger than in the past. Particularly, episodic concentrated heavy rainfall not only inflicts considerable damage but also poses challenges in formulating effective preventive measures.

Table 2 Maximum hourly precipitation by region in 2020

Region	Chun Cheon	Anseong	Daejeon	busan
1-hour maximum precipitation(mm)	116.0	104.0	102.5	81.6

Table 3 Regional Precipitation Status in 2020 Compared to the Common Year

division	2020		Common Year	
	Number of days with precipitation(day)	average precipitation(mm)	Number of days with precipitation(day)	average precipitation(mm)
Central region	34.7	851.7	17.2	366.4
southern region	23.7	573.1	17.1	348.6
jeju island	29.5	562.4	18.3	398.6
Nationwide	28.3	693.4	17.1	356.1

In 2020, the longest rainy season and rainfall caused by climate change caused a lot of damage. According to the 2020 Statistical Yearbook of Natural Disaster, heavy rain caused KRW 1.372 trillion in damages, the first trillion won in 14 years since Typhoon Ewenia in 2006 and the KRW 1.834 trillion in July rain. It was also one of the most challenging years for climate change in the last decade, with 44 people killed by torrential rains during the rainy season and KRW 4.16 trillion spent on disaster recovery in 2020. (Ministry of the Interior and Safety, 2020)

The damage caused by climate change is only different in degree, but large-scale damage accidents such as the flooding of the Gangnam Station area in 2022 and the flooding of the underpass at Osong Station in 2023 have been repeatedly occurring, and we are experiencing the fear of climate change and the difficulty of preventive measures every year by establishing recovery measures.

1.2 Chungju Dam Status

The Chungju Multipurpose Dam is the largest concrete gravity dam in South Korea, constructed in the central part of the Korean Peninsula, managing the Namhan River basin. It aims to efficiently develop the water resources held in the Namhan River basin, supplying various types of water to downstream areas, generating hydroelectric power, and addressing peak power demand during periods of maximum power demand.

The project commenced with the construction of the access road in 1978 and was completed in 1985. The total project cost amounted to 585.5 billion Korean won, secured through sources including the Japanese government. The Chungju Dam has a height of 97.5 meters, a length of 447 meters, and a total reservoir capacity of 2.75 billion cubic meters, covering a watershed area of 6,648 square kilometers. In addition to the main dam, a regulating dam was constructed downstream at a point 19.6 meters below, with a height of 21 meters, a length of 480.7 meters, and 20 gates. This auxiliary dam contributes to maximizing power generation and ensuring stable water supply downstream.

The construction effects of the Chungju Multipurpose Dam can be broadly categorized into three main aspects: water supply, flood control, and power generation benefits. The annual water supply capacity of the Chungju Dam is 3.38 billion cubic meters, with 2.731 billion cubic meters allocated for industrial and domestic water use. It plays a crucial role as a primary source of industrial and domestic water supply for major cities and the metropolitan area, including Seoul, Incheon, and Suwon. Additionally, it reliably supplies 315 million cubic meters of irrigation water and 334 million cubic meters of river maintenance water to the downstream areas of the Namhan River. Furthermore, the Chungju Dam has had a significant impact on flood control in the Namgang River region. Previously, the region experienced annual flooding during the concentrated heavy rainfall period from July to September, causing considerable damage to life, property, and economic activities. However, 616 million cubic meters of flood control capacity, the dam has substantially reduced the impact of flooding. Lastly, the hydropower plant at Chungju Dam has a facility capacity of 412,000 kW, generating 844 GWh annually. In addition to contributing to renewable energy production in the carbon-neutral era, it has made a significant contribution to the overall power supply in South Korea

Figure 1 Chungju Dam Site Photo

1.3 Purpose of the study

In recent years, climate change and dams have become highly correlated. Dams are the most efficient facilities to prepare for droughts and floods due to climate change, but they can also cause great damage to downstream areas in the event of abnormal or extreme discharges due to climate change.

In the current capstone project, a integrated water management approach is being examined with a focus on three key aspects: water supply, flood control, and conflicts with the local community. These three elements are closely interconnected in the context of Chungju Dam's integrated water management strategy to adapt to climate change. The capacity of a multipurpose dam like Chungju can be divided into two main components: the capacity for water supply (intake) and the capacity for flood control (discharge). Unless the dam size is increased, these capacities remain constant. Adjusting the dam's capacity in response to repeated occurrences of floods and droughts due to climate change has been a subject of debate, with some groups advocating for capacity adjustments. However, sudden changes in capacity management are not straightforward. For example, in the case of Dalkbange Dam in Gangneung-si, preemptive discharges were made to secure additional flood control capacity against concentrated heavy rainfall from typhoons. However, this led to significant problems in subsequent water supply due to lower-than-expected rainfall. Therefore, change from the dam's original purpose can be a challenging decision. Moreover, conflicts with the local community are closely related. Even with various alternatives for water supply and flood control, negative perceptions from the local community persist. Past projects related to Chungju Dam, designed to prepare for climate change, have faced opposition from the local community. Despite being projects for the national benefit, framed as ensuring dam safety and utility, they were pushed forward without addressing local concerns. However, the current situation reflects a greater awareness of the potential damages caused by dams in the region. Even with optimal solutions for climate change adaptation, progressing without convincing the local community and providing support is challenging in reality. For these reasons and others, the

capstone project places particular emphasis on examining these three aspects.

In the case of dams, their size and height are determined by a comprehensive evaluation of factors such as the water supply status, watershed characteristics, soil composition, and precipitation in the area during the design phase. Dams are designed to operate reliably even during extreme rainfall events, minimizing the risk of flooding in downstream areas. Additionally, they play a crucial role in providing an adequate water supply during periods of severe drought, contributing to our comfortable daily living.

However, recent climate change has posed significant challenges to the water management strategies of dams. In the case of Chungju Dam, the climate has changed considerably since its design in 1978. The altered climate has revealed limitations in the dam's capacity to handle discharge, indicating potential challenges. Unpredictable extreme rainfall events, such as the typhoon 'Rusa' in 2002 that caused extensive damage in South Korea, can occur at any time, leading to a situation where the dam may struggle to accommodate the resulting floods. In such cases, the dam could overflow, leading to the possibility of dam failure and subsequent secondary damages. The issue with Chungju Dam extends beyond a simple infrastructure problem. It has the potential to cause significant flood damage throughout the metropolitan area. If the dam loses its freshwater function, it could lead to interruptions in water supply and power generation, creating a national disaster. Therefore, proactive measures are crucial to address these significant issues.

The importance of acitive storage, which is the opposite of flood control, is also crucial, and proactive measures should be taken. In the case of Chungju Dam, during the nationwide droughts in 2015 and 2017, there were reductions in river maintenance water supply, but the restriction was contained before extending to the reduction of industrial and domestic water supply. However, this was attributed to the large storage capacity of Soyanggang Dam, which supplies industrial and domestic water to the metropolitan area, as well as Chungju Dam's flexibility in operation and rainfall during the monsoon season. It cannot be considered entirely secure for intake

water, especially in the era of climate change, where there is a need to prepare for potential limitations on the water supply to the metropolitan area's drinking water sources. A representative case could be the extreme drought situation in the Gwangju and Jeonnam regions in 2023. Due to persistent drought since 2022, the reservoir capacity of Jwadam Dam, domestic water source in the Gwangju and Jeonnam regions, dropped to 15%. This led to a severe situation, prompting a visit from the President to the site to direct the formulation of countermeasures. Fortunately, adequate spring rainfall helped prevent the worst-case scenario of water supply restrictions. However, situations like these underscore the urgent need for proactive efforts to secure Active storage

Finally, I think there is a need for research on appropriate solutions to regional conflicts. Even if an appropriate solution is established, it is difficult to establish an active policy without local acceptance. The negative perception of the Chungju Dam in the Chungju region is relatively strong. Although the construction of the Chungju Dam has enabled flood control and stable water supply in the lower reaches of the Namhae River and the metropolitan area, the Chungju region has suffered a lot of damage due to the designation of surrounding water supply protection zones and restrictions on development due to the construction of the dam. In particular, there has been a continuous demand for the expansion of reclaimed water supply for the purpose of creating an industrial complex in the Chungju region, but the water from the Chungju Dam is actually supplied to neighboring cities such as SK Hynix, so there is a strong negative perception of the development of the Chungju Dam in the region. Before establishing the optimal plan, we would like to examine active measures to coexist with the region as a research task.

1.4 Research Topic and Outline

The following topics will be the final research results and future tasks of this paper. Firstly, what are the impacts of climate change on Chungju Dam? Secondly, have the measures we have formulated and planned in response to climate change

been appropriate for Chungju Dam? Thirdly, despite the formulation of numerous plans, some have faced difficulties in active implementation. What were the reasons for this? Lastly, what policies and measures can be established for integrated water management at Chungju Dam in collaboration with the local community?

The capstone is structured as follows: In Section 2, a literature review will be conducted on the current status and measures related to climate change phenomena and water management. Despite approximately 40 years passing since the construction of Chungju Dam in 1985, there is a lack of preparedness for climate change. To understand this phenomenon, a comprehensive review of relevant literature is deemed crucial. In Section 3, issues will be examined by integrating literature and local contextual understanding. This includes exploring whether adequate plans were formulated but faced opposition from the local community or if there were other challenges. The section aims to determine the need for alternative solutions and planning. In Section 4, an integrated water management approach for climate change adaptation will be proposed, focusing on Chungju Dam. The process of presenting integrated water management plans will involve discussing anticipated issues and potential solutions for the future. Finally, the capstone will conclude by presenting the research findings and outlining future research and development tasks.

This capstone will be of interest to governments, public organizations, and civil society in formulating policies for integrated water management in the face of climate change, and will ultimately contribute in a small way to the design and implementation of policies for sustainable development in the era of climate change.

2. literature review

2.1 Water Utilization Project : Goesan Dam Redevelopment Project

The redevelopment project of Goesan Dam is being considered due to the continuous increase in water demand in the metropolitan area, driven by rapid urbanization, population growth, expansion of housing supply, and improvement in living standards. As the metropolitan area's water demand is expected to continue rising, there is a concern about future water shortages. Additionally, within the Han River basin, Chungju and Soyang Dams contribute to flood control, but the flood control capacity is insufficient. There is a need to secure the ability to cope with concentrated heavy rainfall events resulting from additional climate change.

Therefore, the redevelopment of the existing Goesan Dam into a multipurpose dam was examined in order to stabilize the water demand in the metropolitan area and reduce flood risk in the lower Han River area. This literature review summarizes the literature focusing on water supply rather than flood control contribution.

Goesan Dam is a single-purpose hydroelectric dam managed by Korea Hydro & Nuclear Power Corporation and is located on the Dalcheon, the first tributary of the Namhan River in Chungcheongbuk-do, about 30 kilometers in a straight line from Chungju Dam. Completed in 1957, Goesan Dam stands as the first hydroelectric power plant in South Korea designed and constructed with domestic technology. This concrete gravity dam has a height and length of 28 meters and 17 meters, respectively, with an effective storage capacity of approximately 5.7 million cubic meters. As of 2002 (or 66 years as of 2003), 45 years have passed since its completion, reaching the end of its economic lifespan and requiring ongoing maintenance.

The redevelopment method of the Goesan Dam was considered by raising the existing dam in consideration of terrain conditions and technical aspects. The height of the dam was increased from 28 meters to 54.5 meters and the length of the dam was increased from 171 meters to 282 meters at the current dam location.(KDI,2002)

During the preliminary feasibility study, both the Ministry of Land, Infrastructure and Transport (formerly the Ministry of Construction and Transportation) and K-water, as the entities responsible for the project, expressed strong intentions to pursue the redevelopment of Goesan Dam. Additionally, Korea Hydro & Nuclear Power Co., Ltd., which currently owns and manages Goesan Dam, has generally responded positively to the redevelopment project. They are inclined to agree with the project, especially considering the potential severity of water shortages in the future, which may require a national-level response. However, it should be noted that the vested river user is Korea Hydro & Nuclear Power Co., Ltd. Therefore, they are in a position to demand compensation, development rights, and the management rights of the dam as part of the redevelopment agreement.(KDI, 2002)

It is anticipated that the redevelopment of Goesan Dam will secure an annual water supply of 219.0 million cubic meters. This allocation is expected to be distributed for domestic and industrial use (125.7 million cubic meters), agricultural use (5.3 million cubic meters), and river maintenance (88.0 million cubic meters). The total project cost of the Gosan Dam redevelopment project is 634.9 billion won, and the benefit-cost ratio is estimated to be 1.28, but if there is no water shortage in the metropolitan area, the benefit-cost ratio of the project is estimated to be 0.09, indicating that the economic feasibility of the project is extremely low.(KDI, 2002)

In the comprehensive evaluation of the report, it was suggested that water is an essential factor for human survival and economic activities, and since the construction of a dam takes a long time of more than 10 years, it is essential to plan in advance for smooth water supply, but Rigorous Demand Estimation is essential to avoid wasting financial resources, so it is desirable to promote redevelopment based on the analysis of future demand change trends.(KDI, 2002)

division		unit	detail
Location			Gosan-gun, Chungcheongbuk-do
Dams	Dam format		Concrete Gravity Type
	Dam Elevation	EL.m	137.65
	Dam height and length	m	28.0×171.0
	Waremaru Elevation	EL.m	128.65
Reservoirs	stream names		Dalcheon River
	Watershed Area	㎢	671
	Total Storage	million cubic meters	15.33
	Effective Storage	million cubic meters	5.73
	Planned Flood Levels	EL.m	136.93
	Always High Water Level	EL.m	135.65
	Limits	EL.m	134.00
	Low water level	EL.m	131.65
	Planned Flood Volume	㎥/s	2,711
	Maximum Discharge	㎥/s	3,080
Sluice gate	Hydrologic formats		Roller Gate
	Sluice siz	m	8.0(w)×7.0(H)×7(DOOR)
Generating Facility Capacity		㎾	1,400×2
Construction period			1952. 11 ~ 1957. 4

Figure 2 Goesan Dam specifications

2.2 Flood control Project : Chungju Dam Flood control Capacity Increase Project

After Typhoon 'Lusa' in 2002 and Typhoon 'Cicada' in 2003, it was necessary to secure the safety of the dam against abnormal floods as the amount of oil entering the dam during floods increased from the time of design due to the effects of intense rainfall caused by recent climate change.(The Board of Audit and Inspection of Korea, 2003)

As a result of the hydrological safety review of existing dams and the basic plan for increasing dimensional capacity, 24 dams, including the Chungju Dam, were concerned about the risk of dam collapse due to excessive flooding due to climate change and lack of headroom, so the project to increase dimensional capacity was promoted starting with the Soyang River Dam in 2003.(Ministry of Construction and Transportation, K-water, 2004)

In the case of Chungju Dam, the project was started for the 20th time, and the basic concept was established in 2013, and the basic and detailed designs were implemented from 2014. In 2015, the main contents of the detailed design of the Chungju Dam control Capacity Increase Project were that the Probable maximum Flood (PMF) increased by about 1.2 times from 26,680㎥/s (2 days) to 32,727㎥/s (38 days) during the construction of Chungju Dam in 1985. Based on this, flood tracing of the reservoir of the existing Chungju Dam was conducted, and the peak water level during the 200- year flood frequency was EL.145.13m, which exceeded the planned flood level (EL.145.0m), and the peak water level during the PMF flood was EL.149.85m, which was about 2.35m higher than the dam floor level of EL.147.50m. In the event of extreme floods due to climate change, the existing dam is expected to overtopping and large-scale damage is expected, so the construction of an additional discharge facility to increase the discharge capacity of the dam was planned.

During the implementation design, the outline of the discharge facility project was to construct three tunnels (1,542 meters) with a diameter of 16.3 meters on the left bank of the Chungju Dam, and then install two sluice gates (10 meters wide and

19.8 meters high) per tunnel. In addition, to resolve interference during construction, the water culture center, roads, and bridges were planned to be relocated.

The project period was planned from 2013 to 2018, and the total project cost was set at KRW 235.4 billion. Upon completion of the project to increase the dimensional capacity of the Chungju Dam, there will be no change in the dam's specifications and operation, such as the planned flood level and storage capacity, and the discharge facility to the auxiliary spillway installed as part of the dimensional capacity increase project will be utilized only as a facility to prevent large-scale damage in the event of disasters such as extreme floods caused by climate change.

In addition, the park and water culture center created during the water capacity increase project are expected to provide a place for local relaxation and education, while also linking with the existing tourism resources of Chungju Dam.

Figure 3 Chungju Dam flood control capacity expansion project forecast map

2.3 Flood control-related : Chungju Dam Flood Flood Control Status

Among the major floods that caused major damage in the Han River system in the past, there were major floods in 1990, 1998, 2002, and 2006, and we will review the status of flood control in 1990, which was the most damaging.

The Great Flood of 1990 formed and developed in the central region of Korea when Typhoon No. 17, which had made landfall in China, connected with a mid- latitude low pressure system that passed over Seoul on September 8, 1990. From September 10 to 12, 1990, a cold, dry continental air mass and a hot, humid maritime air mass over the sea south of Japan stalled over the central part of Korea, causing a lot of rain to fall intensively and causing large-scale flood damage in the Han River basin, and for three days from September 9 to 12, 1990, heavy rains in the central part of Korea recorded an average rainfall of 452 mm, causing a lot of water damage.

During the great flood of 1990, the maximum inflow of Chungju Dam was 22,164㎥/s, which exceeded the planned flood volume of 16,000㎥/s when the dam was designed, and the maximum discharge was 14,000㎥/s, which was almost close to the design discharge volume of 14,200㎥/s. The flood control volume was 8,164 ㎥/s and the maximum water level was EL.146.03m, which exceeded the planned flood level of EL.145.00m by 1.03m, causing major damage to surrounding facilities such as power plants. However, in the case of the Chungju Dam, there was 2.5 meters of clearance, so although the dam did not overflow, a major disaster could have occurred.

Table 4 Maximum water level and maximum inflow and discharge at Chungju Dam during the 1990 flood.

Maximum water level		Maximum inflow		Maximum Discharge	
Water level (EL.m)	When it happened	Flow Rate (CMS)	When it happened	Flow Rate (CMS)	When it happened
146.03	9.12 13:00	22,164	9.12 01:00	14,000	9.12 13:00

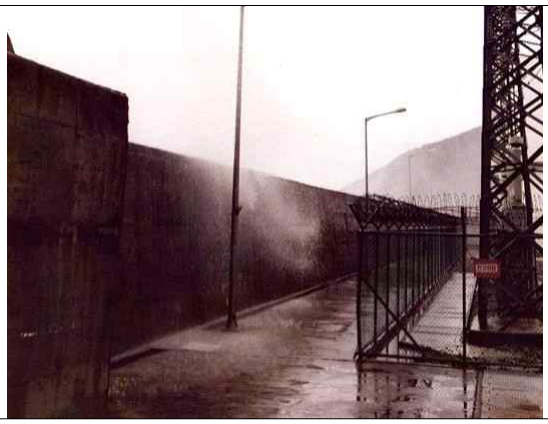
	
Hydrologic discharge status	Hydrologic discharge status
	
Hydroelectric power plant flood damage	Hydroelectric power plant flood damage
	
Damage status downstream of dam	Damage status downstream of dam

Figure 4 Status of major damage to Chungju Dam in 1990

2.4 Local conflict: Chungju cuts water purification costs (2018.12)

Local conflicts related to the Chungju Dam have been around for a while, but the most recent case of local conflict that became a major issue was the Chungju City Council's decision to cut the cost of water purification (2018).

The city of Chungju supplies its citizens with water from the Chungju Dam, which is purified and treated, so the city has to pay a water purchase fee every year. Water rates are the same across the country to ensure balanced development of local communities and the nation. In response, Chungju City requested regional development constraints such as the designation of a water supply protection zone due to the Chungju Dam and an increase in support costs for the area around the dam, and cut the budget for the purchase of water purification in Chungju City in '18.12.19 by 62.5 billion won.

In January 19, the Chungju City Council, civil society, and residents of Chungju City participated in the 'Chungju City Pan-Citizen Task Force' and subsequently promoted continuous consultations between the government, the Water Resources Corporation, and Chungju City, and the needs of the region are largely as follows.

Table 5 Chungju Dam Area Requirements

division	Requirements	examine
Chungju city	■ Dam support project cost increase	- Amendments to the law
Chungju city	■ Water bill reduction	- Violation of Legal Policy
civic group	■ Leisure town creation	- unenforceable
	■ Bridge construction canceled	- Available for review
local residents	■ Regional deregulation	- No deregulation possible

Chungju City pointed out that even though the dam was built in the region, water rates are the same across the country, and the dam support costs for the region are far less than the revenue generated by the Chungju Dam, which is the biggest cause of water price disputes. Since then, as a win-win agreement (K-water, Chungju City, local lawmakers, and citizens' task force participated) was signed in November 19 to enhance the value of Chungju Dam and develop the region, a communication platform was established with the region and a development plan for the area around Chungju Dam was agreed upon, and in 21, Chungju City began paying for water purification.

Through the amendment of the 'Act on Dam Construction, Management and Support for Surrounding Areas' in the National Assembly, the annual support for Chungju City was increased from 7.2 billion won to 12.1 billion won, and the plan for K-Water and Chungju City to participate in the tourism revitalization plan around the Chungju Dam was finally discussed, but the request for lowering water rates was finally rejected. In fact, not only in Chungju, but also in Chuncheon City and Boryeong City, where major dams were built, water price disputes are constantly occurring, and conflicts in the region are temporarily sealed afterwards, but the biggest regret is that there is no way to resolve the conflict clearly.

In particular, an active regional cooperation system should be introduced for integrated water management in preparation for climate change, but given the development process around the Chungju Dam, it is unlikely that communication and persuasion with the region will be easy.

3. Analyze an integrated water management plan

3.1 Related to water Utilization

There are several ways to secure water sources to stably supply water, including(1) river water, (2) dams and reservoirs, (3) groundwater, and (4) other seawater desalination. Among them, river water intake accounts for the largest absolute proportion, but in fact, river water is difficult to maintain a constant quantity and quality due to climate change, and the utilization of groundwater is limited due to the limitations of the amount of water intake and the influence of local topography. In this capstone, we focus on the Chungju Dam, and we analyze the options for the transfer of water from the Chungju Dam.

First, it is necessary to check whether there is an actual water shortage. According to the Korea Water Resources Corporation's Water Management Practice Manual (2022), Chungju Dam, a source of drinking water in the Seoul metropolitan area, has a raw water supply rate of 96.2% and Soyang River Dam has a supply rate of 96.9%, indicating that the dam is supplying water to the maximum extent possible.

In addition, the second phase of the Chungju Industrial Water Supply Project, which supplies 200,000 tons of water to six municipalities including Icheon and Chungju, has been completed, but a preliminary feasibility study for the third phase of the Chungju Industrial Water Supply Project is underway as new industrial parks continue to develop in the Chungcheongbuk-do region. The expansion of Hynix semiconductor plants in Icheon and Cheongju, and the intensive development of industrial complexes in Chungcheongbuk-do, which has easy access to the Seoul metropolitan area, confirm that water shortages in the Seoul metropolitan area are a reality, not a prediction.

In response, the government and K-water actively reviewed countermeasures to prepare for drought at the Chungju Dam due to climate change. A representative example of this was the reallocation of the dam's agricultural water and the diversion of bioprocess water. Since 2014, localized droughts have been occurring every year

due to regionalized precipitation and lack of precipitation due to changes in the location of the North Pacific cyclone, so the government and K-water reviewed the re-evaluation of agricultural water in 2018 as a solution to drought. Dams have the right to use dam water for their respective purposes, including bioprocessing water, river water, and agricultural water. Since the right to use dam water is the property right of water, no matter how severe the drought is, the water for a specific purpose cannot be reduced.

In the case of the Chungju Dam, it was planned to provide 315 million m3/year of water for agriculture downstream of the Paldang Dam when the dam's basic plan was established in 1985, but the National Survey of Water Rights (Ministry of Land, Infrastructure, and Transport, 2015) showed that the area of agricultural land decreased by 56% from 22,272 ha to 9,774 ha compared to the dam's design. In addition to the decrease in agricultural land area in the Namhang River basin, the development of agricultural technology has also been examined as a cause of the decrease in water usage. In response, the government has changed its agricultural water supply plan to 224.2 million cubic meters per year from 2019, with a reserve of 90.8 million cubic meters per year for drought. The 90.8 million cubic meters/year of spare water is the second phase of the Chungju Dam Industrial Water Supply Project, which is 4.5 times the amount of water supplied to six municipalities in the Chungcheong region, and is judged to be a great help in providing stable raw water supply in case of drought in preparation for climate change.

In addition, a plan to forcibly withdraw the emergency capacity (428 million cubic meters) and shooting capacity (26 million cubic meters) from the water supply capacity below the low water level through pumping facilities during the worst drought has also been completed. However, this part has already been planned, and in order to secure an optimal water source in preparation for future climate change, the redevelopment plan of Gosan Dam is actually the most realistic plan for Chungju Dam.

Table 6 Chungju Dam water level-storage capacity

(Unit: EL.m, million ㎥)

Water level	water storage capacity	Water level	water storage capacity	Water level	water storage capacity
74	1.832	90	65.205	100	201.837
76	3.783	91	74.702	110	454.027
78	6.696	92	85.024	138	1,997.121
80	10.800	93	96.210	141	2,251.672
82	16.366	94	108.297	145	2,619.614
84	23.710	95	121.323	-	-
85	28.728	96	135.326	-	-
86	34.687	97	150.342	-	-
87	41.274	98	166.409	-	-
88	48.530	99	183.561	-	-

Figure 5 Photo of Chungju Dam emergency discharge facility

The Goesan Dam Redevelopment Project. This capstone examines the Goesan Dam redevelopment project as the best solution to the Chungju Dam for two reasons.

The first is to secure the safety of the Goesan Dam against climate change. As mentioned in the review of existing literature in Section 2, the economic life of the Goesan Dam is coming to an end and it is in need of continuous maintenance due to its severe age. In addition, due to the nature of hydropower dams, the dam's purpose is to generate electricity, so its ability to respond to heavy rainfall due to recent climate change is significantly reduced. In 2023, the dam overflowed due to heavy rainfall in a climate change-affected area, causing flooding of roads and houses in the downstream area, and 1,800 residents were evacuated. Fortunately, rainfall became less frequent after the overflow, and extreme situations such as the collapse of the dam did not occur even after the overflow due to the characteristics of the concrete dam, but given the continuous occurrence of intense rainfall due to climate change, it is necessary to take active measures to secure flood safety in the Chungju region and even the metropolitan area such as the Namhan River.

Figure 6 Photo of Goesan Dam overflow discharge

The second is that existing dams can be utilized to secure water storage. In order to secure the safety of Isu against climate change, I think most people would agree that building a dam is the surest way to secure the safety of Isu. However, even if there is a suitable site for building a dam, it is not easy to build a dam. In the Chungju Dam area, the Odaesan Dam was planned upstream of the dam, but it was canceled due to local opposition, and in other areas, the need to build dams in preparation for droughts and floods was raised, but the plan was repeatedly canceled due to local opposition. The difficulty of promoting dam construction due to local opposition can be understood from the fact that there are currently only two dams in the country, Wonju Cheon Dam and Bonghwa Dam, which are being built on local initiative.

In this situation, if the number and dimensions are secured by utilizing the existing dam, it is possible to minimize problems such as local opposition and environmental damage, and it is expected to have a great impact in terms of efficiently utilizing existing resources. In fact, redevelopment cases of existing dams have been continuously reviewed and developed in Korea. The largest examples are the Seomjin River Dam Redevelopment Project, which redeveloped the Seomjin River Dam to supply hydropower and agricultural water, and the Seongdeok Dam Construction Project, which built a dam by utilizing the submerged land of an agricultural reservoir in Cheongsong. Among them, we would like to mention the Seomjin River Dam Redevelopment Project, which has the same purpose as the Gosan Dam and the same dam operator as Korea Hydro & Nuclear Power Co.

The Seomjin River Dam is a dam located in Imsil County, Jeollabuk-do, and was under construction during the Japanese occupation, but after the construction was suspended, the government promoted its construction as part of the First Five- Year Economic Development Plan in 1960 and completed the dam in 1965. Later, the government transferred the right to use the dam to the current Korea Hydro & Nuclear Power Co. and the Rural Affairs Corporation, and the management of the dam was entrusted to the current K-water. The Seomjin River Dam faced a major

problem after its completion in 1965, when it was planned to provide land for a resettlement complex for flood victims, but due to delays in construction, flood victims were resettled upstream of the dam, and in 1969, the area upstream of the dam was flooded due to heavy rains, so the dam's planned flood level was lowered by 5 meters from EL.196.5 meters to EL.191.5 meters after 1969. Since then, the government has made continuous efforts through Jeollabuk-do to normalize the dam's operation, but the efforts of local governments alone were limited. Later, as the water supply was insufficient due to the rapid growth of the refinery and chemical complex in Yeosu, Gwangyang, the government decided to utilize the 65 million cubic meters/year secured through the normalization of the Seomjin River Dam operation to supply industrial water to Gwangyang. In addition, the National Audit Office ordered the government to take the lead in normalizing the dam's operation, rather than local governments, and to come up with effective measures such as state funding, which accelerated the pace of the project. In response, the Ministry of Land, Infrastructure, and Transport established a plan for the Seomjin River Redevelopment Project in 2005, and relocated residents and built alternative roads at the expense of the state. In 2015, the Seomjin River Redevelopment Project was completed, and it can be said that it is a good example of securing raw water through active utilization of existing dams.

However, as mentioned in the future challenges in Section 4, after the redevelopment of the Seomjin River Dam, a lawsuit was filed by the state (K-water), Korea Hydro & Nuclear Power Corporation, and Korea Rural Development Corporation. All parties agreed to normalize the dam operation of the Seomjin River Dam, but the issue of compensation for the dam use rights to K-water and the Rural Development Corporation was an issue. KWNP requested about 130 billion won, taking into account the estimated loss of power generation from the dam every year, while the government stuck to the compensation cost of 8.8 billion won, which was calculated by the KDI. In the end, the state (K-water) won the case, but as the conflict was resolved through litigation, it could be a difficult case to organize

cooperation between the government and public institutions for future development.

3.2 Flood control-related

In order to prevent disasters such as dam overtopping during extreme floods caused by climate change, the Chungju Dam has been promoting the Chungju Dam Dimension Capacity Increase Project since 2014, and the project is currently scheduled to be completed in 2025 with a process rate of about 90%. If the project is completed, the Chungju Dam is expected to operate stably enough without dam overtopping or damage even in the event of extreme flooding due to climate change.

However, there is another challenge for us in the future regarding the dimensions of the Chungju Dam. As mentioned in Section 2, the dimensional measures for the Chungju Dam were established in 2004, and the basic and implementation designs were implemented in 2014. All these plans were calculated based on the PMP (Probable Maximum Precipitation) established by the government in 2004. The PMP in 2004 was an estimate of the extreme rainfall that could occur under the most extreme weather conditions after Typhoon Lusa in 2002 and Typhoon Cicada in 2003, which is statistically equivalent to a frequency of 10,000 years.

there has been no change in the PMP calculation since 2004, which is the most important element of dimensional planning. We were still using data from 20 years ago, while the intensity of extreme floods continues to increase due to climate change.

In 2019, the government (Ministry of Environment) conducted a study to reevaluate and supplement the PMP calculation process and completed the study in 2022. Since then, the government (MOE) has been conducting a review of the impact of major national facilities based on the PMP calculation results as a follow-up service. The results of this service are expected to have a significant impact on the Chungju Dam facilities and operation system in the future. In the case of a dam with a small water storage capacity compared to the area of the dam's basin, such as the Chungju Dam, it is expected that the safety of the dam will be greatly affected by the concentration

of rain in the basin at one time during extreme floods.

As mentioned in the previous section, the Chungju Dam was planned for various purposes in the upstream area to maximize the use of the dam. Among them, a representative dam construction plan related to dimensions is Yeongwol Dam, also known as Donggang Dam. The Yeongwol Dam was planned not only to secure a source of drinking water for the Seoul metropolitan area but also to share the dimensions of the Chungju Dam, but the dam plan was canceled in 2000 due to the backlash from civil society against the destruction of the environment and ecology. Since then, various plans to prepare for climate change, including purely dimensional dams such as the Odaesan Dam, have been considered, but local opposition has made it difficult to implement the plans.

In this situation, if the PMP calculation service results in an increase in the PMP of the Chungju Dam compared to 2004, we will have to bear the burden of planning another dimensional countermeasure. In a situation where it is difficult to establish dimensional measures upstream of the dam, it will be opposed by the local community to build an additional discharge facility to cope with the increased rainfall in addition to the dimensional capacity increase project on the existing dam. Even so, the local community is concerned that Chungju City will be flooded if large-scale discharges are made during extreme floods due to the Chungju Dam capacity increase project. As an alternative, there may be a plan to secure the flood control capacity of the dam by changing the operation of the dam, but this is not an easy option because the capacity of the dam is fixed and there is no choice but to reduce the capacity of the dam.

As mentioned in Section 4, if the Goseongsan Dam is to be redeveloped, it will be necessary to review various scenarios, such as flood control measures through linked operation with the Chungju Dam, and resolution of measures through dam operation if the increase in extreme rainfall is relatively small.

3.3 Regional conflict related

Conflicts between Chungju City and Chungcheongbuk-do over the Chungju Dam have arisen through various causes, including regulations and damages, and are still ongoing. Recently, Chungcheongbuk-do judged that the Chungju Dam and Daecheong Dam are the largest dams in Chungcheongbuk-do, and demanded government support and deregulation for regional development.

The government and K-water are in the process of continuous communication with the local community to consider ways to reduce the conflict over the Chungju Dam. The 20th Presidential Transition Commission has planned a tourism development project for the Chungju Dam in the Chungju region as part of regional balanced development, and is in the process of contracting for the creation of an ecological park and tourism resources. As the government, local governments, and K-water are making active efforts to promote the project, including planning to support 50% of the national budget, we believe that conflicts with the region will be resolved by contributing to the development of the region.

In addition, the tourism resource development project around the Chungju Dam, which is being promoted this time, is not a service promoted unilaterally by one party, but a result of fully reflecting local needs as K-water, which manages the dam, and Chungju City have established a specific action plan through regular meetings.

However, some officials and citizens are still expressing conflicts related tothe Chungju Dam, such as water distribution issues, and it is becoming an issue, but ultimately, the Chungju Dam, Chungju City, and K-water must be together for the next 100 years, so continuous communication is urgently needed.

4. Conclusion and future challenges

4.1 Related to water Utilization

The conversion of hydropower dams to multi-purpose dams has been discussed continuously due to the increase in extreme floods caused by climate change. In particular, the Goesan Dam has been one of the key dams in the discussion due to the continuous flood damage. The debate on unifying dam management arose when the Park Geun-hye administration recommended that K-water operate dams for power generation, citing the need for water management by adjusting the functions of the energy sector. On the other hand, Korea Hydro & Nuclear Power Co. opposed the government's recommendation, arguing that there is no difference in changing the agency that operates the dam, as it operates the dam under the control of the flood control center while operating the dam for power generation. I think it is natural for any public institution to oppose any coordination of work that is disadvantageous to the organization from the perspective of managing the organization, but I think the current reality is different from the situation where we are vaguely predicting the damage caused by climate change. I think it is important for us to act on the opinion of Korea Hydro & Nuclear Power Co. in the Gosan Dam Redevelopment Report (KDI, 2002) in Section 2, "If it is true that water shortage will become serious in the future, it should be dealt with at the national level, so I agree with the redevelopment of Gosan Dam." The response to climate change should be carried out at the national level, not in the business area of one public institution.

In addition, the state will need to come up with a compensation plan that local communities and organizations can understand and accept, rather than a compensation fee that takes into account the cost of the dam at the time of construction. Some amendments to the 'Special Act on Dam Construction, Management and Support for Surrounding Areas' are needed. There will be many difficulties, but it is time for the government to actively mediate and prepare alternatives instead of solving problems between public institutions.

4.2 Flood control-related

The dimensional measures for climate change related to the Chungju Dam require the prompt completion of the ongoing Chungju Dam dimensional capacity increase project. Initially, the project was scheduled to be completed within four years from the start of the project to prepare for extreme flooding due to climate change, but due to issues during construction, the project has not been completed for more than 10 years. Fortunately, construction interferences have been resolved and the project is now under normal construction, but it is necessary to complete the ongoing project as soon as possible because we do not know when extreme floods will hit the Chungju area.

In addition, it is necessary to prepare follow-up measures according to the results if the PMP calculation service project promoted by the Ministry of Environment is completed. When approaching the scenario of possible redevelopment of Goesan Dam, it would be possible to consider adjusting the discharge of the dam through the linked operation with Goesan Dam. In fact, in order to reduce flood damage in the Imjin River basin, the Gunnam Flood Control Center was constructed on the mainstream of the Imjin River and the Hantan River Dam on the first tributary of the Imjin River to reduce flood damage by controlling the downstream discharge, so linkage operation between dams could be a good alternative.

Finally, it is also necessary to establish dimensional measures for the downstream area of the dam. The Namhan River basin downstream of the Chungju Dam is a national river, but the recurrence frequency of the river embankment is 100 years, and it is true that there are concerns about the overtopping of the embankment and flooding of the area during extreme floods.

It is not wrong to say that not only the Chungju Dam, but also the local governments around the dam may end up causing more damage to the downstream areas in order to prevent the damage of the dam. During the heavy rains of 2020, the discharge of Seomjin River Dam, Yongdam Dam, and Hapcheon Dam caused a lot of damage to downstream areas. It is judged that it is urgent to secure the

dimensional capacity of the dams, as well as national river maintenance projects to reduce the damage to the areas immediately downstream of the dams.

4.3 Regional conflict related

It is true that the construction of dams in the region creates regulations and delays development, but it is also true that the natural resources around the dams have not been actively utilized. When I visited Hoover Dam in the United States this summer, what impressed me the most was that the dam was developed as a tourist product and the entire hydroelectric power plant, including the gallery in the dam, was built as a tourist course, attracting many tourists every year.

I have managed many dams in my career, not only the Chungju Dam, and have seen outstanding natural landscapes and resources. In addition, the government should lay the groundwork to lead regional development and win-win cooperation through bold investments rather than small-scale support through dam projects.

It will take a lot of thought and effort to make the dam a facility that all citizens can see and enjoy up close, rather than from afar.

4.4 Integrated Water Management Plan

As an integrated water management plan for disaster prevention in preparation for climate change, the study examined water transfer, dimensions, and efforts to resolve conflicts with local communities. None of them are unimportant, and given the speed of climate change, it is necessary to establish policy measures as soon as possible. While writing this capstone, I still believe that the most urgent need for continued review of the three options is the hydraulic option. This is because there is no other alternative but to build new dams, raise dams, or change the operation of dams. If a large-scale dam like the Chungju Dam were to collapse or be damaged and become inoperable, the damage and impact would be difficult to imagine and would be more than a national disaster. Although it may be difficult to do, alternatives such as limited water supply and connection with other regions may be

alternatives, but the dimensions of the dam limit additional alternatives other than the capacity and discharge capacity of the dam.

Integrated Water Management for Disaster Prevention during Climate Change;While writing my capstone on the Chungju Dam, I realized that we are still far from being prepared for climate change. It will take a lot of hard work and effort, but we all know that climate change is something we are experiencing now and that we will experience greater climate change in the future. I hope that the government and many experts will find the wisdom to solve this problem wisely through more diverse communication and discussion.

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