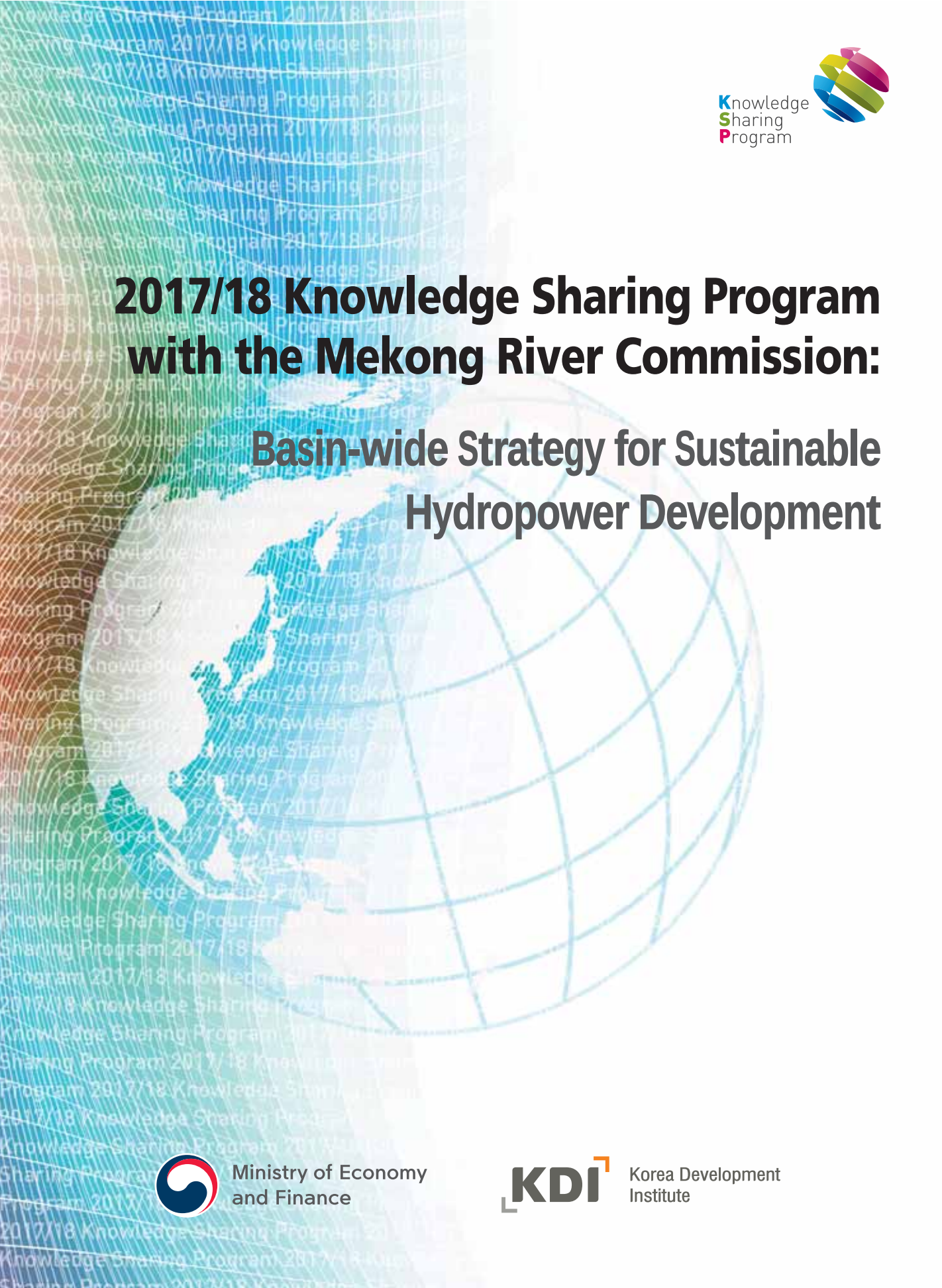
Knowledge Sharing Program

2017/18 Knowledge Sharing Program with the Mekong River Commission:

Basin-wide Strategy for Sustainable Hydropower Development



Ministry of Economy and Finance

KDI Korea Development Institute

2017/18 Knowledge Sharing Program with the Mekong River Commission

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Project Title	Basin-wide Strategy for Sustainable Hydropower Development
Prepared by	Korea Development Institute (KDI)
Supported by	Ministry of Economy and Finance (MOEF), Republic of Korea
Prepared for	Mekong River Commission (MRC)
In Cooperation with	Mekong River Commission (MRC) Mekong River Commission Secretariat (MRCS) Thailand National Mekong Committee (TNMC) Lao National Mekong Committee (LNMC) Cambodia National Mekong Committee (CNMC) Vietnam National Mekong Committee (VNMC)
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English Editor	Korea Institute of Culture and Arts Translation

Government Publications Registration Number 11-1051000-000820-01

ISBN 979-11-5932-304-1 94320
979-11-5932-302-7 (set)

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Knowledge Sharing Program

Government Publications Registration Number

11-1051000-000820-01

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Preface

Knowledge is a vital ingredient that determines a nation's economic growth and social development. Its true value was brought to light by the advent of the knowledge economy and a key question policymakers now face, especially in developing countries, is how an environment can be established that encourages and facilitates the creation and dissemination of knowledge across the nation. This need has led many countries to engage themselves in active policy dialogue to share their development experiences and benefit from mutual learning.

Korea's development has also depended heavily on knowledge. Its remarkable transition from a predominantly agrarian economy to an industrialized country was made possible by its well-rounded and extensive understanding of technology, management, public policy, and other diverse issues acquired from domestic and foreign sources and through trial and error. Building on these rich experiences, the Korean Ministry of Economy and Finance (MOEF) launched the Knowledge Sharing Program (KSP) in 2004 to assist partner countries to improve their policymaking. KSP, as implemented by Korea Development Institute (KDI), focuses on providing solutions customized to each country's economic, social and administrative settings, building capacity for effective policymaking and strengthening global networks for development cooperation. In 2017/18, KSP policy consultations were organized with 31 partner countries, with Mekong River Commission joining the partnership for the first time.

The 2017/18 KSP with the Mekong River Commission was undertaken by the MOSF and the Mekong River Commission (MRC) with the aim of "Basin-wide Strategy for Sustainable Hydropower Development." To that end, the KDI research team and the MRC counterpart made a range of collaborative efforts by exchanging development experiences, conducting joint studies and designing a policy action plan in line with the country's development targets.

With that, it is with great optimism for the future of MRC that the results of the 2017/18 KSP are presented. I firmly believe that KSP will serve as a stepping stone to further elevate the mutual learning and economic cooperation between the two countries and hope it will contribute to MRC's sustainable development in the future.

I wish to convey my sincere gratitude to Senior Advisor Kyungsik Kim, Principal Investigator Prof. Seungho Lee as well as project consultants Dr. Ilpyo Hong, Dr. Hyun Jung Park, Dr. Dong Jin Choi and Prof. Jooheon Lee for their extensive contributions to the successful completion of the 2017/18 KSP with MRC. I am also grateful to Executive Director Dr. Youngsun Koh, Project Manager Dr. Kyoung Doug Kwon, Project Officers Ms. Yerim Kim and Ms. Seungju Lee and all members of the Center for International Development for their hard work and dedication. Lastly, I extend my warmest thanks to the MRC, Mekong River Commission Secretariat (MRCS), Thailand National Mekong Committee (TNMC), Lao National Mekong Committee (LNMC), Cambodia National Mekong Committee (CNMC), Vietnam National Mekong Committee (VNMC) and related MRC agencies for their active cooperation and great support.

Jeong Pyo Choi
President
Korea Development Institute (KDI)

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2017/18 KSP with the Mekong River Commission

Yerim Kim (Project Officer, Korea Development Institute)

The Greater Mekong Subregion—Myanmar, Thailand, Cambodia, Laos, Vietnam, and China's Yunnan Province and Guangxi Zhuang Autonomous Region—has experienced rapid economic growth (average annual GDP growth of 6.5%) in the past decade. With its rapid economic growth, the energy demand of the lower Mekong countries—Cambodia, Laos, Thailand, and Vietnam—is projected to double from Mtoe (million tons of oil equivalent) to 319.6 Mtoe for combined agriculture, commercial, residential, industry, and transport construction needs. The increased demand has implications for energy trade and energy security within and among the Lower Mekong countries.

With increasing global energy prices and inflated forecasts in energy demand, the Mekong countries view hydropower development along the Mekong River, which runs through China's Yunnan Province, Myanmar, Laos, Thailand, Cambodia, and Vietnam, as an attractive, renewable resource. It will not only help meet the countries' needs to explode energy demands, but also diversify their energy mix. With the river's 4,350 km length, the potential of hydropower in the region is approximately 53,000 MW, consisting of 23,000 MW in the Upper Mekong Basin (China) and 30,000 MW in the Lower Mekong Basin (Lao PDR, Thailand, Cambodia, and Vietnam).

Since the Mekong River's significant water resources are shared by multiple countries, Cambodia, Laos, Thailand, and Vietnam are participating in designing a sustainable hydropower development strategy and policy as member states of

Mekong River Commission (MRC), with the dialogue partners of Myanmar and China. MRC is an inter-governmental organization, operated based on the four member states' Agreement on Cooperation for Sustainable Development of the Mekong River Basin (the Mekong Agreement), which was concluded on April 5th, 1995. As a regional facilitating and advisory body governed by water and environment ministers of the four countries, the MRC aims for the efficient and mutually beneficial development of the Mekong River, while minimizing the potentially harmful effects on the people and the environment in the Lower Mekong Basin.

The priority political agenda of MRC and its member states is hydropower development, as reflected in the 2016-2020 MRC Strategic Plan, Lao PDR National Socio-Economic Development Plan 2016-2020, Cambodia National Strategic Development Plan 2014-2018, Thailand National Economic and Social Development Plan 2012-2016, and Vietnam Socio-Economic Development Strategy 2011-2020. For the agenda, MRC and its member states have requested policy consultation on Basin-wide Strategy for Sustainable Hydropower Development to KDI as 2017/18 KSP with MRC. The KSP with MRC is the first multilateral KSP project in Asia, although diverse bilateral KSP projects have been conducted: 82 projects with Vietnam (in 2004 and from 2006 to 2016), 39 projects with Laos (from 2010 to 2016), 50 projects with Cambodia (in 2006 and from 2009 to 2016), and 5 projects with Thailand (in 2014 and 2016).

2017/18 KSP with MRC is composed of the following consultation team (refer to Table 1).

〈Table 1〉 2017/18 KSP with the MRC Consultation Team

Project Title: Basin-wide Strategy for Sustainable Hydropower Development
Senior Advisor: Kyungsik Kim (Former Vice Minister for Ministry of Land, Infrastructure and Transport, Republic of Korea)
Project Manager: Kyoung Doug Kwon (Director, KDI)
Principal Investigator: Seungho Lee (Professor, Korea University)

Sub-topics	Researchers
Water Security and Integrated River Basin Management	Prof. Seungho Lee (Korea University)
Challenges and Opportunities in Sustainable Hydropower Development	Dr. Ilpyo Hong (Korea Institute of Civil Engineering and Building Technology)
Environmental Impact Assessment on Hydropower Development	Dr. Hyun Jung Park (Korea Research Institute for Environment and Development) Dr. Dong Jin Choi (Korea Research Institute for Environment and Development)
Future Direction of Sustainable Hydropower Development	Prof. Joo-Heon Lee (Joongbu University)

To determine the specific demands of submitted KSP topics, gather relevant data and information, finalize the scope of the consultation, and formalize the partnership between the Korean and MRC sides by concluding an MOU, the Korean research team led by Kyoungsik Kim (Senior Advisor and former vice minister of the Ministry of Land and Infrastructure, Republic of Korea) conducted the launching seminar and pilot study in Vientiane, Lao PDR and in Bangkok, Thailand from August 27th to September 1st, 2017. During the launching seminar, the MRC and Korean counterparts discussed the contents and scope of the consultation. They finalized the sub-topics and tentative working plans for the project. For the pilot study, the Korean research team visited the Ministry of Natural Resources and Environment and the Ministry of Energy and Mining of Lao PDR, LMNC, IUCN, International Rivers, and TNMC, and the research team gained relevant data for the research project. To formalize the KSP partnership between Korea and MRC, the parties discussed the contents of the MOU and agreed to conclude. Since this project is about the hydropower development of the Mekong River, which runs through the four member states of MRC, KDI and MRC agreed to recruit local consultants who have expertise in hydropower development of Mekong River Basin, so that comprehensive understanding of the Mekong region as a whole, as opposed to country-specific expertise, was incorporated.

From January 10th to 13th, 2018, the KSP policy seminar and in-depth study were conducted in Vientiane, Lao PDR. KDI launched the KSP policy seminar at MRC Secretariat along with seven national Mekong committee representatives. Korean and local researchers gave presentations on their interim reports, and the contents of the consultation paper were shared and discussed among National Mekong Committee representatives, Korean counterparts, and local consultants. Through the high-level dialogue between the KDI director and MRC Secretariat CEO, the content of the policy practitioners' workshop was discussed, and the contents of the MOU were finalized. In addition, in-depth studies with MRC local consultants were conducted.

From January 29th to February 2nd, fourteen MRC delegates led by Pham Tuan Phan, the MRC Secretariat CEO, were invited to the Republic of Korea for the Interim Reporting and Policy Practitioners' Workshop. The visit was composed of a policy practitioners' workshop, interim reporting workshop, and business seminar. For the policy practitioners' workshop, the MRC delegation visited Korean organizations and relevant private firms to share and view the development experiences of Korea regarding relevant KSP topics. The delegation visited Sihwa Tidal Plant, GS E&R Banwol Combined Heat and Power Generation Factory, GS E&R Solar Energy Panel Facility, Han River Flood Control Office, K-water, Daechung Multi-purpose Dam, Chungju Multi-purpose Dam, and the Floating Solar Panel Facility as part of this workshop. During the interim reporting workshop, Korean and local experts

gave presentations on their interim reports and shared comments. After the policy practitioner's workshop, on February 1st, KDI, KOTRA, and ICAK co-hosted the business seminar in Seoul. The MRC delegation gave a presentation on the prospects and opportunities for investment to the Mekong region. 105 participants from 73 Korean corporates attended the seminar. At the end of the visit, the MRC and Korean parties signed an MOU for the KSP project.

The final reporting and high-level policy dialogue was conducted from June 26th to 30th, 2018 in Bangkok, Thailand. To this event, seventeen MRC officials were invited, and a total of 71 stakeholders from international organizations and relevant ministries for this year's project participated in the final reporting workshop on June 28th, during which the final findings and policy suggestions were introduced. The high-level policy dialogue was held on June 28th, 2018 after the workshop. The MRC representatives requested the 2019/20 KSP with MRC on flood control in the Mekong River Basin. From June 28th to 29th, an end of project evaluation was conducted and fourteen relevant officials participated in the evaluation interview. Interviewees' levels of satisfaction regarding the content of the consultation topics and the project itself differed, but, overall, they expressed high satisfaction regarding the policy practitioners' workshop and suggested pre-feasibility studies with the active involvement of the four countries' representatives.

The 2017/18 KSP with MRC is the first multilateral KSP project with international organizations in Asia. The active participation of the national Mekong committee representatives of Cambodia, Laos, Thailand and Vietnam National Mekong and the MRC secretariat in designing, implementing, and evaluating the project and their co-hosting and co-working mechanism could serve as a model for the multilateral KSP project.

This year's KSP topic is the priority political agenda of the MRC member states and the MRC secretariat. The KSP suggestion can be utilized as a reference in drafting the MRC development strategy for hydropower in the Mekong River Basin. After conducting the policy practitioners' seminar at the Han River Flood Control Office (HRFCO) and K-water's Floating Solar Panel Facility in the Chungjoo Multi-purpose Dam in Korea, the MRCS showed interest, leading to inviting KDI, HRFCO, and K-water to the MRC Summit in Cambodia. MRC expressed interest in Korea's development experiences in flood control systems and requested consultation in the field via the KSP project. Also, the EGAT of Thailand showed interest in policy suggestion on topic four, dam reassessment strategy, and LNMC expressed interest in flood control systems in Laos.

Executive Summary

Seungho Lee (Korea University)

This project evaluated the experiences and practices of water security and the Integrated River Basin Management, as well as the development, planning, and operation of multi-purpose dams of South Korea as a benchmarking case for the Mekong River Basin as part of the Knowledge Sharing Program (KSP). Challenging aspects explored related to hydropower dam development, particularly socio-environmental impacts caused by dams, were also explored. The study highlights potential for the improvement of existing dams by converting single-purpose dams, namely those for hydropower generation, into multi-purpose dams that can nurture more socio-economic and environmental benefits based on Korean experiences.

It was in 1995 when collective efforts for the achievement of sustainable development were made in the Mekong River Basin through the signing of the 1995 Agreement, and, since then, the Mekong River Commission (MRC) has endeavored to implement numerous projects in line with the agreement. Among numerous projects commissioned by the MRC, the most sensitive projects have been associated with hydropower development. While there is virtually no alternative for energy generation in the river basin except for hydropower, there have been growing tensions among the upstream and downstream countries along the river. For instance, China, as an upstream country, has built a series of large-scale hydropower dams without comprehensive consultations with the downstream countries, and Laos, as a downstream country, has continued to pursue its goal of becoming the battery of Southeast Asia by building large dams, including the Xayaburi and the Dong Sahong Dams, on the mainstream and in tributaries.

Such a boom of hydropower dams on the mainstream of the river has sparked debates on the positive and negative impacts caused by hydropower dams, including socio-economic benefits, socio-environmental challenges, and the problem of out-of-date dams that require retrofitting and upgrade. In order to tackle the complexity of such challenges, the MRC and the Korea Development Institute have decided to consider plausible solutions by reflecting useful experiences of Korea since the 1960s related to the development and operation of multi-purpose dams as part of the Integrated River Basin Management (IRBM).

The experiences of the IRBM and the continuous efforts to achieve water security in South Korea deliver a variety of useful suggestions for the Mekong River Basin. South Korea was first committed to establishing a system of stable water supply for the agricultural and industrial sectors for increasing agricultural and industrial productivity in the early part of its socio-economic development plan in the 1960s-1970s.

As time went on, particular focus was placed on the expansion of piped water supply and sewage treatment networks centered in urban areas, which resulted in improving the quality of life in urban centers, ultimately cementing social stability and enhancing education opportunities. In addition, such a good foundation of water and wastewater services has led to the transformation of the country's focused industries from agriculture to heavy, manufacturing and service industries.

Despite the socio-economic benefits brought by multi-purpose dams in South Korea, there has been a series of challenges, such as micro-scale climate change near dam sites, ecosystem disruption due to impoundment, and difficulties of resettlers. Faced with these critical issues, the government has striven to provide the reflection of eco-friendly approaches for dam operation and maintenance, adequate levels of compensation for resettlers through financial assistance, and social welfare services.

The emergence of civil society, primarily led by environmental NGOs, in the mid-1990s of South Korea pushed forward the adoption of the concept of stakeholder participation in the IRBM and resulted in the establishment and implementation of water governance. The dams that have been built since the 1960s are currently numerous, including 15 multi-purpose dams, over 50 water supply dams, and over 20,000 agricultural dams in the country. These dams, however, need to be retrofitted or upgraded soon, and, therefore, it is time to conduct thorough reassessment of the dams for the enhancement of their efficiency and impacts on the environment. The integrated operation and efficiency improvement project for the dams along the Han River since 2010 is one of the core tasks of the Korean IRBM that should be achieved in the near future.

Such experiences and practices of South Korea can be useful food for thought to the Lower Mekong countries that are still at the early stage of socio-economic development. With regard to the strategies of achieving water security, the Lower Mekong countries are recommended to recognize the magnitude of water resources management for socio-economic development and should opt for the establishment and implementation of the Integrated Water Resources Management (IWRM) through domestic financing and international aid.

Specific actions are required to do so by building multi-purpose dams and agricultural water supply dams that can lead to an increase of food production alongside land reclamation projects, and these experiences can be emulated to the countries in the Mekong River Basin, especially the ones that are at the early stage of socio-economic development, such as Cambodia and Laos. Continuous efforts to improve water and sanitation services in urban areas, stable water supply and flood and drought management through multi-purpose dams, and water quality control are also good practices that can be benchmarked by the Lower Mekong countries.

Simultaneously, numerous dams in operation with a single purpose, usually hydropower generation, in the river basin should be reassessed to ensure sustainability and improve the practicability of converting them into multi-purpose ones. This new approach will help the countries in the river basin achieve mid- and long-term targets related to socio-economic development and environmental protection.

Recognizing over 100 additional dams to be added in the river basin, it is urgent for the Lower Mekong countries to consider the introduction of an integrated approach to water resources management. This approach should be centered on multi-purpose dams for the establishment and implementation of socio-economic development and land use plans, taking careful consideration from the planning stage to minimize impacts on the environment.

2017/18 Knowledge Sharing Program with the MRC:
Basin-wide Strategy for Sustainable Hydropower Development

Chapter 1

Water Security and Integrated River Basin Management

1. Introduction
2. Integrated River Basin Management in Korea
3. Review of Strategies for Water Security and Sustainable River Basin Management in the Mekong River Basin
4. Implications and Recommendations

Water Security and Integrated River Basin Management

Seungho Lee (Korea University)

Summary

This chapter draws particular attention to a strategic approach to water security and the characteristics of the Integrated River Basin Management (IRBM), with special reference to South Korea and the Mekong River Basin. In general, water security is regarded as a conceptual and strategic approach that accommodates a variety of aspects in water resources management, such as water supply, water quality, water related disasters, and water environments (ecosystems). This chapter, however, aims to delineate more strategic aspects of the conventional understanding of water security via the case of South Korea and the Mekong River Basin, which shed light on their unique path to achieving multi-faced dimensions of water security, reflecting institutional reforms and structural measures in the forms of multi-purpose dams, multi-regional water supply networks, and tap water supply and wastewater treatment plants. In a nutshell, for the purpose of this study, water security is defined as the capacity to provide stable and sufficient amounts of clean water to human beings and ecosystems and to cope with water-related disasters. The approach to achieving water security should improve upon the situations of inequalities between the regions in terms of water related benefits, increase resilience against climate change driven events, consider the Water-Energy-Food Nexus, establish good governance, and opt for basin-wide and cross-cutting strategies for sustainable development related to water resources management.

Keywords: Water Security, IRBM, Sustainable River Basin Management, Mekong River Basin

The process of the establishment of the Integrated River Basin Management (IRBM) has demonstrated the significant contribution of IRBM to the unprecedented and eye-catching economic growth of South Korea within the three decades between the 1960s and the 1990s. The basic principles for achieving IRBM are basin-wide planning, public participation, demand management, domestic and industrial compliance with water pollution abatement measures, and human and financial capacity. These elements have well been achieved over the course of Korea's river basin management. Spearheaded by the Ministry of Land, Infrastructure and Transport and the Ministry of Environment, Korea's river basin management is based on four major Rivers: the Han, Nakdong, Geum and Youngsan Rivers.

The first IRBM plan was the 10 Year Comprehensive Water Resources Development Plan, which was launched in 1966 and carried out until 1975. The first decade of the IRBM experience explicitly indicates Korea's commitment to establishing a firm foundation for economic take-off by providing a stable supply of water for domestic, industrial, and, most importantly, agricultural sectors. Food security and basic access to water and sanitation services were achieved in this period. Whilst large-scale river basin management plans were established and implemented with a focus on the four large rivers, the capital of Seoul underwent a dramatic socio-economic and environmental change through the Comprehensive Development of the Han River Plan (1968-1970, 1982-86). The current features of the Han riverside were created to make the city an international city with a reliable level of flood prevention measures, adequate water quality control, large areas of housing spaces along the river, and a wide range of leisure facilities.

The Comprehensive Four Major River Basins Development Plan (1971-1981) integrated more Korean characteristics in water resources management by promoting the construction of more multi-purpose dams that provide the benefits of water supply for households, industries, and agriculture, flood and drought control, hydropower generation, and inland navigation. Thanks to the dams, large metropolises emerged, including Seoul, Pusan, and Daejeon. The experiences of IRBM in Korea will be a useful benchmarking case for the counterparts in the Mekong River Basin, namely the member countries of the Mekong River Commission: Thailand, Laos, Vietnam, and Cambodia.

Environmental aspects have been emphasized since the outbreaks of numerous water pollution accidents, including the phenol discharge incident in the early 1990s, which culminated in the creation of the Ministry of Environment, which is now in charge of water quality control in the four major rivers and overseeing tap water supplies and sanitation services. In order to ensure the quality of drinking water in the upstream of the Four Major Rivers, demand management tools have been introduced in accordance with the Polluter-Pays-Principle. At the same time,

Water Vision 2020, the top level water management strategy and master plan in the country, has begun to recognize not only environmental dimensions of socio-economic development supported by water, but also a bottom-up way of decision making in water resources management, a process also known as governance-based decision making.

The case of the Lake Sihwa Water Quality Improvement Project since the mid-1970s implies the gradual acceptance of environmental discourses and policy shifts, from the increase of food production through reclamation, the upscale of industrial production via industrial complexes, to the ecological rehabilitation through the influx of seawater into the lake. The Four Major River Project (2009-2012) was a bold and strategic attempt of the Korean government to cope with a complexity of challenges driven by climate change, urbanization, population growth, and industrialization. The purposes of the project were to provide additional water supplies against climate change-caused droughts, improve water quality of the rivers, enhance flood protection measures, improve leisure facilities in waterfront areas, and boost local economies. It is still too early to judge the final outcomes of the project, but Korea needs to take a more prudent and careful approach to the post-project consequences.

The Agreement for the Cooperation for the Sustainable Development of the Mekong River Basin has been the backbone cementing the collaboration between the lower Mekong countries, Thailand, Vietnam, Laos and Cambodia. The agreement provides a formal framework for basin planning with a requirement to prepare the Basin Development Plan (BDP). There were two phases of the BDP Programme. The first BDP was conducted between 2001 and 2006, and the second BDP was conducted from 2007 to 2010. These programmes facilitated the establishment of participatory basin planning processes between the member countries and their stakeholders. In addition, the IWRM-based Basin Development Strategy was developed and promoted in order to identify development opportunities and advocate strategic priorities for optimizing opportunities and minimizing risks.

The BDP Programme 2011-2015 followed the two phases of the BDP Program, which were implemented until 2010. The new programme was proposed together with the development of the MRC Strategic Plan 2011-2015. The overall objective of the BDP 2011-2015 was to integrate and implement the principles, guidance, and process of the IWRM based Basin Development Strategy in national planning and regulatory systems for the member countries. The strategy consisted of several key areas, namely basin wide water resources development scenarios, IWRM-based basin development strategy, and a project portfolio. There are numerous sectoral achievements related to basin planning in the MRC programmes, such as the Mekong-Integrated Water Resources Management, Agriculture and Irrigation

Programme (AIP), the Drought Management Programme (DMP), and the Fisheries Programme (FP).

In retrospect, whilst the MRC has endeavored to play a significant role in advocating and promoting mutual collaboration for sustainable development since the establishment of the 1995 agreement, either the approaches have been too complex or capacity building for the member countries and other stakeholders has been insufficient for successful implementation. Inadequate coordination at the national level and insufficient engagement of relevant line agencies have continued to undermine regional and national efforts. Coordination between the MRC and its Member Countries has not been seen as effective as it should be. MRC and its Member Countries should consider how its coordination with various national and sub-national agencies can be strengthened to implement the developed basin-wide sector and cross-cutting strategies.

1. Introduction

1.1. Definitions and Objectives of Water Security in the Korean Context

1.1.1. A Working Definition of Water Security

Although there are many different definitions of water security, the two working definitions are worth referring to in this study. Grey and Sadoff (2007) introduces the definition of water security as the reliable availability of an acceptable quantity and quality of water for production, livelihoods and health, coupled with an acceptable level of risk to society of unpredictable water-related impacts." The UNESCO-IHP (International Hydrological Program) in 2012 provides a more comprehensive definition, "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" (UNU and UNESCAP, 2013).

These definitions touch upon multi-faceted areas of water resources management, i.e. provision of an adequate level of water supply, safeguarding good quality of water, protection from water-related disasters and water-borne diseases, and ecosystem protection and puts an emphasis on the roles of sound water management for socio-economic development and environmental sustainability. In addition to these, critical aspects embedded in the definition of water security are as follows, and these aspects implicitly reflect major issues discussed in the SDG No.6

Clean Water and Sanitation (Grey and Sadoff, 2007; UNU and UNESCAP, 2013):

- Access to safe and sufficient drinking water as an affordable cost in order to meet basic needs, i.e. sanitation and hygiene, health and well-being
- Protection of livelihoods, human rights, and cultural and recreational values
- Protection of ecosystems in water allocation and management systems
- Water supply for socio-economic development, including the sectors of energy, transport, industry and tourism
- Wastewater treatment for protection of human life and the environment from pollution
- Collaborative approaches to transboundary water resources management
- Capacity building for coping with uncertainties and risks of water-related disasters, such as flood, drought and pollution
- Good governance and accountability coupled with consideration of the interests of all stakeholders

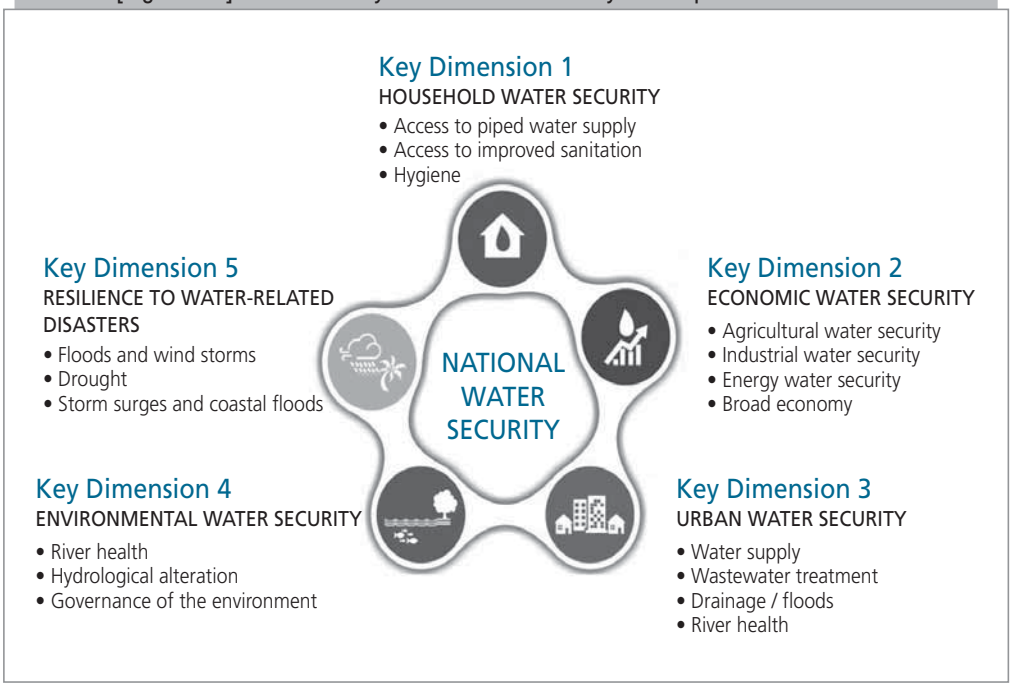
As discussed above, water security requires integrated and multi-faceted approaches and has to reflect what is needed in society. This implies the urgency to prepare unique and tailor-made measures depending upon regions, societies, and countries. In Asia and the Pacific, including South Korea and the Mekong River Basin, the water security framework introduced by the Asian Development Bank (ADB) is useful in order to have a better understanding of the degree of water security relevant to the countries in the region in 2013 (ADB, 2013; 2016).

In the framework, there are five key dimensions in measuring water security in a country: (1) household water security; (2) economic water security; (3) urban water security; (4) environmental water security; and (5) resilience to water-related disasters. The key dimension (1), household water security assesses access to piped water supply, access to sanitation, and hygiene, and the key dimension (2), economic water security reflects economic growth related indicators, agricultural, industrial, energy water security coupled with impacts on broad economy.

Urban water security, the key dimension (3), appraises the situations of water supply, wastewater treatment, drainage and flood prevention or protection systems, and river health in urban areas. Environmental water security is set as the key dimension (4), assessing the performance of various environmental sectors, i.e. river health (on a broader scale – river basins), hydrological alteration, and environmental governance that advocates stakeholder participation in the decision making process. The key dimension (5), resilience to water-related disasters, explicitly emphasizes the commitment of a national government to provide safe and sound disaster-prevention and preparedness, response, and recovery policies and programs. The fields to look into are floods and wind storms, droughts, and storm surges and coastal floods, which are directly linked to adverse impacts of climate change (ADB,

2013; 2016). [Figure 1-1] illustrates the five key dimensions of water security in Asia and the Pacific.

[Figure 1-1] Water Security Framework of Five Key Interdependent Dimensions

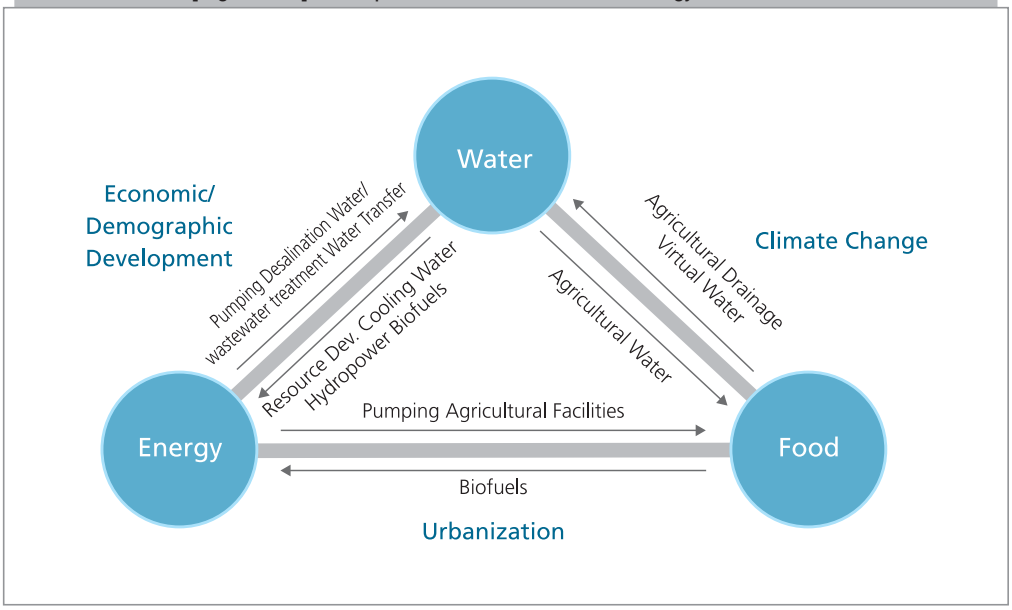


Source: ADB (2016).

The discussion of water security is associated with the newly emergent attempt to enhance resource management in an integrated fashion, the Water-Energy-Food Nexus. Risks and uncertainties are rising as global trends, i.e. population growth, urbanization, and industrialization that are often compounded by climate change, pose a grave threat to the security of three sectors, and an innovative and cross-sectoral approach is urgent. Water is not only essential for life but also instrumental for energy generation as a cooling purpose as well as direct use, i.e. hydropower generation. The linkage between energy and food is easily found in electricity for pumping and grain products for generation of bio-energy. Virtual water and water footprints encapsulate the intricate relationship between water and food in connection with international trade. The Water-Energy-Food Nexus can be defined as "a way of thinking about the interdependencies, tensions and trade-offs between water, energy and food security in the wider context of environmental change with a focus on the impact on social systems" (Bazillian *et al*., 2011; Houses of Parliament, 2016).

Interdependencies, trade-offs, and synergistic effects should be considered to avoid emerging risks in the Water-Energy-Food Nexus security but numerous developing countries have a lack of capacity in guaranteeing the security. It is necessary to incorporate such nexus-based approaches into policies and programs through coordinated decision-making, i.e. establishment of the Water-Food-Energy Nexus Council at the regional and national level (UNU and UNESCAP, 2013; Lee, 2017). [Figure 1-2] visualizes the concept of the Water-Energy-Food Nexus.

[Figure 1-2] Conceptualization of the Water-Energy-Food Nexus



Source: Author.

1.1.2. Water Security in the Korean Context

It is necessary to have a good understanding of major water challenges prior to delving into what water security means in the Korean context. Water resources management in Korea has contributed to the overall socio-economic development of the country despite a large degree of seasonal variability in rainfall, an uneven distribution of water resources, water pollution caused by industrialization, and an intense exploitation of water intake for domestic, agricultural and industrial purposes. However, Korea's water resources management is at a crossroads in spite of the monumental achievements in a few decades, due to adverse impacts of climate change. Korean society should be ready to face an unprecedented challenge for achieving a good degree of water security against any unexpected and abrupt changes of climate and hydrologic regimes (Kang *et al*., 2013). No conspicuous socio-

economic achievements could be possible without the adequate provision and conservation of water resources for Korean society since the 1960s. More detailed investigation will be shown in the sections of 1.2.

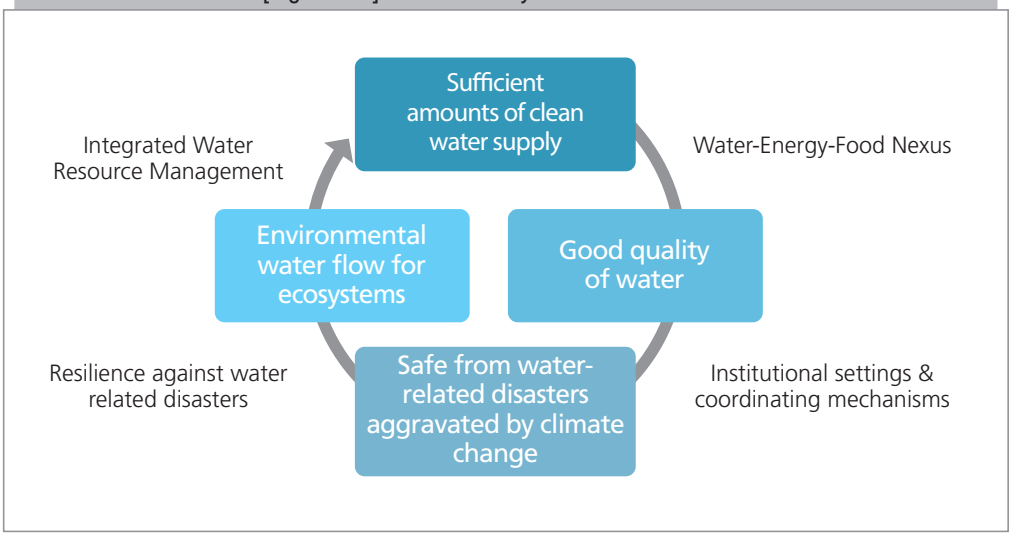
In the Korean context, water security can be defined in simple terms as 'the capacity to provide stable and sufficient amounts of clean water to human beings and ecosystems and to cope with water-related disasters' (Kim *et al*., 2011). This indicates that water resources management ensures the sustainability of human development and ecosystems and an adequate level of water, and safeguards a good quality of water for various purposes in society. Socio-economic and environmental uncertainties have increased related to water resources management, and therefore, it is urgent for water managers to take into serious account adverse impacts of climate change that are more intense and frequent, which often spawns long spells of droughts and intensifying torrential rainfall and typhoons (Kim *et al*., 2011).

Korean society needs to nurture its structural as well as non-structural capacity so as to tackle extreme weather events, especially associated with rivers and various water bodies such as agricultural and dam reservoirs. An adequate level of water security in South Korea can be achieved through a synergistic and integrated system in which all stakeholders work together reflecting concerns about stable water supply, flood and drought prevention, the enhancement of water quality and water ecosystems, efficient water use, and the mediation of water conflicts. Such a mechanism well functions based on not only a good set of structural measures (dams, embankments, water supply systems, sewers and sewage treatment plants, and flood and drought monitoring systems) but also non-structural systems (basic water law, law enforcement, good compliance of domestic, agricultural and industrial users, and systemization of stakeholder participation in decision making).

The Presidential Commission on Sustainable Development (PCSD) in Korea (2004) maintains that there are seven significant tasks to achieve water security in the country. First, Korean society should have stable access to clean water. Second, Korea should establish the socio-economic fundamentals to cope with flood events and droughts. Third, it is necessary to introduce the Total Water Pollution Load Management System in the Four Major Rivers. Fourth, various levels and kinds of water conflicts have to be resolved. Fifth, joint management and monitoring in the transboundary rivers, namely the Imjin River and the North Han River, should continue to be undertaken between the two Koreas. Sixth, one of the best ways to achieve water security in the country is to introduce the Integrated River Basin Management. The IRBM not only includes water related sectors but also non-water sectors, such as agriculture, forest, land use, and urban development. Seventh, the commission emphasizes the significance of institutional rearrangement, particularly the enactment of the Basic Water Law which can be a legal and

institutional foundation for the country's water security. [Figure 1-3] illustrates the conceptualization of water security in the Korean context.

[Figure 1-3] Water Security in the Korean Context



Source: Author.

1.2. Major Principles and Case Studies

1.2.1. Major Principles

In order to achieve an adequate level of water security in South Korea, it is necessary to take into account major principles with which different levels of government authorities and non-state actors collaborate. There are five major principles: 1) Integrated Water Resources Management; 2) Water-Energy-Food Nexus based resilience; 3) equal distribution of water and environmental benefits between regions; 4) good water governance; and 5) adaptive capacity to cope with challenges caused by climate change.

The first major principle, IWRM, is an almost cliché but significant component as a fundamental to achieve water security in the country. Although the country has endeavored to safeguard stable water supply, the good quality of water, flood and drought prevention and participatory decision making process, these efforts have not necessarily been undertaken in collaboration with non-water sectors at different levels of society, not only between ministries but also diverse agencies, sectors, and industries. In particular, the water-concerned ministries, such as the Ministry of Land, Infrastructure and Transport (MOLIT), and the Ministry of Environment (ME), have

made tremendous efforts to improve water resources management. However, water issues are sometimes marginalized because of pro-growth policies and development oriented projects or not well reflected in urban development plans or industrial complex creation projects. Therefore, the promotion of IWRM should be undertaken as part of national, regional, urban and local development plans.

Second, socio-economic and environmental resilience needs to be promoted in Korean society based on the understanding and awareness of the Water-Energy-Food Nexus. As discussed above, the interdependencies between these three elements have to be adequately recognized not only within the public sector but also the private sector, and then public authorities have the mission to disseminate the magnitude of this approach to the general public who would be ready to change their way of thinking as well as consumption behaviors. Here, resilience means resilience in water management, which can avoid devastating situations such as anthropological disasters (water pollution accidents) and water-related disasters (flood and drought events) by providing core water services for daily living, economic activities and ecosystems confronted with extreme weather events triggered by climate change (Kim *et al*., 2011). This nexus approach facilities the socio-economic progress of water management resilience and strengthens the degree of sustainability in Korean society in the future.

The third major principle is the equal distribution of water and environmental benefits between regions. This principle has not necessarily been recognized until recently in the country, because the government has put a large emphasis on the stable provision of water related services at the national level in a top-down fashion. Such a policy trend has culminated in an even distribution of water and environmental benefits between the Four Major River Basins and even between provinces, municipalities and smaller-scale local communities.

For instance, local residents living in remotes areas of the Gangwon Province have had limited access to piped water supply, because these areas are located in highlands, and many households are scattered in long distances. To make things worse, the weather of the province is generally harsh, particularly in the winter time, and small-scale facilities for potable water cannot cope with the cold winter, because the water of the facilities are frozen. In order to resolve such issues, the Korean government has endeavored to expand the multi-regional water supply systems to marginalized areas, and to enhance small-scale water supply facilities in rural areas (Kang *et al*., 2013).

The fourth major principle, good water governance is the matter that cannot be completed in a short period of time. In the period between the 1960s to the 1990s, most of water related policies and projects were decided without proper consultation

with the general public and local communities. The government in the period was intolerant of complaints or diverse opinions on water policies and projects. However, since the beginning of the mid-1990s, the number of water related conflicts between government authorities or companies and local people and even between different regions has dramatically increased and has become one of the thorny agendas in society.

That is the reason why the government has begun to accommodate a variety of opinions from different stakeholders and reflected these into one of the revision processes of the Water Vision 2020 in 2006. The revision process illustrates the extent to which the decision making process of national water plan has become democratized and accommodative thanks to the collective wisdom. The government has come to realize the value of governance, inviting different stakeholders at all levels and allowing these stakeholders to discuss and decide the most plausible options for national water planning. This good exercise should be duplicated and trickled down to other water policy and project cases.

The fifth major principle reiterates the importance of Korean society's recommitment to dealing with water and climate change challenges. The Korean government has made efforts to tackle adverse impacts of climate change by establishing a myriad of national level coping strategies and plans, i.e. the Comprehensive Basic Plan of Climate Change Adaptation that was set up in December 2008. Nevertheless, climate change triggers unpredictable and uncertain consequences, and because of these, relevant measures should not be limited only in government policies and projects. More investment and relevant policies are necessary at the national level but also the government encourages the whole society to be aware of the urgency and graveness of water and climate change-driven results, i.e. torrential rainfall, frequent typhoon, and long spells of droughts.

Standards and design categories in water resources management should be revised in order to reflect climate change adaptation policies. For example, the standards and design categories of drainage systems in Seoul need to be altered for tackling extreme concentrated rainfall events. Manufacturing companies have to utilize water-saving technologies, i.e. water reuse, water recycling, and rainwater harvesting for coping with water shortage caused by droughts. Schools teach students about the significance of water and climate change challenges and encourages them to change their consumption behaviors, considering the Water-Energy-Food nexus, and understand the significance of virtual water and water footprints.

1.2.2. Case Studies

Multi-dimensional approaches are required in order to achieve an adequate level of water security in South Korea, not only stable supply of clean water and water quality control but also proper prevention of water-related disasters coupled with ecosystems protection and good governance. The following paragraphs delineates the dimension of water security against water-related disasters, especially flood events in Korea. Korea's efforts of managing flood events over a few decades imply the assessment of previous attempts to achieve water security but also provide food for thought on what should be necessary in due course for strengthening the dimension of water-related disaster prevention in water security.

Attention is given to previous flood events in South Korea from 1945 to 2007. 17 major typhoons had badly affected Korea. Several major flood events are worth having a closer look at, for instance, the national-level flood in July 1984, the large-scale flood in the Han River Basin, 1990, and devastating impacts on the Nakdong River Basin by the two typhoons Rusa in 2002 and Maemi in 2003 (Kim *et al*., 2007). With regard to the flood event in September, 1990, some of the riverine areas along the Han River within the Seoul Metropolitan Area and the Gyeonggi Province were flooded, 155 people were killed or missing, and around 184,000 people were evacuated from flood-prone areas due to the heavy rainfall. More than 400 mm of torrential rain were poured over a few days in the Suwon City, the Gyeonggi Province, and the total amount of economic losses was estimated at KRW 330 billion (US$ 303 million) (Herald Photo, 2017; Kang *et al*., 2013) (See Figure 1-4).

Typhoon Rusa in 2002 and typhoon Maemi in 2003 have been regarded as the most devastating typhoons in the history of flood management in South Korea. Typhoon Maemi badly damaged the southern part of the country in 2003 and triggered insured losses of KRW 480 billion (US$ 4.8 billion), and typhoon Rusa in 2002 wreaked havoc on the peninsular, causing insured losses of KRW 670 billion (US$ 6.7 billion). <Table 1-1> shows a list of the most damaging typhoons in Korea between the 1950s to the 2000s.

There is an interesting difference between the two monstrous typhoons. The amount of precipitation of Tyhpoon Maemi reached just 50% of that of Rusa. No major reports were given about inundation cases beyond embankments of rivers related to Typhoon Maemi in 2003 whereas Rusa in 2002 heavily impacted on river bank areas in many parts of the country by heavy rainfall, thereby causing many riverine areas to be inundated. Therefore, Typhoon Maemai is categorized as a dry typhoon whereas Typhoon Rusa as a wet typhoon.

[Figure 1-4] Photo from the Han River Large Flood, September 1990



Source: Woo (2017).

〈Table 1-1〉 The Most Devastating Typhoons in Korea

Year	Name of Typhoon	Economic Losses (US$ Million)	Maximum Rainfall (mm/h)
1959	Sarah	NA	NA
1987	Thelma	530	NA
1991	Gladys	260	600
2000	Prapiroon	560	247
2000	Saomai	890	491
2002	Rusa	6,700	871
2003	Maemi	4,800	432

Source: Kim *et al*. (2007).

Typhoon Rusa brought in tremendous amounts of rainfall together with gusty winds in 2002, and the historic concentrated rainfall was recorded in the Gangreung City of the Gangwon Province, estimated at 870.5 mm, which was about 60% of the annual average rainfall in the city. The typhoon claimed 321 casualties, and over 63,000 people had to be evacuated. The economic losses were estimated at over US$ 6.7 billion. The most serious damage caused by Typhoon Maemi 2003 stemmed from strong winds, estimated at 60m/sec, not heavy rainfall, and many devastated areas

were near industrial sites. More than 130 people were killed, and around 10,000 people had to leave their homes and suffered from the loss of their homes and properties. The economic losses caused by the typhoon were estimated at around US$ 4.8 billion. [Figure 1-5] and [Figure 1-6] show the seriousness of impacts triggered by the two typhoons (Kim *et al*., 2007; Kim, 2006a; 2006b).

[Figure 1-5] Janghyun Reservoir Breached and a Whole Village Swept by Typhoon Rusa



Source: Kim *et al*. (2007).

[Figure 1-6] Container Cranes in Pusan Port Destroyed by Strong Wind of Typhoon Maemi



Source: Kim *et al*. (2007).

Such a bitter experience related to the two consecutive years' typhoons pushed the Korean government to conduct urgent and comprehensive reviews of its flood prevention and recovery systems. Scientific communities, government authorities and the general public became more aware of the risk of gigantic human and economic losses caused by super typhoons, and this risk would rapidly increase thanks to climate change.

The two typhoons left four lessons to Korean society on basic principles for disaster prevention, preparedness, management, and recovery, especially for flood, typhoons, and torrential rainfall. First, the government was heavily criticized by the general public due to their slow relief measures after Typhoon Rusa in 2002. This dysfunctional behavior was not rectified when Typhoon Maemi landed in the country in 2003, and the general public complained of ineffective evacuation policies and activities. Since then, the government made efforts to improve relief and evacuation systems and operated the special task force for planning comprehensive flood mitigation measures under the Office of the Prime Minister.

Second, scientific communities asked the government to take into serious account adverse impacts caused by climate change and to establish flood prevention and protection measures accommodating such elements. Prior to these typhoons, relevant planning and countermeasures did not include such elements, and therefore, various policies and measures were ineffective consequently. The Korean Meteorological Administration came to recognize the urgency to revamp its weather forecasting systems and ensured that more accurate and systematic weather forecasting would be possible reflecting climate change.

Third, the review and assessment of the two typhoons unlocked the unpreparedness of Korean society against such large-scale typhoons or flood events thanks to the rapid urbanization and industrialization over a few decades. Although Korea had become wealthier, an adequate level of infrastructure was lacking, especially for disaster management. The lack of infrastructure prevailed over not only in urban areas but also in rural communities which turned out to be more vulnerable to climate change driven adverse impacts.

Fourth, the government had declared special disaster zones and offered generous compensation to the victimized people by the typhoons. Also a supplementary budget bill was quickly passed for providing not only compensation but also short-term and long-term investment of building various facilities against future flood events. However, it is better to prevent devastating impacts than recover from major flood events, and Korean society increasingly understood the need to put more emphasis on the preparedness and prevention measures against water-related disasters. Since then, the government decided to allocate more R&D investment for flood prevention technologies and systems (Kim *et al*., 2007).

2. Integrated River Basin Management in Korea

2.1. Overview of Integrated River Basin Management in Korea

One of the most sustainable and efficient ways for achieving river basin management is to apply the Integrated River Basin Management (IRBM) into practice. Prior to shedding light on the Korean practices in river basin management, it is useful to explore the definition and primary elements anchored in the IRBM. The IRBM is defined as 'an integrated and coordinated approach to the planning and management of natural resources of a river basin, one that encourages stakeholders to consider a wide array of social and environmental interconnections, in a catchment or watershed context' (Hooper, 2005).

This definition advocates a holistic and integrated approach to river basin management, not only dealing with water resources but also non-water sources in a river basin, i.e. land, forest, and minerals and puts an emphasis on promoting active engagement of diverse stakeholders. In addition, the interface between human activities and ecosystem services is recognized, and socio-economic influences should be reflected in river basin management coupled with environmental considerations (Lee, 2011).

There are major elements for implementing the IRBM more effectively. First, it is imperative to introduce a basin-wide planning. The planning should accommodate all stakeholders' requests and needs for water resources now and for the future, and should reflect spatial developments at the same time. In addition, the planners have to take into serious consideration vital human and ecosystem needs. Second, public participation should be encouraged in decision making. Planning authorities should encourage local communities to take an active part in decision making, which results in enhancing river basin management. It is imperative to provide local communities with the media or channel in which they put their feedback and opinions on river basin plans or projects.

Third, one of the essential elements in river basin management, although often de-emphasized, is demand management. Numerous cases in developing countries have prioritized supply management in river basin management, such as provision of aqueduct, construction of multi-purpose dams, and expansion of irrigation systems. Such practices, however, have discouraged water users from saving or opting for efficient use of limited amounts of water resources. The IRBM should introduce and promote demand management which gives water users incentives to save water or discourage them from wasting precious water resources.

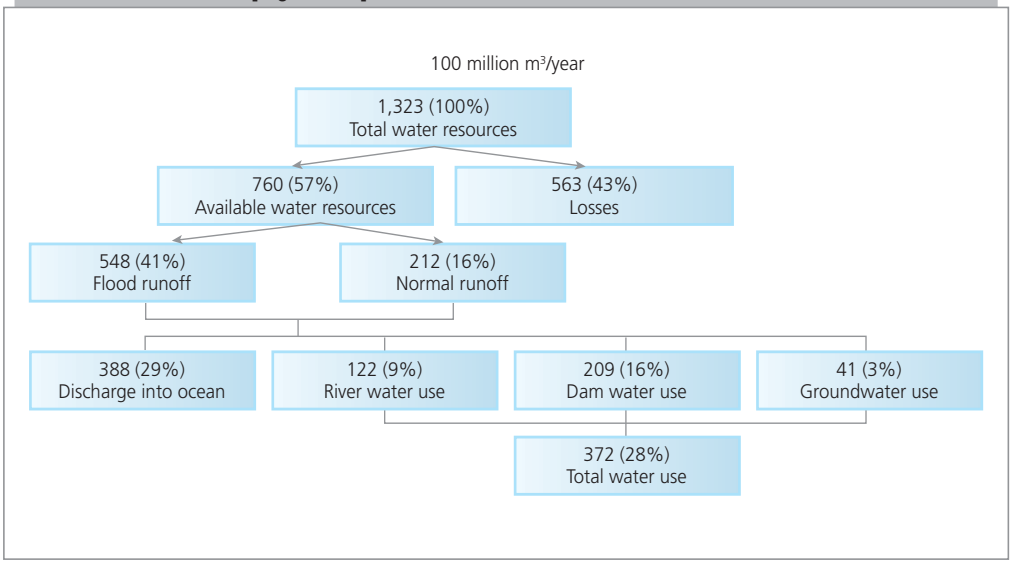
Fourth, domestic and industrial compliance with agreements and arrangements in river basin management should be carefully monitored. This includes not only domestic, industrial, and agricultural compliance with water pollution-related standards but also diverse stakeholders' commitments to following accords and agreements for sustainable river basin management. Fifth, the IRBM requires long-term human and financial capacity, which means that water authorities have responsibility for guaranteeing a stable supply of public funding and establishing a system that train water managers for the IRBM and facilitate river basin governance through educating stakeholders (Hooper, 2005).

The Presidential Commission on Sustainable Development in Korea (2004) argues additional prerequisites for the establishment of the IRBM. First, clear purposes should be addressed for the IRMB. Second, the IRBM has to accommodate views and opinions from water managers and different stakeholders through river basin surveys and assessment. Third, the systemization of river basin management accompanies different kinds of models that help prepare a variety of situations in the future. Fourth, as part of demand management, economic instruments should be introduced for sustainable water resources management, including an adequate level of water pricing, taxes, and incentives (PCSD, 2004).

It is necessary to discuss the overview of water resources management in South Korea before shedding light on river basin management. An annual average precipitation in South Korea reaches over 1,270mm, and large amounts of precipitation are concentrated in the summer monsoon season, usually from June to September, estimated at 870 mm, which is equivalent to a 68% of the total amount of precipitation per annum. Typhoons often come in every summer, which engender economic and human losses in the country (Choi *et al*., 2017; OECD, 2017; Shim, 2014).

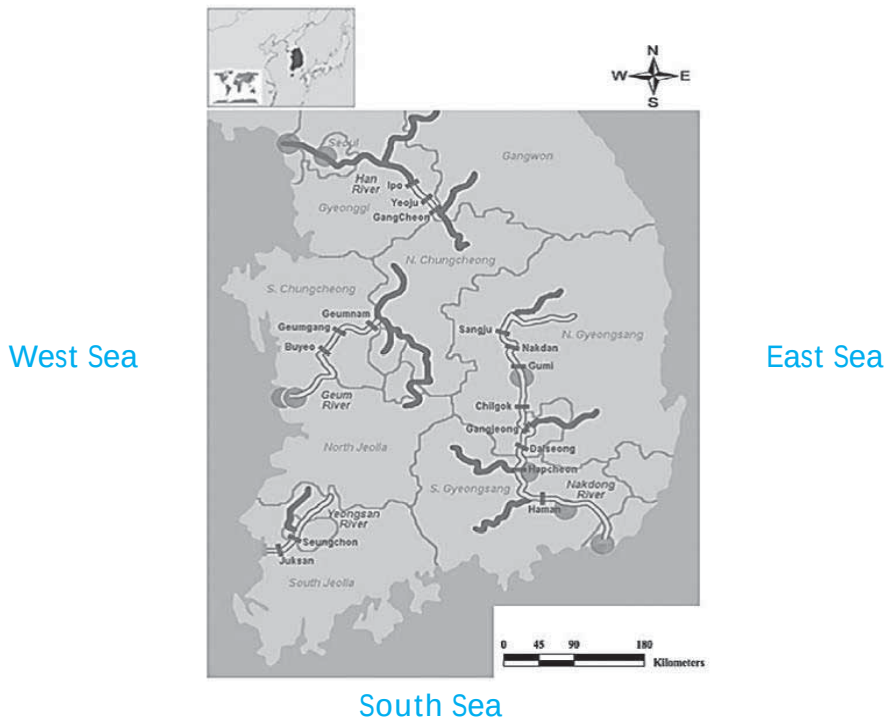
[Figure 1-7] anatomizes the status of water resources in the country. 28% of the total water resources (37.2 billion m^3/year) is available for various purposes, including river, dam, and ground water uses. An amount of available water resources per capita was estimated 1,553 m^3/year, which is approximately 18% of the world average, 8,372 m^3/year. The location and average water availability in the Four Major Rivers, namely the Han, the Nakdong, the Geum and the Yongsan/the Seomjin Rivers are illustrated in [Figure 1-8] and [Figure 1-9] respectively. The Han River boasts the largest volume of water available, which is as large as 29,600 million m^3 (39%), followed by the Nakdong River, 20,928 million m^3 (27%), the Geum River, 12,814 million m^3 (17%), the Seomjin River, 6,841 million m^3 (9%), and the Yeongsan River, 5,792 million m^3 (8%) (OECD, 2017 cited from MoLIT, 2017).

[Figure 1-7] Water Resources Status in South Korea



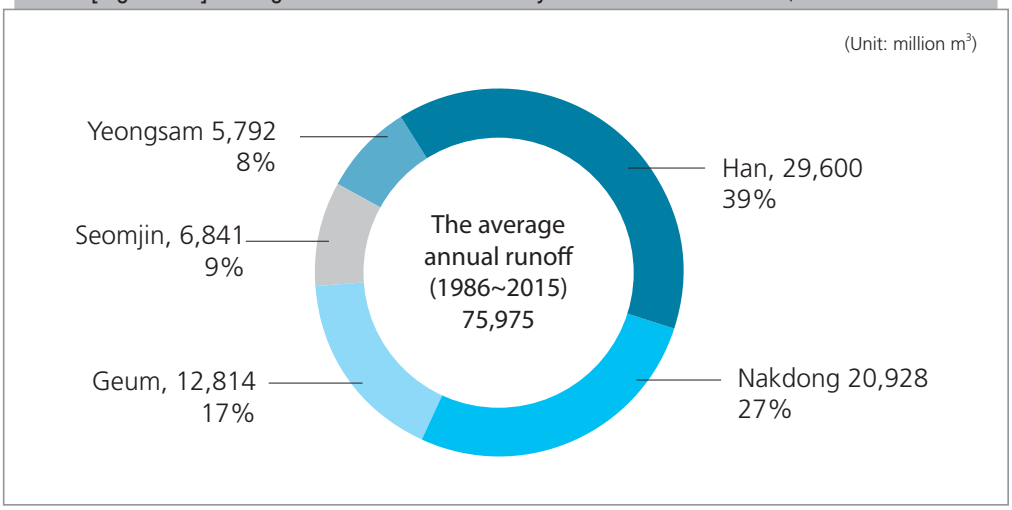
Source: OECD (2017).

[Figure 1-8] Four Major River Basins in South Korea



Source: Choi *et al*. (2017).

[Figure 1-9] Average Annual Water Availability in the Four River Basins, South Korea

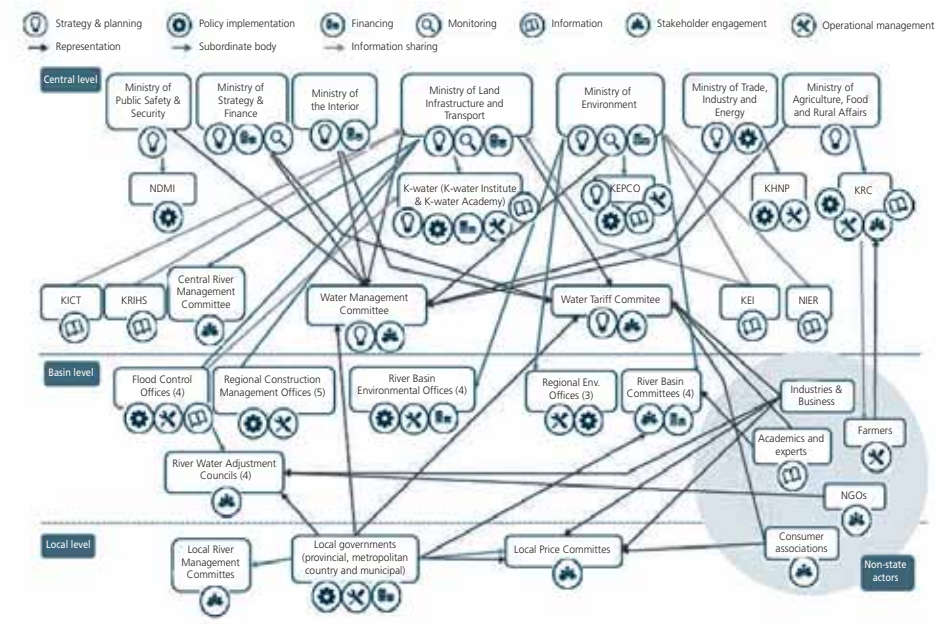


Source: OECD (2017).

With regard to river basin management, there are two major ministries involved in South Korea, the Ministry of Land, Infrastructure and Transport (MOLIT) and the Ministry of Environment (ME). Whereas MOLIT is in charge of bulk water supply and flood management, ME takes responsibility for water quality, and local water supply and sanitation services. In addition to these ministries, an array of ministries is involved in river basin management, i.e. the Ministry of Agriculture, Food and Rural Affairs (agricultural water supply), the Ministry of the Interior and Safety (assessment of local water and wastewater companies), and the Ministry of Trade, Industry and Energy (hydropower dams). [Figure 1-10] illustrates the way how a constellation of ministries and public agencies and research centers are engaged in the overall management of water resources in South Korea (Lee, 2011; Lee and Kim, 2009; OECD, 2017).

The MOLIT has been the most influential ministry in the water sector of South Korea and has the overall responsibility for water resources management and development. Large structures in water resources management have been overseen by the ministry, primarily through its subsidiary public company, K-Water (previously Korea Water Resources Corporation), which include multi-purpose dams, canals, aqueducts, and multi-regional water supply systems. Since the construction of the Seomjin River Dam in 1964, the first multi-purpose dam, the country has constructed a total of 20 multi-purpose dams, 55 water supply dams (domestic and industrial water supply), 12 hydropower dams, and 17,569 agricultural water supply dams in the Four Major River Basins in 2017 (Korea National Committee on Large Dams, 2017). <Table 1-2> displays the overall situations of dams and the details of multi-purpose dams are illustrated in <Table 1-3>.

[Figure 1-10] Institutional Mapping for Water Resources Management in South Korea



Source: OECD (2017).

〈Table 1-2〉 Specifications of Dams in South Korea

Items	Total	Multi-purpose Dams	Water Supply Dams	Hydropower Dams	Agricultural Water Supply Dams
No.	17,656	20	55	12	17,569
Capacity (million m^3)	13,327	9,108	503	944	2,772
		68.3%	3.8%	7.1%	20.8%

Source: KNCOLD (2017).

〈Table 1-3〉 Specifications of Multi-purpose Dams in South Korea

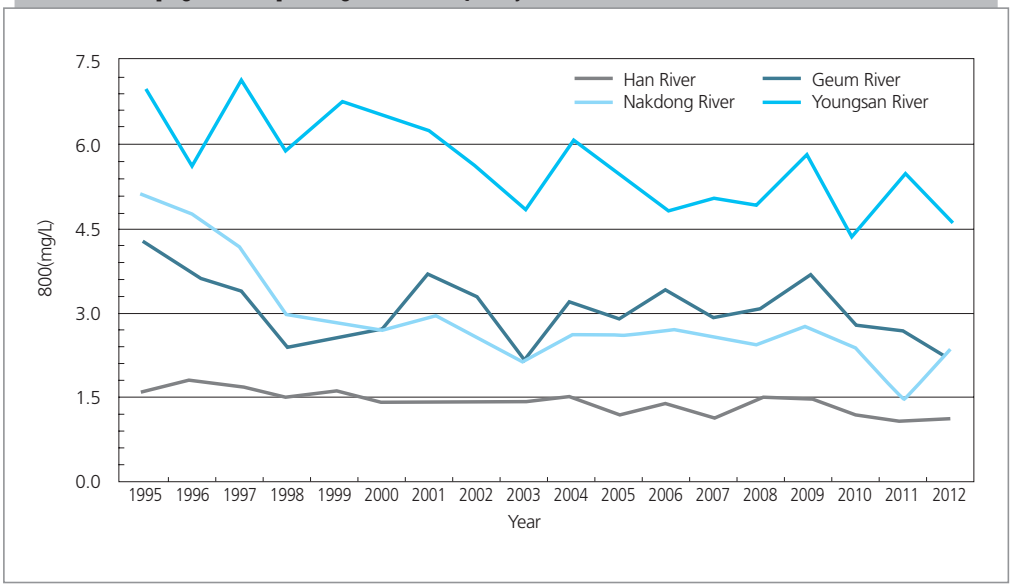
River Basin	Multi-purpose Dam	Basin Area (km^2)	Data		Total Capacity of Reservoir (million m^3)	Active Capacity of Reservoir (million m^3)	Installed Capacity of Power station (MW)	Enterprise Effect		Construction Period
			Height (m)	Length (m)				Flood Control (million m^3)	Water Supply (million m^3/year)	
Han-River	Soyang	2,703	123	530	2,900	1,900	200	500	1,213	''67-''73
	Chungju	6,648	97.5	447	2,750	1,789	412	616	3,380	''78-''86
	Hoengseong	209	48.5	205	86.9	73.4	1.3	9.5	119.5	''90-''02
Nakdong-River	Andong	1,584	83	612	1,248	1,000	91.5	110	926	''71-''77
	Imha	1,361	73	515	595	424	51.06	80	591.6	''84-''93
	Hapcheon	925	96	472	790	560	101.2	80	599	''82-''89
	Namgang	2,285	34	1,126	309.2	299.7	14	269.8	573.3	''87-''03
	Miryang	95.4	89	535	73.6	69.8	1.3	6	73	''90-''02
	Gunwi	87.5	45	390	48.7	40.1	0.5	3.1	38.3	''00-''12
	Gimcheon-Buhang	82.0	64	472	54.3	42.6	0.6	12.3	36.3	''02-''14
	Bohyun Mountain	32.61	58.5	250	22.11	17.88	1.414	3.49	14.87	''10-''14
Guem-River	Daechung	4,134	72	495	1,490	790	90.8	250	1,649	''75-''81
	Yongdam	930	70	498	815	672	26.2	137	650.43	''90-''06
Seomjin-River	Seomjin-River	763	64	344.2	466	370	34.8	32	350	''61-''65
	Junam	1,010	58	330	457	352	1.44	60	270.1	''84-''92
	Junam Regulation	134.6	99.9	562.6	250	210	22.5	20	218.7	''84-''92
Etc.	Buan	59	50	282	50.3	35.6	0.193	9.3	35.1	''90-''96
	Boryeong	163.6	50	291	116.9	108.7	0.701	10	106.6	''90-''00
	Jangheung	193	53	403	191	171	0.8	8	127.8	''96-''07

Source: KNCOLD (2017).

The Ministry of Environment (ME) tackles water quality management at the national level. The mandates of ME encompass not only water quality control but also overseeing tap water supply and sewage treatment facilities that are operated by local water supply and sewage treatment authorities and companies as found in the institutional map. Since the inception of the ministry in 1994, ME has served as a primary authority to manage water quality issues in the Four Major Rivers. Numerous sewage treatment facilities have been built since the mid-1990s after a series of water pollution accidents in the Nakdong River Basin, and the overall quality of water has improved to a great deal.

The trend of water quality enhancement has been slow since the advent of the new millennium. As [Figure 1-11] vividly shows, the situations of water quality in the Four Major Rivers vary. The level of Biological Oxygen Demand (BOD), a major indicator of the degree of oxygen consumption in water by biological organisms, in the Han River Basin has appeared to be stabilized below 1.5 mg/L of BOD concentration whilst that in the Nakdong River and the Geum River Basin fluctuates from 1995 to 2012. The water quality of the Youngsan River has been worst amongst the four rivers according to the level of BOD in the same period (Choi *et al*., 2017).

[Figure 1-11] Change in Water Quality in South Korea from 1995 to 2012



Source: Choi *et al*. (2017).

As shown earlier, the structure of water resources management, including river basin management, appears to be fragmented rather than integrated. Challenging issues remain unresolved related to the fragmented nature, i.e. overlapping of similar projects by different ministries or overinvestment in similar projects. However, the socio-economic and technical capacity of Korea's water resources management seems to be vigorous and sturdy in the era of climate change, industrialization, and urbanization. This implies the expertise that has been nurtured and enshrined in each ministry regarding water resources management.

Major issues on river basin management have been dealt with by the two competent agencies in South Korea, the Ministry of Land, Infrastructure and Transport, and the Ministry of Environment as discussed earlier. These two ministries embrace their own subsidiary arms in order to undertake relevant programs and

projects more effectively. The MOLIT encompasses six local land management bureaus. The bureaus take responsibility for river basin management in their own areas alongside Four River Management Committees in each river.

The other significant units under the auspice of the MOLIT are Four River Flood Control Offices that are responsible for flood forecasting and warnings, flood control dam management, and the issuance of water intake licenses. A variety of works tackled by these bureaus and offices reflect the two main pillars of work areas by the MOLIT related to river basin management, water resources development and management, and flood prevention and control although the task of water resources management is closely associate with water quality in the rivers (K-Water *et al*., 2015; Lee, 2011; Lee and Kim, 2009).

Whilst the MOLIT is largely responsible for bulk water supply and flood control issues, the ME primarily pays attention to water quality coupled with tap water supply and wastewater treatment services. Similar with the case of the MOLIT, the ME embraces its own subsidiary arms, the River Basin Environmental Offices in the Four Major Rivers. The mandate of the offices is associated with water quality control, and the details of their works are to: 1) regulate polluting activities; 2) levy and collect water use charges; 3) manage the River Basin Management Fund; and; 4) give subsidies to local communities upstream who have been banned to be engaged in possible polluting activities against water intake protection zones. One significant fact found from the mandate of the River Basin Environmental Offices is that the offices only deal with water quality control, because water quantity issues should be tackled by the MOLIT's local land management offices (Lee, 2011; Lee and Kim, 2009).

2.2. Development of River Basin Management from the 1960s to the Present

One of the policy priorities for South Korea in the early 1960s was linked to its early stage of socio-economic development, i.e. promoting agricultural productivity through a stable supply of water resources, which is the most essential element for agricultural production. In order to come out of poverty and scale up socio-economic development, South Korea embarked on an array of development plans and programs, including policies related to river basin management. This section introduces a myriad of significant water resources management plans that have culminated in the establishment of efficient water resources management systems.

Prior to a closer look at various plans, it is worth focusing on an overall structure of water resources management planning in the country. There is a myriad of national-level water resources management plans established under the auspice of

the Ministry of Land, Infrastructure and Transport (MOLIT). On top of the plans, it is the Five Year Economic Development Plan from 1962 to 1997 through seven phases that served as a backbone for socio-economic development strategies and plans enshrined in the modernization of South Korea from 1962 to 1996. In the period, water resources management planning and development were incorporated into the plans, and the detailed plans are shown in [Figure 1-6], such as the Comprehensive Land Development Plan and the 10 Year Comprehensive Water Resources Development Plan including river basin management (K-Water *et al*., 2015).

2.2.1. The 10 Year Comprehensive Water Resources Development Plan (1966-1975)

As the title of the plan implies, this plan functioned as one of the first comprehensive water plans and the backbone to jumpstart socio-economic development in South Korea, especially for securing a stable supply of water resources for the agricultural and industrial sectors and guaranteeing sufficient amounts of electricity. Prior to the inception of the plan, the River Basin Law was established in 1961, which still functions as a de facto basic water law in the country, and the Specific Multi-purpose Dam Law was introduced in 1966. In order to implement the plan, the Water Resources Bureau was established under the Ministry of Construction (precursor of the MOLIT) in 1967. As a policy implementing arm, the Korea Water Resources Development Corporation was also created (precursor of K-Water) (Choi *et al*., 2017). Against previous sector-by-sector approaches, water managers in the country were committed to introducing an integrated approach to water resources management by emulating success practices from the Tennessee Valley Authority (TVA) in the United States (K-Water *et al*., 2015).

There were six primary purposes of the plan, which together neatly reflect the government's commitment to achieve socio-economic development in an integrated fashion based on effective water resources management. The list of purposes are as follows:

- To increase food production through a stable supply of water for the agricultural sector
- To guarantee sufficient amounts of water for industrial units
- To pursue effective land use
- To prevent human and economic losses caused by flooding
- To build hydropower plants
- To create jobs

Strategies and detailed action plans within this comprehensive planning concentrated on a few sectors, specifically multi-purpose dam construction,

stable water supply, irrigation projects including reclamation projects, and the establishment of relevant institutional settings, such as the laws for multi-purpose dams. There are several characteristics of the plan. First, the main policy direction in dam construction was to avoid building single-purpose dams and promote building 10 multi-purposed dams, such as the Soyang and Chungjoo Dams (the Han River), the Namgang and the Andong Dams (the Nakdong River), the Yongdam (the Geum River), and the Bosunggam Dam (the Seomjin River). Hydropower dams, the Uiam Dam (45,000 kW), the Paldang Dam (80,000 kW), and the Chungpyong (40,000 kW, enhanced capacity), were aimed at supplying a total capacity of 530,000 kW over the course of a decade.(K-Water *et al*., 2015). In addition to hydroelectricity, multi-purpose dams would be constructed to improve the preparedness and prevention for flood events, which often devastated the country by triggering economic losses and killing many people in urban and rural areas and triggering economic losses.

Second, agricultural development plans for increasing food production were closely linked to this 10 year water resources plan, and one of the detailed action plans was to expand areas of reclamation for irrigation projects. The backdrop of the government's priority for agricultural production was connected to dire situations of food supply in the early 1960s. Consecutive droughts and flood events disastrously impacted the agricultural sector from 1960 to 1963, which culminated in a reduction of a total amount of food production by approximately 20%. The government strove to increase food production by improving the basic infrastructure for agricultural production. For example, the government set up a plan to increase rice production up to 703,100 suk (about 100 tons) (KRC, 2007; K-Water *et al*., 2015).

Third, stable water supply should be guaranteed in the given period. As discussed above, the first priority of the government for water supply was dedicated to agricultural purposes, and the second most important aim in the water supply sector was to safeguard universal access to clean water for the general public and secure sufficient amounts of industrial water supply for industrial development. In 1975, the level of industrial water demand was measured, and both overall and contingency plans, especially in drought events, for industrial water supply were established.

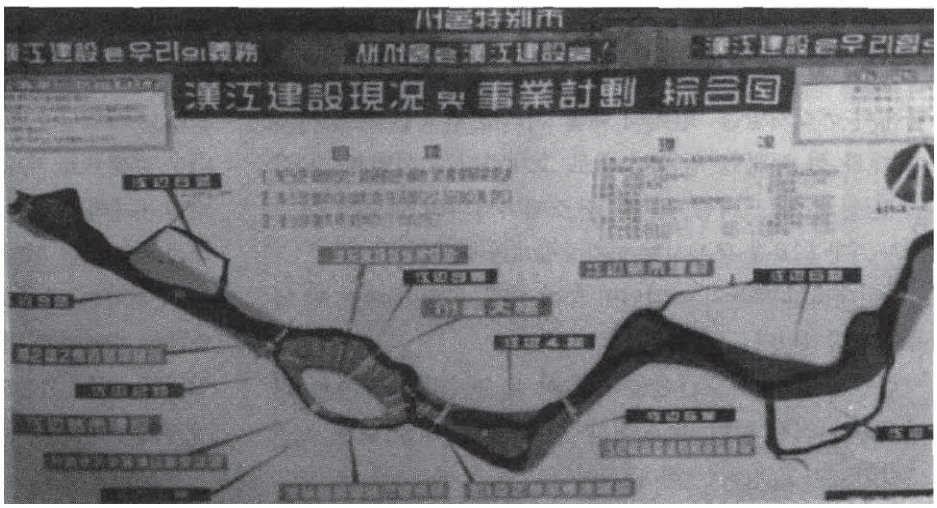
Fourth, it was imperative to prepare a good set of institutional settings to support effective water resources management. Numerous water resources management laws were introduced reflecting urgent needs of society, including but not limited to, Special Multi-purpose Dam Law, Korea Water Resources Development Corporation Law (K-Water), the Reclamation Promotion Law, and the Natural Disaster Countermeasures Basic Law (K-Water *et al*., 2015; PCSD, 2004).

2.2.2. The Comprehensive Development of the Han River: 1st Phase (1968-1970)

Whilst Korea's economy grew rapidly, the capital city, Seoul, had to accommodate a bigger population than before thanks to the upsurge of migratory workers from rural areas, thus having to take into consideration an expansion of the city boundary from the early 1960s. In 1963, the administrative boundary of Seoul was enlarged to include the vast landmass of the Gangnam Area. The Han River flows around 41 km in the heart of the city and was about to be reshaped to meet the new demands of Seoul (Hong, 2010).

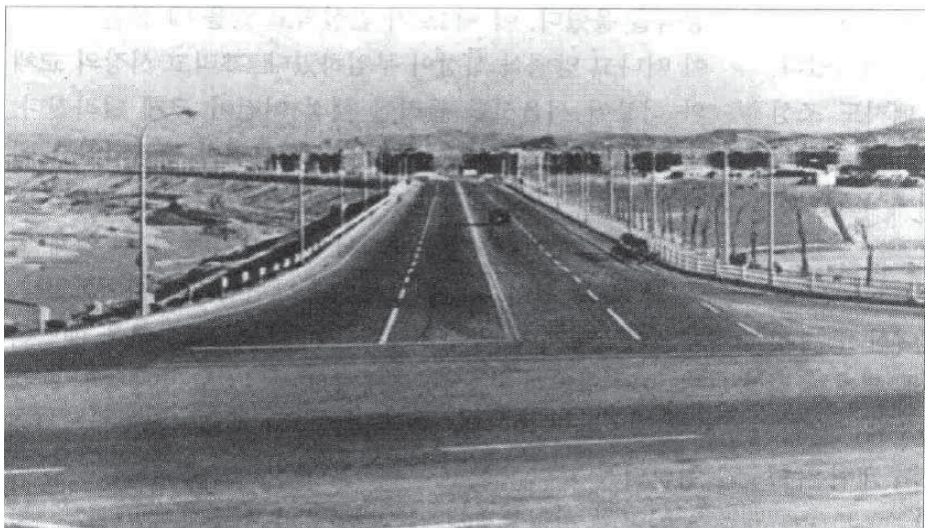
Faced with a growing population, urbanization, and industrialization, the Seoul Metropolitan Government decided to embark on a new urban development project in 1967, called the Three Year Development Plan of the Han River, as part of the Comprehensive Development of the Han River, the 1st Phase (1968-1970) (See Figure 1-12). The primary purposes of the plan were threefold: 1) to build embankments that aimed to stretch over 74 km on both the north and the south front of the river to protect against severe flood events; 2) to construct riverine highways on the embankments in order to alleviate traffic jams (See Figure 1-13); and 3) to create plots of land for housing, including large apartment blocks that would accommodate the growing population at the city center. These purposes were successfully achieved, thus shaping the basic contour of the contemporary Seoul city center (Hong, 2010; Kim and Kim, 2015; Son, 1997).

[Figure 1-12] Blueprint of the Three Year Development Plan of the Han River (1968-1970)



Source: Son (1997).

[Figure 1-13] A Highway Constructed on the Embankments of the Han River in 1971



Source: Son (1997).

The embankments for preventing flood events and resolving traffic jam along the Han River within the city have had both positive and negative impacts. Whilst the embankments seem to have been effective in tackling the intensifying heavy rainfall and typhoons compounded by climate change, Seoul residents lost their opportunity to have access to waterfront areas and witnessed the demolition of riverine environments that were replaced with concrete embankments and highways. In retrospect, the plan was unsuccessful in reflecting various aspects for river basin management, including environmental protection, efficient water resources management, and accessibility of the public to waterfronts. Environmentalists heavily criticized that this plan decimated the natural elements of the Han River and turned the river into an artificial waterway tuned for the industrialization of the country (Hong, 2010; Kim and Kim, 2015).

2.2.3. The Comprehensive Four Major River Basins Development Plan (1971-1981)

Primary attention was given to the sufficient supply of water for industrial sectors in urban areas and irrigation projects in order to guarantee a stable level of food supply in the early 1970s. These foci stemmed from the intention of the government to beef up economic growth in order to increase the productivity of industrial and agricultural sectors, and, at the same time, to reduce damages triggered by water-related disasters, such as flood and drought.

In order to cope with these issues, the government decided to revise the River Basin Law in 1971 and decided to establish the Four Major River Basin Comprehensive Development Plan. It is necessary to have a good understanding of the overall situations of the Four Major River Basins in 1971. The river basins were home to 62% of the total population in the country, contributed to 67% of GNP, included 53.7% of arable land, and embraced 62.2% of potential water resource availability. In addition, around 70% of flood damage and 60% of drought damage occurred in the river basins. This plan paved the way for the government to shift its policy from single- to multi-purpose dam construction. As such, it can be regarded as a turning point for water policy in South Korea and served as a platform to create major urban centers in the country, such as Seoul, Busan, and Daejeon (Choi *et al*., 2017; Ko *et al*., 2012).

The success of the rapid economic development in the 1970s entailed an upsurge of water demand for domestic, agricultural, and industrial use, and water managers grew wary of water shortages. In addition to economic growth, rapid industrialization, urbanization, population growth, and agricultural development all engendered the consideration of a new water plan, the Long-term Comprehensive Water Resource Development Plan (1981-2001). This plan was part of the 1st Comprehensive National Land Development Project and reflected the outcomes of the Four Major River Basin Reconnaissance Level Investigation Studies from 1966 to 1971. The total investment for the plan reached approximately US$ 300 million (Ko *et al*., 2012).

The purposes of the plan were to rehabilitate river basins, so as to ameliorate impacts caused by natural disasters, especially flood events, and to enlarge the dam networks in order to provide more water. In detail, the government succeeded in building additional 249 reservoirs and achieved an increase in the ratio of the river basins from 48.3% in 1979 to 55.4% in 1989 (Choi *et al*., 2017). More detailed targets are listed below (Ko *et al*., 2012).

1) To decrease flood damage by 50%, which means that annual average flood damage should be reduced from US$ 4.8 million to 2.4 million
2) To eradicate flood damage areas and conduct river improvement projects in the Four Major Rivers to prevent flood inundation
3) To strengthen flood preventing infrastructures focusing on 138 flood-prone areas
4) To irrigate 598,000 ha out of 683,000 ha of paddy rice fields
5) To increase the water supply rate from 30.6% to 65% and increase the amount of industrial water supply by 3.8 times
6) To eliminate devastated mountain regions (41,420 ha) and deforested plots of land (274,016 ha)

7) To prevent water pollution in urban areas and reduce saltwater intrusion damage near urban areas

2.2.4. The Comprehensive Development of the Han River 2nd Phase (1982-1986)

One of the critical challenges for the Han River in Seoul was the rapidly deteriorating water quality. The deterioration of water quality in the river came into being due to industrialization and urbanization throughout the 1960s and the 1970s, and the municipal government decided to move the water intake point for domestic and industrial uses upstream the Paldang Dam, in the middle of the river. In the 1970s, riverine and river bed sediments were overexploited for construction aggregate, which triggered the destruction of water environments in the river. In addition, a lack of adequate riverine management of the river resulted in the exposure to lush weeds and sludge, which led to a poor urban landscape.

An interesting watershed for another phase of the Han River development plan came not because of the recognition of such challenges for the river, but because of the decision of the 1988 Olympic Games hosted in Seoul. The Korean government was determined to rebrand the image of Seoul as well as the country through this golden opportunity, and the Han River would be the center of the modern and beautiful Olympic host city. In addition, large amounts of good quality sand and pebbles in the river could be used as construction aggregate for Olympics related buildings and new infrastructure. This is the background of the 2nd Phase of the Comprehensive Development of the Han River (Hong, 2010; Ko *et al*., 2012).

The 2nd Phase of the Han River Development encompassed more diverse aspects of sub-projects compared with those of the 1st Phase. The overall project went on for five years from 1982 to 1986, with a total investment of US$ 400 million. This large scale investment focused on: 1) river improvement (riverbed channel maintenance); 2) construction of civic parks; 3) expansion of riverside highways (Olympic Highway); and 4) classified sewer pipeline installment and measures for urban drainage system. In addition, in order to keep a stable level of water in the urban section of the river, two submerged weirs were constructed upstream (Jamsil) and downstream (Shingok). Four sewage treatment plants were also built for improving water quality in the river (Hong, 2010; Ko *et al*., 2012).

2.2.5. Comprehensive Management of Water Resources: Environmentally-Friendly River Basin Development (1990 to the Present)

The dynamic socio-economic development of South Korea from the 1960s to the

1980s was possible at the expense of the environment. The Four Major Rivers and their tributaries were not free from the negative impacts of the "pollute first and clean up later" mindset and pro-growth policies. Water quality rapidly deteriorated in all river basins of the country, and water pollution accidents became frequent, not only posting a threat to the quality of drinking water, but also to entire ecosystems.

There were several pollution-related accidents in the 1990s, for example, the detection of trihalomethanes (THM) in 1990, phenols in 1991, and heavy metals and poisonous pesticides in 1994, to name a few. In particular, a shocking level of bacteria in 1993 and 1997 was found in major rivers and provoked public anger and anxiety, and the general public became more hesitant to use tap water as their major drinking water source. Large amounts of chemical fertilizers, pesticides, and insecticides from highland areas had flowed into local water bodies due to agricultural intensification, and such a phenomenon exacerbated acute water pollution, thereby damaging water environments. Korean society began to recognize water pollution as one of the most serious environmental challenges and called for urgent actions (Choi *et al*., 2017).

A new Long-term Comprehensive Water Resources Development Plan (1991-2011) was introduced in 1990, and this plan was the first water plan to accommodate environmentally friendly river basin restoration principles. Over the course of increasing concerns about environmental issues in society, more emphasis was put on the establishment of an independent environmental watchdog, thus resulting in the creation of the Ministry Environment (ME) in 1994, which was upgraded to a ministerial level. The ministry was given the mandate to oversee water quality protection and enhancement in the Four Major Rivers, coupled with managing tap water and wastewater treatment services (Choi *et al*., 2017).

Water pollution did not improve much in the 1990s, despite the various efforts to enhance water quality and quantity situations. The government began to pay close attention to institutional measures rather than structural measures with regard to water supply, water quality control, and wastewater treatment services towards the end of the 1990s. For instance, the Han River Law was enacted in 1999 in order to achieve water quality enhancement and take good care of water intake points, especially for drinking water. A significant feature of the law was to provide compensation for communities in highland areas of the river basin as an economic incentive to decrease the amount of chemical fertilizers and pesticides. Accordingly, downstream water users in Seoul, Incheon, and 25 districts in the Gyeonggi, Gangwon, and Chungcheong North Provinces had to pay additional water fees in accordance with the "polluter-pays-principle". Such additional water fees became the seed fund for the creation of the Han River Fund, which is used for compensating upstream communities and regulating water-polluting activities, including

construction and highland agriculture (Choi *et al*., 2017).

Water managers in Korea were confronted with a number of new challenges in river basin management, triggered by the diversification of water demands from society, such as better quality of water for drinking and leisure purposes, environmentally friendly river basin management policies and projects, waterfront living, and river restoration demands. In addition, unpredictable weather patterns and hydrological regimes began to take place because of adverse impacts caused by climate change. Urbanization and population growth, which occurred mainly due to the migration from rural to urban areas, aggravated difficulties in water resources management.

Attention has been given more to climate change since the mid-2000s, and the River Law was revised again in 2007 to reflect climate change mitigation and adaptation strategies and technology development in the water sector. The Low Carbon Green Growth Policy was established in 2008 as a governing philosophy and strategy, and the government implemented the Four Major River Project in 2009-2012 to secure stable water supplies, enhance water quality, deal with water-related natural disasters, such as flood and drought, and guarantee good access to waterfront facilities. Public concerns about the conservation of riverine environments, the restoration of riparian ecosystems, and waterfront recreation have led to the revision of the Water Vision 2020 in 2011 (Choi *et al*., 2017; Lee, 2017).

2.2.6. Long-term National Water Resources Plan (Water Vision 2020)

As the most significant water management strategy, the 1st National Water Resources Plan was launched by the Korean government in 1981 in accordance with the 2nd National Land Development Plan. The time span for the 1st plan was 21 years, from 1981 to 2001. Afterwards, the plan was revised twice in 1990 (1991-2011) and in 1996 (1997-2011) in order to cope with the unprecedented challenges triggered by an increasing risk of water shortage and flood damage under the pressure of urbanization, population growth, industrialization, and climate change.

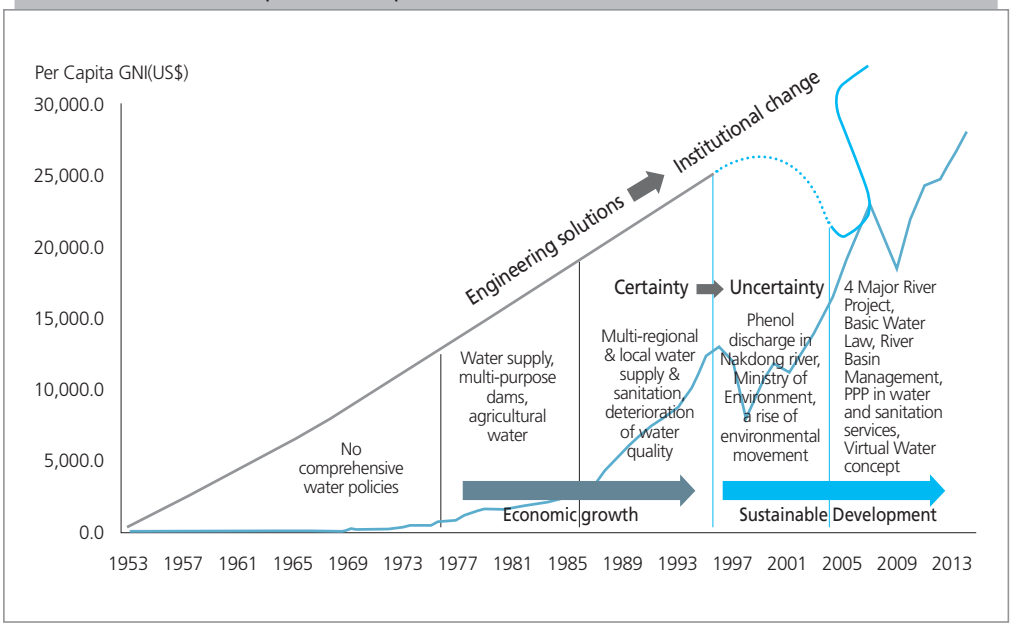
Such a long-term water resources plan became the Water Vision 2020 (2001-2020) in 2001 for the purposes of pushing forward river basin restoration projects, which were expected to tackle severe droughts and flood events, enhance the water supply, and alleviate water pollution. Nevertheless, natural and anthropogenic changes of the water sector in the early 21st century disrupted everyday life, such as the severe drought in 2001, and typhoons and torrential rainfall in 2002 and 2003 that devastated infrastructure and housing and caused human and economic losses.

The Water Vision 2020 was revised in 2006 with a detailed vision for "sustainable

water resources management for human beings and nature". The plan aimed to accommodate socio-economic and environmental demands and succeeded in reflecting a variety of demands by allowing diverse stakeholders to participate in the decision making process. The process was slower and more painstaking than before, with 47 meetings under four consultative committees consisting of consultants, operating committees, experts, and local residents to discuss the prospect for water demand and supply (Ko *et al*., 2012; K-Water *et al*., 2015).

The Water Vision 2020 is to be revised every 10 years and can be reviewed every five years if necessary. The plan was revised in 2016 in order to reflect the rapidly evolving social demands for water and environment and the new political economy landscape at the national and the international levels. The vision of the plan in 2016 was a happy and wealthy society without water-related challenges. Specifically, the Korean government is committed to providing safe and stable water while coping with climate change, to establish equal and cooperative governance for water resources management, and to promote water industries. There are five detailed targets: 1) stable supply of safe water; 2) infrastructure for flood prevention; 3) good waterfront environments; and 4) water resources management R&D and industry promotion (Ministry of Land, Infrastructure and Transport, 2016).

[Figure 1-14] The Trajectory of Water Resources Management and Gross National Income Per Capita in the Republic of Korea from the 1960s to 2010



Source: Modified based on KOSTAT (2015).

[Figure 1-14] illustrates the trajectory of Korea Water Resources Management Policy, which overlaps the path of Korea's socio-economic development since the early 1960s. The trend of Gross National Income (GNI) per capita in the country from 1961 to 2017 matches the evolving development of Korea's water resources management, favoring sustainable development. In particular, the exponential growth rate of GNI per capita since the mid-1980s indicates the diversification and strength of the national economy, which also coincides with the maturity of Korean society that has paid attention to the balance between economic growth and environmental protection. In a similar vein, the Mekong riparian countries can undergo such a policy transformation in socio-economic development and environmental protection in relation to sustainable water resources management.

2.3. Case Studies

2.3.1. Lake Sihwa Water Quality Improvement Project

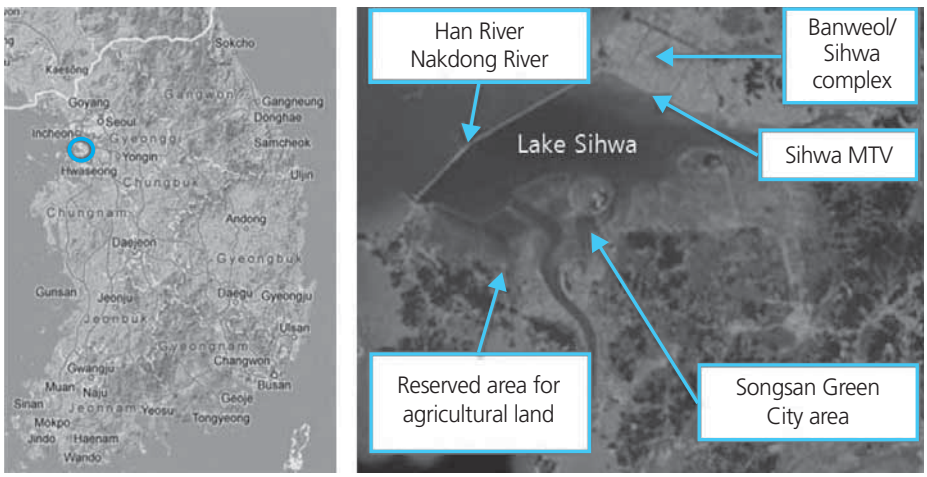
The Lake Sihwa Development Project unveils the environmental impacts of development-first or pro-growth policies and a policy shift from a growth-oriented to a balancing policy between economic growth and environmental protection in South Korea. The project was initially launched in the mid-1970s for the purpose of increasing food production through the expansion of irrigated areas, but the major purposes of the project have been shifted to industrial development and eventually eco-friendly development. The project has been carried out over a few decades, and the trajectory of the progress of the project provides invaluable lessons and experiences for the country's transformation of approach to water security and integrated water resources management.

Prior to delving into the project details, take a look at the overview of the project and relevant issues. The Lake Sihwa is an artificial lake, surrounded by the cities of Siheung, Ansan, and Hwaseong in Gyeonggi Province and close to Incheon Metropolitan City. The name of the lake stems from the first letters of the two cities, Si from Siheung and Hwa from Hwaseong. In 1994, the lake was created thanks to the completion of 12.6 km seawall and as part of the large-scale comprehensive reclaimed land development, which had been envisaged since the mid-1970s.

The total area of the lake is 476.6 km^2 and flat, similar with the other areas of the western coastal areas. Around 332 million m^3 of water are stored in the lake, and the water level is situated 1 m below the sea level with the deepest point at 18 m. The seawater intake of the lake per annum is estimated at 380 million m^3 with a retention time of 300 days (Min *et al*., 2013).

There are two major industrial complexes in the lake basin, the Banweol (15.39 km^2) and the Sihwa (16.46 km^2), coupled with the Sihwa Multi-Techno Valley (MTV) (9.26 m^2). These are all located in the northern part of the lake, whereas the southern part of the lake embraces plots of land for agricultural purposes (36.36 m^2) and for other uses, especially the Songsan Green City and the Daesong Farmland, which are under construction as of February 2018. In the eastern part of the lake, several rivers and small streams flow, and K-Water installed the Sihwa Tidal Power Plant in the western part of the lake (Korea Institute of Ocean Science and Technology, 2018; Min *et al*., 2013) (See Figure 1-15).

[Figure 1-15] Location and Satellite Image of Lake Sihwa



Source: Min *et al*. (2013).

The project can be divided into three phases: 1) pro-growth development (1975-1996); 2) balanced development for economic growth and environmental protection (1996-now); and 3) the eco-friendly development period (2004-now).

1) 1st Phase: Pro-Growth Development (1975-1996)

The 1st Phase of the project dates back to 1975 when the Ministry of Agriculture, Food and Rural Affairs proposed a reclamation plan in the western and southern coastal areas of the country to increase food production. Over the course of the project, the significance of industrialization was more emphasized in the 1980s, and therefore, the primary purpose of the project was shifted towards the creation of industrial complexes in 1985.

A turning point for the Lake Sihwa Development Project was the decision to construct a seawall to make the project site an artificial freshwater lake, and the construction was completed in January 1994. Since then, the water quality of the lake deteriorated dramatically due to a huge influx of industrial wastewater and domestic sewage, and the lake became called the "Lake of Death." In addition, the media began to broadcast the heavily polluted lake widely as a symbol of severe water pollution in 1996 and drew much attention from the public (Korea Institute of Ocean Science and Technology, 2018; Min *et al*., 2013; 2017). <Table 1-4> summarizes policies and key events between 1975 and 1996 regarding the Lake Sihwa Development Project.

〈Table 1-4〉 Timeline of Policies and Key Events of the Lake Sihwa Development Project: Phase 1

	Timeline of Policies and Key Events: Phase 1
1975	The plans of reclamation and development of mudflats of the West and South Seas for agriculture established by the Agricultural Development Corporation (now Korea Rural Corporation)
April, 1982	Surveys for reclaimable lands undertaken by the Agricultural Development Corporation
August, 1985	The 1st Lake Sihwa Development Plan confirmed by the Economic Planning Board
June 1987	Seawall construction begun and led by the Industrial Sites and Water Resources Development Corporation (now K-Water)
September, 1988	Environmental Impact Assessment conducted by the Han River Basin Environmental Office
January 1994	Sihwa Seawall completed
April 1996	Acute water pollution broadcasted on TV

Source: Min *et al*. (2013).

2) 2nd Phase: Balanced Development between Economic Growth and Environmental Protection (1997-2004)

Severe water pollution of the lake became widespread from 1994. This phenomenon occurred because of one-sided pro-growth policies and plans without careful consideration of environmental impacts by the anthropogenic structure, as well as the poor management of wastewater discharge from households and industrial units. The heavy water pollution also devastated ecosystems in the lake, and fish and aquaculture were badly damaged. A TV show in April 1996 on the disastrous situation of the water environments in the lake alarmed the public, and the issue of the dying Sihwa Lake became a national issue (Min *et al*., 2013).

In response to this matter, the government set up special water quality enhancement measures, spearheaded by the Ministry of Environment (ME), and the Ministry of Land, Infrastructure and Transport (MOLIT) had to share its administrative power with ME. ME became more active in implementing environmental regulations and law enforcement, such as the establishment of the 1996 special measures for the lake and the allocation of pollutant discharge quotas on factories near the lake.

The special measures included the plans to invest KWR 449.3 billion (US$ 40 billion) in water quality restoration measures until 2001. Other measures encompassed the construction of oxidation ponds, wetlands, and temporary intercepting sewers and facilities for circulation of seawater in the short term. In the long term, there would be the expansion and building of wastewater treatment plans and intercepting pipes. Although these measures would improve the water quality of the lake, it would not be feasible fill the lake with good quality freshwater.

In February 2001, the plan of making the Lake Sihwa a freshwater lake was officially discarded, and the gates of the seawall were opened for the influx of seawater into the lake. Since then, water quality of the lake became increasingly improved. The ministry in charge of the project was shifted from the Ministry of Construction and Transport (now MOLIT) to the Ministry of Maritime Affairs and Fisheries (MOMAF, now the Ministry of Oceans and Fisheries). The ministry was determined to carry out the Lake Sihwa Comprehensive Management Plan and established the Lake Sihwa Management Committee in 2002.

In addition to the institutional rearrangements, MOMAF proposed a sub-plan to set up a tidal power plan in order to promote clean energy production within the 1996 special measures (later becoming the Lake Sihwa Comprehensive Management Plan) in 2003. In the meantime, MOLIT established the Sihwa District Policy Council in September 2000 in order to tackle water and air pollution simultaneously.

In this council, a series of ministries, local governments and public companies were involved, including ME, the Ministry of Agriculture, the Ministry of Commerce, Industry and Energy, Gyeonggi Province, Siheung and Hwaseong Cities, the Korea Water Resources Corporation (now K-Water), and the Korea Agricultural and Rural Infrastructure Corporation (KARIO, now Korea Rural Corporation). The council invited diverse stakeholders, but it did not include non-state actors, such as district residents, civil society organizations or any entities opposed to the development plan. A better form of water governance was introduced in January 2004 with the newly named Sihwa District Sustainable Development Council, in which the existent stakeholders and non-state actors were all invited (Min *et al*., 2013; 2017). <Table 1-5> summarizes significant policies and events in the 2nd Phase.

〈Table 1-5〉 Timeline of Policies and Key Events: Phase 2

	Timeline of Policies and Key Events: Phase 2
July 1996	Announcement of the Lake Sihwa Water Quality Improvement Measures with an investment of KWR 449.3 billion (US$ 40 billion) until 2001
November, 1996	The Sihwa Freshwater Lake Water Quality Restoration Project audited by the Board of Inspection and Audit
March 1997	Sihwa Seawall Sluicegate opened and seawater flowed in
December 1998	The plan of providing irrigation water from the Lake Sihwa abandoned by MOMAF
September 2000	The Sihwa District Policy Council formed
February 2001	The formal announcement of the abandonment of the plan to make the Lake Sihwa a freshwater lake
August 2001	The Lake Sihwa Comprehensive Management Plan established by MOMAF with an investment of KRW 745.1 billion (US$ 68 billion) until 2006
December 2002	The Lake Sihwa Management Committee formed
October 2003	The construction of a tidal power plant included in the Sihwa District Development Plan
January 2004	The Sihwa District Sustainable Development Council formed

Note: MOMAF means the Ministry of Maritime Affairs and Fisheries
Source: Modified based on Min *et al*. (2013).

3) 3rd Phase: Eco-friendly Development (2005-Now)

A key feature of this phase is the role of the Sihwa District Sustainable Development Council. The council is a decision-making entity in which the central and local governments, private companies, local residents and civil organizations take an active part, and there were 53 members. Looking at the governing structure, there were two co-chairs, one from the government and the other from the non-state sector. What was decided in the council encompassed not only environmental remediation, but also development plans, and the decision making process of the council has been transparent. One of the eye-catching achievements of the council was to reduce the size of the development of the Multi-Techno Valley (MTV) from 10.5 to 9.3 km^2.

More advanced eco-friendly measures for the lake have been introduced, including the Total Pollutant Load Management System in July 2010, and technical indicators were adopted for the system in January 2012. In addition, after 8 years since the proposal of the plan, the Sihwa Tidal Power Plant was installed in August 2011 to facilitate seawater circulation for restoring water quality and to generate

electricity for enhancing air quality and promoting green energy (Min *et al*., 2013; 2017). <Table 1-6> summarizes key policies and events in the Phase 3. [Figure 1-16] shows the current situation of the Sihwa Lake.

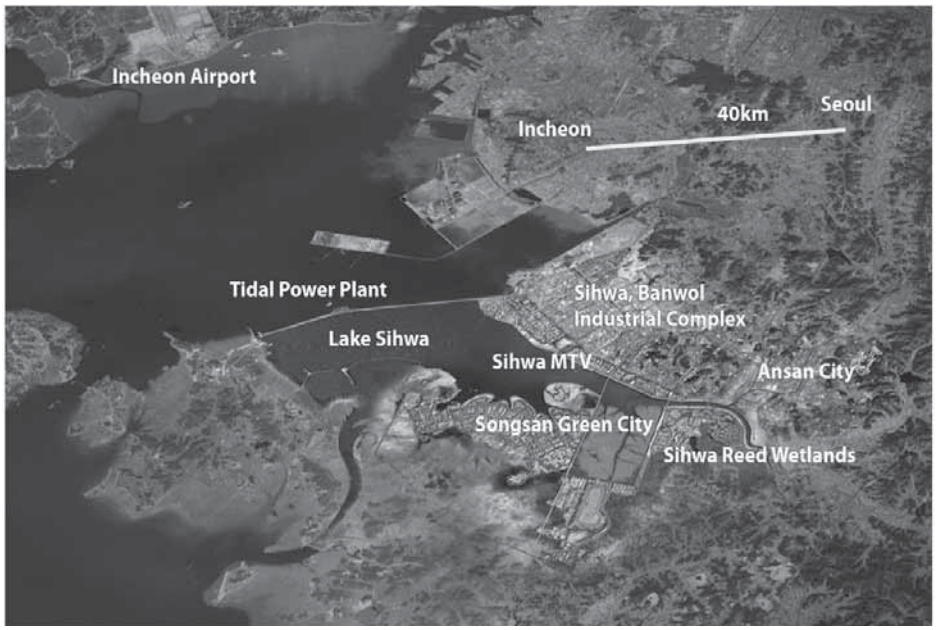
〈Table 1-6〉 Timeline of Policies and Key Events: Phase 3

Month and Year	Timeline of Policies and Key Events: Phase 3
September 2004	The Lake Sihwa Comprehensive Management Plan endorsed by the Lake Sihwa Management Committee with an increase of budget by KRW 270.1 million (US$ 25 million)
October 2004	Environmental Improvement Roadmap announced (water quality and atmospheric quality)
January 2005	The Joint Chair System adopted for the Sihwa District Sustainable Development Council
June 2007	The size of the Sihwa Multi-Techno Valley (MTV) reduced from 10.5 to 9.3 km^2
April 2008	The Sihwa District Sustainable Development Council recognized as a formal organization
July 2010	The Total Pollutant Load Management System adopted
August 2011	Partial operation of the Sihwa Tidal Power Plant begun
February 2012	The South Bank (Songsan Green City) Development of the reclaimed land begun
December 2012	The Lake Sihwa Total Pollutant Management Master Plan adopted

Source: Modified based on Min *et al*. (2013).

In retrospect, the Lake Sihwa Water Quality Improvement Project has turned out to be successful in several aspects. First, there are economic benefits. One of the initial purposes of the project was to promote industrial development. The project site has attracted a number of business units and labor forces from Seoul and Gyeonggi Province. The growth rate of the total and youth population were 5.7% and 3.2% until 2012, respectively, which indicates a much higher level of growth compared with that of the nation, 0.7% and -0.7% respectively. Another indicator is the number of employment opportunities, and the project has provided job opportunities from 183,053 in 1994 to 246,134 in 2009 (1.3 times increase). The annual economic growth rate of the 2nd and 3rd Phases was higher (11.6%) than that of the 1st Phase (9%) (Min *et al*., 2017).

[Figure 1-16] Sihwa District Now

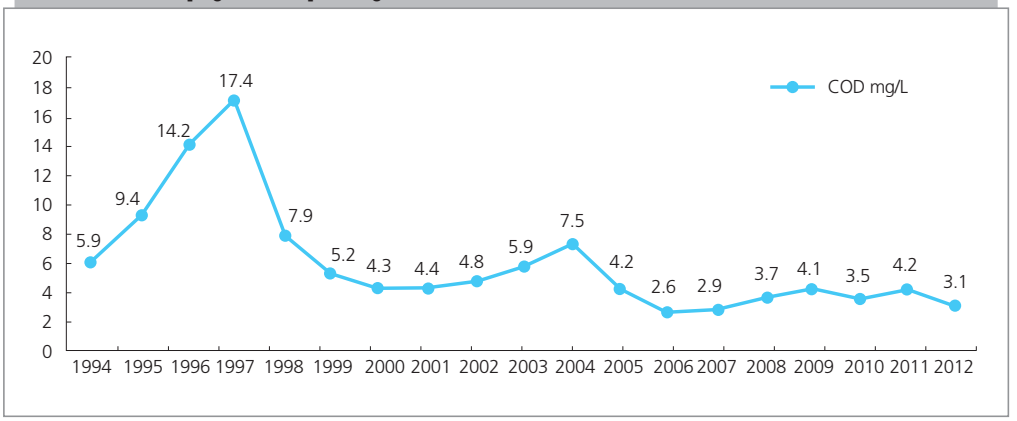


Source: Min *et al*. (2013).

With regard to social benefits, the role of the Sihwa District Sustainable Development Council (SDSDC) has been imperative in lieu of stakeholder participation. The council has introduced a consensus-based decision making system and common learning mechanism, allowing diverse stakeholders to take an active part in decision making. In addition, the system has consolidated trust between state and non-state actors and has resulted in making the lake a more people- and eco-friendly space, while meeting the needs of economic development in the local areas.

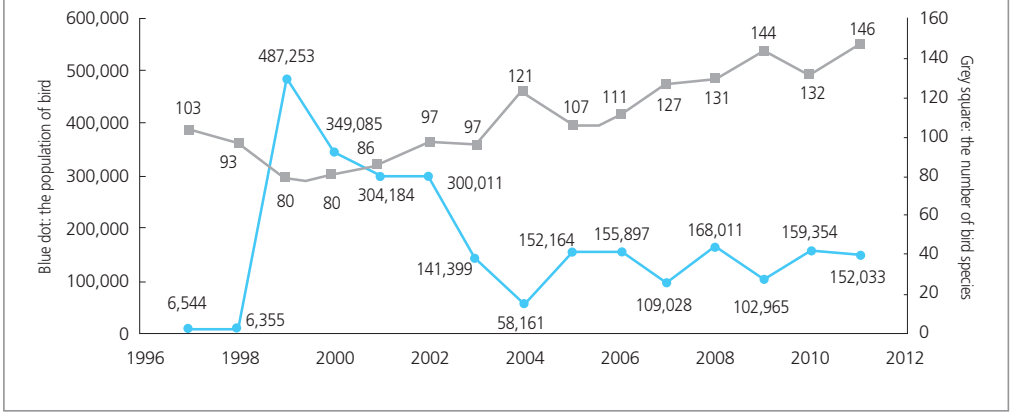
The most monumental achievements of the project is the revival of the lake through environmental restoration. The water quality of Lake Sihwa has significantly improved from a COD level of 17.4 ppm in 1997 to 3.1 ppm in 2012, which was better than the 1994 level of 5.9 ppm (Figure 1-17). Biodiversity within the lake has also improved. For instance, bird species increased from 97 in 1998 to 132 in 2010 (Figure 1-18). Only 2 species of fish were detected in the lake in 1994, and the number soared to 9 in 2000, and the number of fish in the same period increased from 5 to 374 (Figure 1-19).

[Figure 1-17] Change of the COD Concentration in the Lake Sihwa



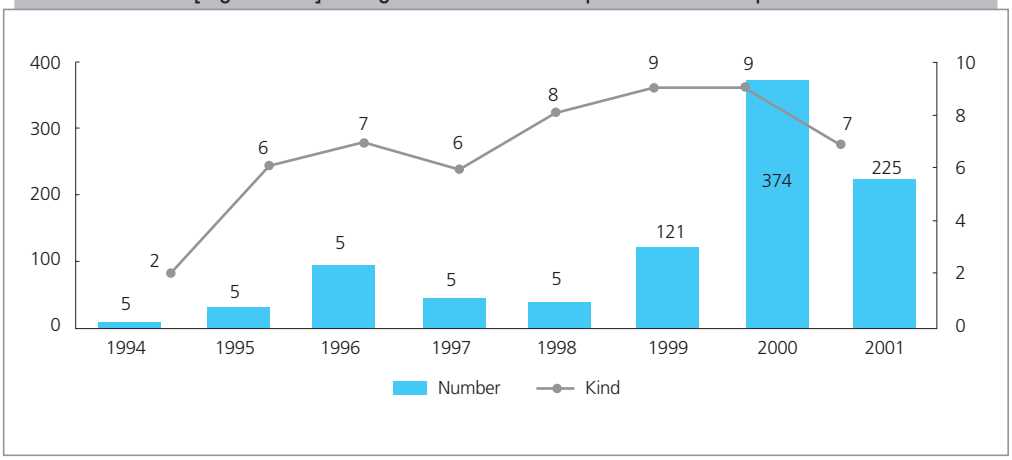
Source: Min *et al*. (2013).

[Figure 1-18] Change of the Kind and Population of Bird Species



Remarks: blue means the population of bird, and red means the number of bird species
Source: Min *et al*. (2013).

[Figure 1-19] Change of the Kind and Population of Fish Species



Source: Min *et al*. (2013).

In addition to achievements, it is important to discuss several challenges embedded in the project. First, although water quality has improved thanks to the evolution of governing structures coupled with continuous efforts to enhance water environments, development projects related to reclaimed lands were embarked on in the early 2010s. These include the Shihwa Multi-Techno Valley (MTV) project, the Songsan Green City, and large-scale irrigation projects, which might trigger an increase of Non-Point Source (NPS) pollution discharge and pose a threat to swamps and habitats for flora and fauna in the lake.

Second, possible impacts given by the Sihwa Tidal Power Plant are unknown, because there has been no case of such a large-scale tidal power plant at the global level. No one can predict what kind of environmental damage or impacts might take place in the course of operation of the plant. For instance, green algae were reported to have increased since the launch of the tidal plant, which caused damage to fishery industries nearby, more polluted sediments were accumulated near the tidal power plant, and the plants can result in an upsurge of the number of jellyfish in the lake (Lee, 2012).

Third, although the Sihwa District Sustainable Development Council has played a pivotal role in facilitating discussions and dialogues between different stakeholders, the assessment of the projects decided through the council has not necessarily been positive. One of the fundamentally weak points of the council has been the lack of a financing mechanism. In addition, the council should be equipped with the mandate to conduct the Integrated Coastal Zone Management, mediate conflicts between concerned bureaus and entities, rearrange relevant projects, and undertake monitoring and evaluation of continuous projects (Kim *et al*., 2013).

2.3.2. Four Major River Project (2009-2012)

Special attention is given to the most recent large-scale project of river basin management in the country, the Four Major River Project (2009-2012), in order to delineate policy direction and efforts of the Korean government in accordance with the IRBM under the framework of sustainable development. The Four Major River Project was launched as part of the Green Growth Policy in the Korean government in 2009, and the government promoted the project as the national grand scheme to achieve sustainable development with, an emphasis on the balance between economic development and environmental protection against adverse impacts triggered by climate change (Lah *et al*., 2015).

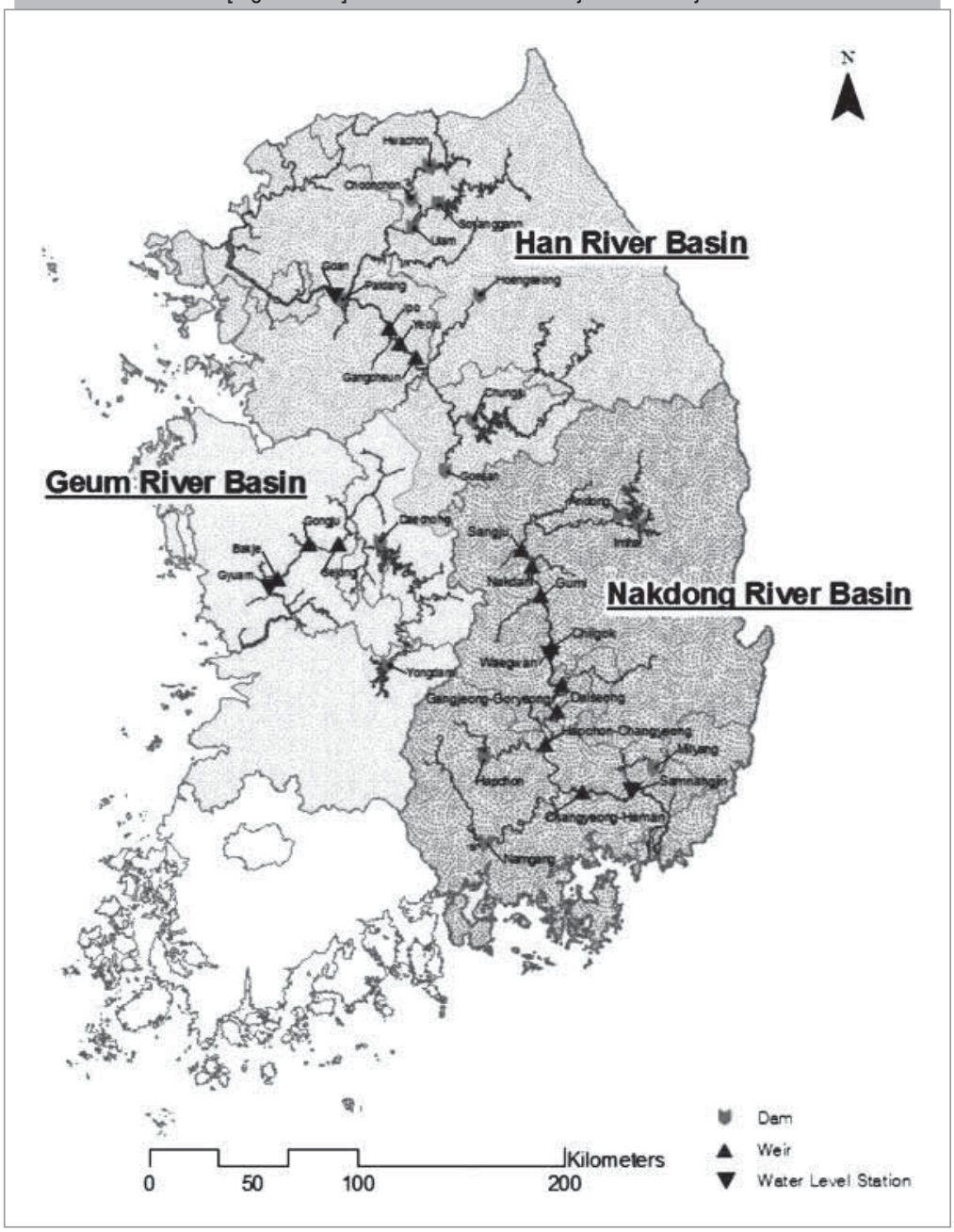
The purposes of the project are to: 1) augment water supply; 2) improve water quality; 3) increase the capacity of flood control; 4) enhance water welfare elements through the construction of amenities for local residents along the rivers; and 5) push forward regional development centered on the rivers (K-Water *et al*., 2015; OECD, 2017; Shim, 2014). The specifications of the project are shown in <Table 1-7>, and the locations of 16 weirs are found in [Figure 1-20] and [Figure 1-21] shows a photo of one of the 16 weirs, Bakje Weir.

〈Table 1-7〉 Specifications of the Four Major River Project

Items	Contents
Project Period	October 2009-December 2012
Project Area	Total length: 1,266 km Han River 255 km, Nakdong River 470 km, Geum River 272, Yeongsan River 269 km
Project Scope	Total 170 construction zones
Major Facilities	Dredging: 450 million m^2 Weir: 16 Bank reinforcement: 784 km New dam: 3 Reservoir connection: 1 Flood retention and storage reservoir: 5 Reservoir embankments: 110 Farmland remodeling projects: 140 Environmental treatment projects: 1,281 Ecostream: 929 km Flood retention reservoir: 2 Small-size hydropower: 16 (total capacity of 50,771 kW)
Project Cost	Total US$ 19.4 billion Ministry of Land, Infrastructure and Transport: US$ 13.5 billion Ministry of Agriculture, Food and Rural Affairs: US$ 2.6 billion Ministry of Environment: US$ 3.3 billion

Source: K-Water *et al*. (2017), Lah *et al*. (2015), OECD (2017) and Shim (2014).

[Figure 1-20] Overview of the Four Major River Project



Source: Ahn *et al*. (2014).

[Figure 1-21] Bakje Weir in the Geum River



Source: water portal http://www.water.or.kr (accessed 5th February 2018).

The vision statement of the project was "Rivers where life is alive, New Korea", and the project constituted five main works (Lah *et al*., 2015):

1) Securing Abundant Water Resources to Mitigate Water Scarcity

Task 1 aimed to secure approximately 1.3 billion m^3 of water that would cope with possible future water scarcity and severe droughts triggered by climate change. As sub-projects, reservoirs and small and medium-sized dams were planned, and the storage capacity of numerous agricultural reservoirs was set to be improved.

2) Implementing Comprehensive Flood Control Measures

Flood control measures were geared towards increasing the flood control capacity of 920 million m^3, and this capacity could be useful for 200 year flood frequency. Detailed sub-projects were dredging sediment, reinforcing old levees, and constructing dams.

3) Improving Water Quality and Restoring Ecosystems

The primary target in the improvement of water quality of the rivers was to make the general water quality of the rivers reach an average of level II (Biochemical

Oxygen Demand less than 3mg/L) by 2012. In order to do this, the government was committed to building additional sewage treatment facilities and green algae reduction facilities. Together, with such efforts, ecosystems of the rivers were planned to be restored through the careful management of wetlands and the adjustment of farmlands.

4) Creating Multi-purpose Spaces for Local Residents

Riverine areas would be transformed into spaces for lifestyle, leisure, tourism, and cultural activities. One of the iconic sub-projects was to install a 1,757 km bicycle lanes coupled with walking paths, and various sports facilities.

5) Restoring Ecology and Regional Development Centered on Rivers

The main focus of the task was on regional development. In order to do this, a series of sub-projects were introduced, including the installation of nature-friendly fishways, ecological wetlands, vacuum dredging, and double-silt protectors.

The overall project was implemented in three phases. In Phase 1, around KRW 16.9 trillion (US$ 15.3 billion) was invested in order to conduct dredging and to build weirs, dams, and reservoirs in the mainstream of the four rivers. Most of the main sub-projects were completed in 2011, and irrigation projects for weirs, dams, and reservoirs were finished by 2012. The government made an investment of KRW 5.3 trillion (US$ 4.8 billion) in Phase 2 to enhance the water flow and sewage systems of tributaries. In Phase 3, sub-projects were undertaken for restoring local and small rivers and developing cultural and tourist attractions.

Various ministries were involved in the implementation of the project, including the Ministry of Land, Transport and Maritime Affairs (now Ministry of Land, Infrastructure and Transport - MLIT), the Ministry of Environment (ME), the Ministry of Culture, Sports and Tourism (MCST), and the Ministry for Food, Agriculture, Forestry and Fisheries (MIFAFF). MLIT was in charge of the overall project implementation, especially related to the construction of 16 weirs and other civil engineering projects, and ME took responsibility for ecosystem rehabilitation and water quality improvement projects. MCST was dedicated to overseeing waterfront leisure, cultural and sports facilities, whereas MIFAFF was responsible for dealing with dam and reservoir improvement projects for irrigation (Lah *et al*., 2015).

It is still early to assess the outcomes of the project since the construction of the project was finalized in 2012. The preliminary appraisal of the project seems to signify the typical two different sides of the coin, achievements and challenges. As for achievements, the number of large scale human and economic losses triggered

by flood events has been reduced. More water resources have been stored and kept ready to provide additional water resources to nearby regions for agricultural production, leisure activities, and emergency waters to drought-stricken areas. In addition, some water pollution-related indicators show the incremental trend of water quality improvement in the rivers.

Challenging issues are drawing attention, such as an increase in algae blooms in some areas, and the possible negative impacts on flora and fauna due to the construction of riverside eco-parks and bicycle lanes. Criticisms of environmental NGOs on the on-going impacts of the project have continued, such as the frequent appearance of green algae along the rivers. However, the cause of the green algae in the rivers is not because of the slow flow of water, but because of the continuous influx of non-treated agricultural wastewater (Non-Point Source pollution) near the mainstream of the river. This implies that more thorough studies and investigations should be conducted for tributaries of the Four Major Rivers and small- and medium-sized local streams, which still receive large volumes of untreated wastewater from rural households, vegetation farms, and livestock farms. Therefore, it is necessary to conduct regular and long-term monitoring works on aquatic ecosystems, river bed variations, possible micro-climate change, and any change in water environments (KWRA, 2012; Lah *et al*., 2015; OECD, 2017).

3. Review of Strategies for Water Security and Sustainable River Basin Management in the Mekong River Basin

3.1. Definitions and Objectives of Water Security in the Mekong River Basin

The Mekong River Basin consists of six riparian countries, namely China (Yunnan Province), Myanmar, Thailand, Lao PDR, Vietnam and Cambodia. Each riparian state has its own development agendas depending upon the degree of socio-economic development and environmental protection. A variety of policy agendas has been thoroughly discussed among the member countries of the Mekong River Commission (MRC) since the 1995 Mekong Agreement was signed. <Table 1-8> shows various policy agendas and priorities of each riparian country in the Mekong River Basin.

〈Table 1-8〉 Policy Agendas of the Mekong Riparian Countries

Country	Major Issues	Others
China	Observer status Hydropower development (15 dams planned, 3 dams completed & in operation)	• No PNPCA for dam required • More cooperation due to economic interests since 2010 (Huahin Summit) *Lancang-Mekong Cooperation Mechanism launched since 2015*
Myanmar	Little concern for resource management	Forest development for timber exports to China & Thailand
Laos	• Largest hydropower potential, competing with China • Construction of 9 dams planned in MK & tributaries	• Construction of Xayaburi Dam, since March 2011 • PNPCA mechanism of MRC first tested
Thailand	Industrialization, escalation of forest cover loss & environmental pollution in the basin	• Growth of NGOs, SEARIN (Southeast Asia International Rivers Network) & TERRA (Towards Ecological & Regional Alliance) • Hydropower broker in the region
Vietnam	• Mekong Delta, accounting for 50% of rice & 40% of total agricultural output • World's leading rice production & export country	• Resource management, low priority than economic growth • Dispute with Laos for Xayaburi Dam in 2011 for fear of low water flow & sediment
Cambodia	The Tonle Sap system, essential for agricultural & fisheries production	50% of GDP from agriculture, fisheries, forestry in MK basin

Source: Author.

The 1995 Mekong Agreement provides the legal mandate of the MRC. It defines the scope of the work and cooperation related to coordinated and joint planning for balanced and socially just development in the Mekong River Basin (MRB), while protecting the environment and maintaining ecological balance. The Agreement also sets out a framework for the achievement of the strategic objectives of the Integrated Water Resources Management (IWRM), recognising that development decisions by sector agencies in the sovereign riparian countries of the Mekong River Basin may have trans-boundary consequences, and that the MRC as an intergovernmental river basin organisation is reliant on the endorsement of its approaches by the Member Countries.

In 2005, Member Countries adopted the strategic directions for IWRM in the Lower Mekong Basin (LMB)[1]. In the context of the MRB, IWRM is "a process that promotes the coordinated development and management of water, land and related resources, in order to maximise economic and social welfare in a balanced

1) MRC (2011) The Mekong River Commission Strategic Plan 2011-2015. Vientiane, MRC.

way without compromising the sustainability of vital ecosystems. IWRM emphasises integration of the management of land and water resources, of surface water and groundwater, of upstream and downstream uses, of sectoral approaches, of economic production and environmental sustainability, and of the state and non-state stakeholders." This is the foundation for the establishment of the Basin Development Plan (BDP) planning process, an important contribution to a strengthened trans-boundary governance system for the Basin. Reflecting the Member Countries' shared views on the future, the IWRM-based Basin Development Strategy was approved by the MRC Council in December 2010.

According to United Nations Educational, Scientific, and Cultural Organisation's (UNESCO) International Hydrological Programme (2012), water security is defined as "the capacity of a population to safeguard access to adequate quantities of water of acceptable quality for sustaining human and ecosystem health on a watershed basis, and to ensure efficient protection of life and property against water related hazards - floods, landslides, land subsidence,) and droughts."

Based upon the MRC's Strategic Plan (SP) for 2016-2020 (2016b), MRC has been focusing its work in delivering outcomes under four key result areas: (i) Enhancement of national plans, projects and resources from basin-wide perspectives; (ii) Strengthening of regional cooperation; (iii) Better monitoring and communication of the Basin conditions; and (iv) Leaner River Basin Organisation. The first two key areas out have been addressing water security by improving and strengthening national plans and knowledge through increased cooperation amongst Member Countries. These highlight why environmental assets require protection for basin-wide benefit (storage, fisheries, biodiversity) and where development can be optimised for basin needs and water security to the benefit of multiple sectors, such as flood protection, hydropower, irrigation, and inland navigation.

Cooperation on water resources development and management to scale up national sector planning towards basin-wide optimal and sustainable development in the Mekong River Basin has been highlighted in the BDS for 2016-2020, as well as in the key area 2 of the MRC's SP for 2016-2020. Engendering stronger relationships by facilitating dialogue among its member countries and with its partners on the options is recognised by the MRC to address pressing and long-term needs and challenges, increase regional benefits, reduce regional costs, and provide water security. These can be underpinned by establishing transparent Procedures that address the Member Countries' needs.

The social and economic assessment (MRC, 2017a) considered changes in a suite of indicator dimensions in response to the development scenarios under the Council Study. Five dimensions comprise the strategic indicator of living conditions and well-

being defined by the four Member Countries. These are water security, food security, income security, health security, and energy security. Water security includes accessing to safe water supplies, water availability for domestic and agricultural use and flood exposure, and effects of floods and drought.

3.2. Major Principles and Case Studies

Basin-wide sector and cross-cutting strategies have been developed by the MRC in collaboration with the Member Countries. The intention of the development of the basin-wide and cross-cutting strategies is to demonstrate how planning at the national level can be improved through increased cooperation among Member Countries. The cross-cutting strategies will help highlight why environmental assets need to be protected for basin-wide benefit (e.g. storage, fisheries, biodiversity) and where developments can be optimised for basin needs and water security to the benefit of multiple sectors such as flood protection, hydropower, irrigation, and inland navigation.

〈Box 1-1〉 Case Study: Development of Fisheries Management Strategy

The Mekong River system hosts one of the most diverse and prolific freshwater capture fisheries in the world. Some 877 fish-species have been recorded and up to 1,200 species or more have been estimated, making the LMB one of the highest fish biodiversity per square kilometre in the world.

The Fisheries Programme (FP) Phase 1, which ran from 2001-2005, was largely concerned with raising awareness on the size, nature and condition of the LMB fisheries and developing the capacity of national agencies and the MRC to manage the fishery in a sustainable manner. From 2006-2010, the FP's second phase, jointly funded by the Danish International Development Agency (DANIDA) and the Swedish International Development Cooperation Agency (SIDA), continued most of Phase 1 activities with a particular emphasis on formulating, promoting and facilitating the implementation of a basin-wide strategy for the preservation and development of Mekong fish resources.

The LMB development context has given an increasing pressure on the fisheries sector. The efforts undertaken by national governments and regional organizations towards sustainable fisheries have been managed and developed. FP's achievements in tackling resulting problems as well as identifying remaining and emerging, challenges points out an urgent need for the Fisheries Programme 2011-2015. These were first addressed in 2008 when the mid-term review of the Programme was available, which was carried out by independent external consultants in close collaboration with riparian agencies. The consultants strongly recommended a continuing support for FP during the period 2011-2015. The objective of FP 2011-2015 presents a key ingredient towards the achievement of this goal, which is the "successful implementation of measures for sustainable fisheries management and development and improved livelihoods by regional and national organizations (both governmental and civil society)".

Through a number of consultation processes with the Member Countries, the fisheries management strategy was finally adopted by the MCs in 2017. The development process indicated the joint effort among the MCs with MRC Secretariat's financial and technical assistance.

Source: MRC, 2017a.

3.3. Development of River Basin Management

The Agreement for the Cooperation for the Sustainable Development of the Mekong River Basin provides a formal framework for basin planning with a requirement to prepare a BDP. There were two phases of the BDP Programme (BDP1: 2001-2006, and BDP2: 2007-2010) with financial support from Development Partners including the Governments of Denmark, Sweden, Switzerland, and Australia, and support of experts from the Government of Japan. The Programme has resulted in a well-established participatory basin planning process between the LMB countries and their stakeholders, and an IWRM-based Basin Development Strategy to identify development opportunities and set out Strategic Priorities to optimise the opportunities and minimise the risk associated with them. At the 1st MRC Summit in April 2010, the LMB Countries Prime Ministers emphasized the adoption and implementation of the Strategy as the 1st priority action for the MRC.

The BDP2 was aimed at supporting all four goals of the MRC Strategic Plan 2006-2010 through the planning cycle[2)], with an emphasis on the first goal: "to promote and support coordinated, sustainable, and pro-poor development", with the preparation of a rolling IWRM-based Basin Development Plan, based on the analysis of water use and demand, and balancing trade-offs between different uses.

The BDP Programme 2011-2015 (BDP 2011-2015) was established in conjunction with the development of the MRC Strategic Plan 2011-2015 and was aligned with the MRC core river basin management functions. The transition of the MRC towards core functions further strengthened the integration of BDP and other MRC activities. For example, the required sector work for basin planning was implemented by other MRC Programmes, including Agriculture and Irrigation Programme (AIP), Fisheries Programme (FP), Flood Mitigation and Management Programme (FMMP), Navigation Programme (NAP), and Environment Programme (EP), and the implementation of MRC procedures have been coordinated by the Mekong IWRM Project (M-IWRMP).

The overall objective of BDP 2011-2015 was "to support Member Countries integrating and implement the principles, guidance and processes in the IWRM-based Basin Development Strategy in national planning and regulatory systems". This was achieved through a process that also aimed at sustaining the country-owned basin development planning process. The BDP 2011-2015 also led the implementation of the Procedures on Maintenance of Flow on the Mainstream (PMFM) within the framework of the M-IWRMP. The plan was a cross-cutting and overarching

2) The planning cycle included: (i) sub-area analysis and regional and national sector review; (ii) project master database and socio-economic database; (iii) development scenario analysis (regional and sub-area levels); (iv) IWRM-based basin development strategy; (v) project portfolio (short and long lists); (vi) rolling IWRM-based basin development plan; and (vii) updating, evaluating, monitoring, and supporting.

programme of the MRC that worked with all MRC programmes.

According to the BDP, the IWRM-based Basin Development Plan consisted of the following key areas:

- Basin-wide Water Resources Development Scenarios – providing the information that governments and other stakeholders need to develop a common understanding of the most acceptable balance between resource development and resource protection;
- IWRM-based Basin Development Strategy – a statement by the LMB countries of their intention to share, use, manage, and protect the basin's resources in an equitable and sustainable way for economic growth and poverty reduction. The Strategy contributes to a wider adaptive planning process that links regional and national planning for sustainable development and management of the LMB; and
- Project Portfolio – including strategically important water resources development projects and non-structural projects that would require either investment promotion or strengthened governance.

Plan preparation brought all existing, planned, and potential water and related resource development projects in a joint basin planning process through a combination of participatory sub-basin and sector activities and a basin-wide integrated assessment framework. The planning process was supported by activities that had improved planning knowledge and tools.

The required sector work for basin planning that was implemented by the other MRC Programmes includes the following:

- *Mekong* – Integrated Water Resources Management (M-IWRMP) was initiated in 2009 to follow up on the Water Utilisation Start-up Project (WUP), which was the foundation of MRC's Procedures under the 1995 Mekong Agreement and its Decision Support Framework. To address IWRM challenges in the LMB, the M-IWRMP has employed a three-tier approach, combining interlinked basin, national, and cross-border initiatives in close synergy with the MRC-led basin development planning process. These form the three respective components of the Project: (i) regional, national, and trans-boundary. The outcome of the regional component is an enabling framework with water resources planning and management tools, procedures and guidelines, processes and capacity in place to implement the 1995 Mekong Agreement. The M-IWRMP implements its activities in close collaboration with both sector and cross-sector programmes of the MRC, with technical aspects of the Procedures for Notification, Prior Consultation and Agreement (PNPCA).

- *Agriculture and Irrigation Programme (AIP)* – a draft Agricultural Strategy for the MRC was prepared in 2009 to identify the added value of the MRC's role in the sector. On the basis of the draft strategy prepared, a concept of AIP 2011-15 was developed. The formulation of the Programme Document for 2011-151 took into account the MRC achievements in the IWRM-based basin development planning to contribute to the goals of the MRC Strategic Plan 2011-2015. The objective of AIP 2011-15 was "to provide national planners with detailed and nuanced analyses of the likely consequences of agricultural development and resources management based on improved knowledge on agriculture and irrigation in the LMB".

- *The Drought Management Programme (DMP)*, which is a trans-boundary water management issue, started in 2011 with the purpose of establishing effective strategy and time-bound action plans for drought awareness, preparedness, planning, and management in the LMB. This has been supported by a comprehensive assessment and "best" available strategy, tools and strategies, and is aimed at facilitating the implementation of high priority national and regional programmes and multi-purpose projects. The programme would contribute to achieving the long-term objective of the DMP, so that the MRC Member Countries would develop technical capabilities and institutional capacity to manage drought in the MRB in an effective, sustainable, and equitable manner.

- *Fisheries Programme (FP)* – concentrated on information and knowledge generation, raising awareness of fisheries in the Mekong, improving fisheries management, and particularly promoting community involvement in management processes. The Programme also put a strong emphasis on promoting the uptake of fisheries information into planning and development decision-making in the Basin. The Programme commissioned research into capture fisheries, trained fisheries managers, promoted aquaculture of indigenous Mekong fish species, and disseminated information to policy makers and planners in the four LMB countries.

- *Flood Mitigation and Management Programme (FMMP)* – at the heart of the Programme is the Regional Flood Management and Mitigation Centre, which provides technical and coordination services to the member countries. Regional flood forecasts, flash flood guidance, flood data, technical standards, and training packages are key outputs of the Programme. The goal of FMMP for 2011-2015 was that the Member Countries applied Integrated Flood Risk Management (IFRM) principles and guidelines to national water and related sector frameworks and development programmes.

- *Initiative on Sustainable Hydropower (ISH)* – the Initiative on Sustainable Hydropower (ISH) recognizes that addressing hydropower challenges in the Mekong goes beyond informing decisions about possible new hydropower schemes or their design features. ISH also advances and clarifies the way of thinking about the type of cooperation needed among Mekong Countries to sustainably manage the growing number of existing hydropower assets in the Basin, as the cumulative and trans-boundary impacts of these projects are increasingly felt. ISH's two-part objective for 2011-2015 was, first, to ensure that decisions concerning the management and development of hydropower in the Mekong were placed in a river basin planning and management context, applying IWRM principles. Second, MRC and key stakeholders should cooperate to take into consideration the regulatory frameworks and planning systems of the Member Countries concerned with hydropower and project-level planning, preparation, design, implementation, and operation activities.

- *Navigation Programme (NAP)* analysed river transport systems and related activities in the Lower Mekong Basin. The programme investigated a network of 4,500 km of waterways, undertook condition surveys for safe navigation in the Mekong River, and installed and maintained a system of navigational aids. Navigation charts were produced and updated, and regulations for free and safe river transport were harmonized. The NAP's objectives were 1) to further promote freedom of navigation and increase the international trade opportunities for the MRC member countries' mutual benefit and 2) to assist in coordination and cooperation in developing effective and safe waterborne transport in a sustainable and protective manner for the waterway environment.

- *The Environment Programme (EP)* was a cross-cutting programme of the MRC that generated data, information, and knowledge in order to balance economic development, environmental conservation, and social equity in decision-making. The overall goal of the EP 2011-2015 was well described in the MRC Strategic Plan (SP) Goal: "Member countries apply basin-wide IWRM approaches in national water and related sector frameworks and development programmes". The objective of the EP responded to this Goal by providing environmental and social data, knowledge, and efficient environmental cooperation mechanisms as necessary supporting instruments for the application of basin-wide IWRM approaches at the national and regional levels.

3.4. Overview of Integrated River Basin Management in the Mekong River Basin

As highlighted in sub-section 3.3, MRC has implemented various programmes to address challenges in the LMB. The EP, in collaboration with the Member Countries, supported routine water quality monitoring at 48 monitoring stations across the LMB and an ecological health monitoring programme at 41 sites in 2015. The routine water quality monitoring programme included technical, such as water quality sampling and data management, thus strengthening the capacity of relevant line agencies of the Member Countries, and financial support.

The Social Impact Monitoring and Vulnerability Assessment (SIMVA) programme was carried out under the EP before the MRC's new structure was implemented (currently under the Planning Division) to conduct a socio-economic survey (including baseline survey for 2011, and shocks and trends for 2015) in the LMB's corridor along the Mekong mainstream and the adjacent floodplains. The survey generated baseline data on the socio-economic conditions of people in the LMB, the extent of their dependence on water resources, and their resilience to changes in these resources (both short-term shocks and long-term trends), and further their climate change associated vulnerability. SIMVA also provided data that were relevant for use in many of MRC's activity areas, including agriculture and irrigation, drought management, fisheries, basin development planning, sustainable hydropower, and climate change.

All LMB countries have been experiencing rapid socio-economic development. The demand for electricity to meet the rapid development has been increasing with sustained growth rates of over 10% a year across the region, placing strain upon the power generation system and triggering investment in the construction of additional generating capacity (ISH, 2014). As for hydropower development, potential cumulative impacts on the environment, fisheries, and people's livelihoods in the LMB have been increasingly intensified. MRC has been exploring sustainable options for hydropower development to mitigate and lessen those trans-boundary impacts. Consequently, the following various activities have been implemented in collaboration with the Member Countries of the LMB:

- The ISH01 study on the "Identification of Ecologically Sensitive Sub-Basins for Sustainable Development of Hydropower on Tributaries" was kicked-off through an inception workshop (Vientiane, Lao PDR) in November 2013 and finalised in June 2015;
- The ISH02 on "Guidelines for the Evaluation of Hydropower and Multi-purpose Project Portfolios", which proposed a portfolio planning process with associated tools for the valuation and evaluation of hydropower and multi-

purpose dam project portfolios to assist the Member Countries in their basin planning and energy/hydropower planning frameworks;

- The ISH0306 study on "Development of Guidelines for Hydropower Environmental Impact Mitigation and Risk Management in the Lower Mekong Mainstream and Tributaries", which was aimed at enhancing the Preliminary Design Guidance for Mainstream Dams (PDG) and providing more effective and detailed documentation of the options and methods that may be used to cover the mitigation of hydropower risks in the Mekong; and
- The ISH11 study addressed a fundamental aspect of the MRCS Basin Development Strategic Priority 3 to "Improve the Sustainability of Hydropower Development", which was commenced in November 2012, with a multi-disciplinary team of experts, to review existing monitoring and information management systems at the MRC with respect to how they meet hydropower planning and management information needs.

The Basin Development Strategy (BDS) (2016a) has identified five major long-term basic needs related to water resources development and management. These long-term needs include: (i) food and livelihood security, access to a safe water supply, and sanitation; (ii) resilience against floods and drought; (iii) energy security; (iv) improved navigation; and (v) protection of key environmental assets and ecosystem services.

The Member Countries and MRCS have, based on the identified long-term needs and anticipated trade-offs related to water resources development and management, identified the major challenges and some risks that could lessen the effectiveness of the BDS's implementation. These challenges include: (i) environmental degradation from developments in water and non-water sectors; (ii) hydropower development in the upper and lower basin; (iii) uncertainties associated with climate change; (iv) water related poverty; and (v) gender mainstreaming. Additionally, the risks that diminish the effectiveness of the BDS implementation include: (i) joint development and cost-benefit sharing; (ii) willingness to implement basin-wide cooperative mechanisms; (iii) limitations in human resource and institutional capacity; (iv) limited coordination across government agencies at national and sub-national levels; and (v) insufficient knowledge and information management and communication.

To address these above challenges, MRC, together with the MCs, has proposed the following major actions:

- Deep and further understandings of the impacts (social and environmental) from all sector developments will address environmental degradation resulting from all the development projects in water and non-water sectors. These can be done through studies of some major areas (i.e. capture fish ecology,

biodiversity, and options to increase natural storage within LMB for flood, drought and environment management) and of real practices of mitigation measures. Additionally, promotion of the sharing and learning of best practices and applicable guidelines and tools, and of implementation of these guidelines and tools to support the development and operation of water and related projects on tributaries of trans-boundary significance are of significance to tackle the environmental challenges. Strategies on basin-wide environmental management and action plan for fisheries management and development as wells as monitoring and reporting systems have also been mentioned in the MRC SP 2016-2020.

- Short- and medium-term actions to address hydropower challenges have been illustrated in the MRC SP, which include: (i) reviewing design guidance for mainstream dams; (ii) developing hydropower environmental impact mitigation and risk management; (ii) improving the effectiveness of MRC procedures implementation; (iii) developing and approving a basin-wide strategy for sustainable hydropower (long-term); (iv) updating and approving a basin development strategy for 2021-2025 (long-term); and increasing cooperation between Member countries and Myanmar and China (long-term).

- Major actions needed to address climate change issues include: (i) updating basin-wide development and climate scenarios and related assessments; (ii) studying water requirement and availability for specific land uses completed for drought management and impacts adaptation and mitigation purposes; (iii) finalizing and implementing the Mekong climate change adaptation strategy and action plan; and (iv) developing guidelines for climate change impact assessments and adaptation planning.

- As stated under the MRC SP, to address water-related poverty reduction, short-term action to support the MCs for minimizing negative impacts caused by development projects of water-related sectors on the poor and vulnerable will be assured. However, medium- and long-term poverty reduction in the basin will depend on developments in the water and non-water sectors. Also, the direct impact on poverty alleviation would reside with the actions of the member countries themselves.

3.5. Case Studies

Article 5 on "Reasonable and Equitable Utilization" of the 1995 Mekong Agreement states that "to utilize the waters of the Mekong River system in a reasonable and equitable manner in their respective territories, pursuant to all relevant factors and circumstances, the Rules for Water Utilization and Inter-Basin

Diversion provided for under Article 26 and the provisions of A and B." Primarily based on this Article, the Procedures for Notification, Prior Consultation and Agreement (PNPCA) was developed by the MRC and then agreed on by the Member Countries.

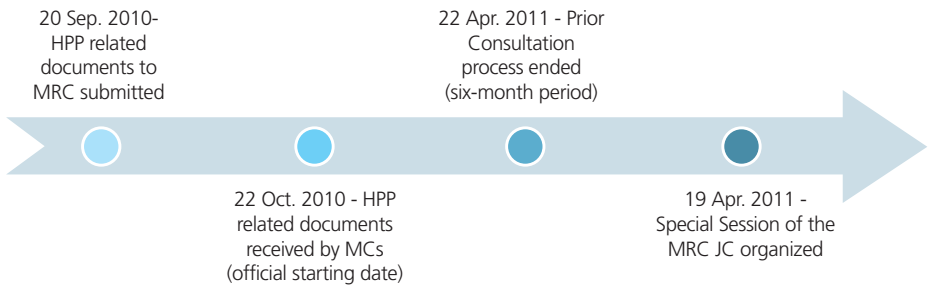
At the 10th MRC Council meeting in November 2003, the PNPCA was adopted. The MRC Joint Committee (JC) then also adopted the "Guidelines on Implementation of the Procedures for Notification, Prior Consultation and Agreement" in August 2005. These guidelines are intended to facilitate the implementation of the PNPCA as well as to address issues or points requiring clarification or elaboration, and they are to be applied in conjunction with the PNPCA.

〈Box 1-2〉 Case Study: Implementation of the PNPCA

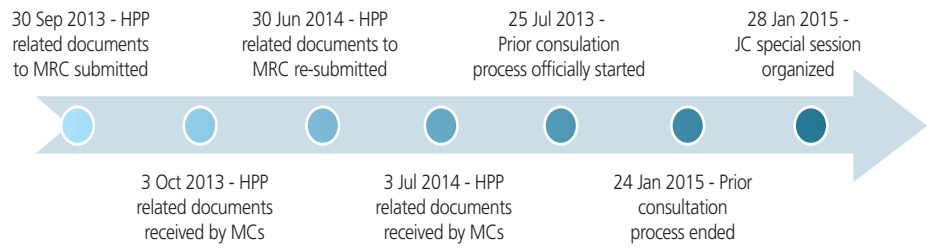
According to the MRC (2015), 49 Notifications for water uses were submitted through the MRC, of which 44 development projects are located on the tributaries (mostly hydropower projects) and 5 are on the mainstream. There have been 2 projects for hydropower on the mainstream have undergone the Prior Consultation process, the Xayaburi Dam and the Don Sahong Dam.

Stakeholders' engagement in the processes, especially the prior consultations, was facilitated by the MRC, which was in line with its perception of public participation. The Prior Consultation process for the Xayaburi Dam did not come to an end point of agreement, while the one for the Don Sahong Dam has gone beyond the Xayaburi Dam.

• Implementation of Prior Consultation for Xayaburi Hydropower Project



• Implementation of Prior Consultation for Don Sahong Hydropower Project



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〈Box 1-3〉 Case Study: Implementation of the PNPCA

The application of the PNPCA for these two projects provided the MCs to participate in a constructive learning process and experience the implementation of the PNPCA and its implementation guidelines. The issues raised by the MCs during the implementation of the PNPCA and its implementation guidelines embraced interpretation of the PNPCA and the guidelines, timely notification, prior consultation time (six-month period – requested to extend), information disclosure, trans-boundary environmental impact assessment, post-consultation process, and roles of the MRC Joint Committee and Council in terms of implementing the procedure.

Source: MRC, 2005.

4. Implications and Recommendations

4.1. Implications

4.1.1. South Korea

Global and regional discourses on water security have been reflected in the establishment of Korea's strategies for water security, and Korea's water security strategies call for an integrated approach to multi-dimensional aspects of water resources management, namely water supply, water quality control, flood and drought management, and ecosystem protection, with serious consideration of adverse impacts of climate change. In addition, trans-boundary water management and good governance have been emphasized together with consideration of economic and urban aspects, and the Water-Energy-Food Nexus provides food for thought on the interconnectivity between water, energy, and food.

In response to these demands and circumstances, water security in the Korean context can be defined as the capacity to provide stable and sufficient amounts of clean water to human beings and ecosystems and to cope with water-related disasters. Korean society has recognized the urgency of the adequate provision of related infrastructure and technologies and has endeavoured to be equipped with non-structural measures through multi-stakeholder dialogues, as seen in the course of revising the Water Vision 2020 in 2006. Major principles for water security have been recognized and embedded in water policies in Korea, such as the IWRM, good governance, and adaptive capacity to cope with challenges triggered by climate change. Unique elements of Korea to water security encompass its efforts to opt for the South and North Korea joint management of the Imjin and the North Han Rivers (trans-boundary rivers), an equal distribution of water and environmental benefits between regions, and consideration of the Water-Energy-Food Nexus.

The case study of Korea's flood management focusing on major typhoons implies the transformation of water-related disaster policies and strategies. Primary attention has been paid to the two historically devastating typhoons, Rusa in 2002 and Maemi in 2003, and these events not only unveils the seriousness of climate change-driven adverse impacts through typhoons, but also the gradual transformation of the country from recovery-focused to preventive-focused policies. In addition, the government would prepare more appropriate policies and projects regarding the rapid urbanization and population growth and admitted to the lack of adequate infrastructure for flood forecasting and preventive measures.

The discussions on the Integrated River Basin Management (IRBM) in Korea has shown the step-by-step efforts of Korean society on how to cope with the challenges for water resources management and its connection with economic growth and environmental protection. Particular emphasis was placed on securing the stable supply of water for agriculture, industries, and electricity, coupled with the prevision of flood events in the early period of the rapid economic development between the 1960s to the 1970s. The Comprehensive Development Plan of the Han River (the 1st Phase) in the late 1960s portrayed the commitment of Seoul to improving flood protection measures, as well as resolving urban challenges, including traffic jams and the lack of housing.

In the period between 1971 and 1981, the Korean government pushed forward the construction of more multi-purpose dams, and large-scale cities like Seoul, Pusan, and Daejeon emerged thanks to the efficient management of water resources through the stable supply of clean water and an appropriate level of flood prevention systems. The Comprehensive Four Major River Basin Development Plan was dedicated to bolstering food prevention infrastructure, irrigating more arable lands, preventing water pollution, and increasing the rate of water supply for the whole population up to 65%.

One of the iconic achievements in the Han River management in the 1980s was to upgrade Seoul to an international city that would host the Olympic Games in 1988 through the 2nd Phase of the Han River Development Plan, which provided a window of opportunity for the central government to enhance river environments, build civic parks, install better sewage treatment systems, and expand highways. Nevertheless, environmental activists and scholars criticized the plan, arguing that this plan turned out to remove the natural features of the Han River by placing too many built environments along the river. Also, riverside highways and apartment housings have prevented Seoul people from have access to riverine areas.

Since the onset of the 1990s, the IRBM of Korea has increasingly been transformed from pro-growth related policies and projects to policies and projects reflecting the

balance between economic growth and environmental protection. Such a policy shift was possible due to a series of water pollution accidents, which forced the government to establish the Long-term Comprehensive Water Resources Development Plan (1991-2011) in 1990 that embraced eco-friendly river basin restoration principles for the first time. Institutional rearrangements favouring ecosystem protection were accompanied together with the creation of environmental regulations, standards, and the polluter-pays-principle for downstream water users.

Continuous economic development, population growth, and urbanization have spawned a complexity of challenges for Korean society, especially in water shortages, water pollution, and ecosystem destruction, which are often compounded by climate change. The launch of the Low Carbon Green Growth Policy in 2008 was timely considering such unprecedented challenges, and the Four Major River Restoration Project was kicked off as part of this policy in Korea.

The Water Vision 2020 demonstrates Korea's commitment to tackling a variety of challenges in water resources management in connection with socio-economic development. In addition to conventional approaches to water challenges, particularly structural measures, water managers in Korea are ready to accommodate various socio-economic and environmental demands and to allow diverse stakeholders to participate in decision making, which is a fundamental step toward implementing good water governance in the coming years. More work for the vision is required, particularly for reflecting how to deal with climate change-driven adverse impacts, various demands by different stakeholders, and the uneven socio-economic and environmental benefits created by water resources management.

4.1.2. Mekong River Basin

Through various discussions in the sub-sections above, it has been demonstrated that MRC, together with its member countries, have been implementing a number of activities, projects, programmes, and actions to address the water security, including hydropower development, expansion of irrigated agriculture, fisheries management, watershed management, navigation, and flood and drought. There are, however, some implications and challenges that MRC has been facing that require major actions.

For successful implementation, either the approaches suggested are too complex, or capacity building is insufficient to support the increased responsibility of the Member Countries. For instance, due to several attempts through various initiatives over the years, the Environment Programme has not yet succeeded in fostering regional cooperation and inspiring a strong sense of ownership for Trans-boundary Environment Impact Assessment (TbEIA) among the Member Countries. Similar with

biodiversity monitoring, there was an issue of too complex of an approach and/or lack of capacity. Consequently, one Member Country announced that it would not participate in biodiversity monitoring activities due to the lack of capacity. The MRC should continue helping its Member Countries to build and strengthen capacity.

Inadequate coordination at the national level and insufficient engagement of relevant line agencies can continue to detach regional and national efforts. Basin-wide sector and cross-cutting strategies that have been or will be developed require a coordinated response to the strategy across all water and other related sectors. The coordination between the MRC and its Member Countries has not been as effective as it should be. MRC and its Member Countries should explore how their coordination with the various national and sub-national agencies can be strengthened and improved to effectively implement the developed basin-wide sector and cross-cutting strategies.

4.2. Recommendations

This chapter provides a set of recommendations with regard to water security and the Integrated River Basin Management of Korea and the Mekong River Basin. These recommendations are not only applicable to South Korea, but also to the Mekong River Basin.

- Water Security

  - Water security in society can be achieved through guaranteeing the stable supply of clean water, effective measures against water-related disasters, such as flood and drought, and sound ecosystem protection. Government authorities should be committed to providing adequate infrastructure and enabling environments in which the Integrated Water Resources Management (IWRM) should be adequately implemented.
  - Confronted with climate change-driven challenges, more investment and technology development are required in addition to institutional rearrangements, including the introduction of new water management standards and regulations. The combination of structural and non-structural measures against climate change paves the way for the government to increase the resilience of society as found in the flood management cases of South Korea.
  - Good water governance is necessary in order to safeguard water security for each country, and the promotion of stakeholder participation is one of the key elements to strengthen the aspect of water security against water-related disasters, especially flood events as seen in the case of South Korea.
  - New and innovative ideas should be considered and adopted for water

resources management policy and planning, including the Water-Energy-Food Nexus. The nexus elucidates the interconnectivity between water, energy, and food, unveiling trade-offs and synergistic effects, and it also provides a new policy tool for South Korea and the member countries of the Mekong River Commission on how to undertake sustainable policies and projects for such limited resources.

- Adaptive capacity for trans-boundary water issues should be nurtured, particularly in relation to the Imjin River, the North Han River, and the Mekong River. Continuous dialogues and basin-wide approaches are prerequisites for resolving conflict issues among the riparian countries and fostering mutual cooperation.
- Each country should have a closer look at the gaps among regions in terms of economic and environmental benefits provided by water resources management. Government authorities should strive to narrow the gap and improve upon the inequalities among the regions in all aspects of water services. For instance, the increase of universal access to clean water and sanitation in remote areas of South Korea and the Mekong River countries can make a big difference in lieu of the living standards and local livelihoods.

• Integrated River Basin Management

- There are essential components to achieve an effective Integrated River Basin Management (IRBM) system in society: 1) basin-wide planning; 2) public participation; 3) demand management; 4) good compliance with environmental standards regarding water pollution; and 5) human and financial capacity.
- Looking back on the experiences of IRBM in Korea, it is important to introduce and implement these five elements. With regard to the Mekong River Basin, basin-wide planning is essential in accommodating diverse aspects and viewpoints from the member countries. Small-scale basin-wide planning can be a good start point as a pilot project.
- To address environmental degradation from development projects of water and non-water sectors, deep and further understandings of social and environmental impacts from all sectors of development should adequately be studied. These could be undertaken through studies of some major areas, such as capture fish ecology, biodiversity, and options to increase natural storage within LMB for flood, drought and environment management, and of real practices of mitigation measures. Most importantly, environmental risk assessment should be conducted with the aim of understanding the basic principles and the added values of impact analysis and risk assessment in the LMB context. Doing so could support the MRC and the Member Countries by identifying risks associated with human-induced impacts on water resources,

enabling effective response with mitigation measures.

- Good water governance is imperative in achieving a good level of IRBM. Stakeholder participation in decision making should be encouraged at the lowest possible level in South Korea and the Mekong River Basin. With regard to the Mekong River Basin, this can be facilitated through the opportunities of public participation and timely disclosure of information during the Prior Consultation process.
- A basin-wide strategy for sustainable hydropower should immediately be developed and approved in order to address hydropower development impacts on both the ecosystem and society, and cooperation among Member Countries, Myanmar, and China should be further improved.
- IRBM should reflect diverse aspects of riverine residents, including the aspect of water welfare. More people would like to have better access to rivers and lakes, and government authorities have to provide well-designed and eco-friendly waterfronts for leisure purposes. These cases can be found in the history of the Han River Basin Development in Seoul and the Four Major River Project.
- Demand management should be emphasized in river basins, as seen from the case of the application of the polluter-pays-principle for the Han River. Downstream users should be informed of the need to pay a fee for upstream communities. The fund created through the collection of the fee should be invested not only for subsidies to upstream people, but also for the safeguarding of water environments upstream. With regard to trans-boundary rivers, upstream and downstream countries should work together to reach an agreement about various aspects of water use, including the amount of allocated water based on the principle of equitable utilization.
- There are numerous socio-economic activities in a river basin, and, therefore, it is significant to decide priority sectors or fields for socio-economic development and ecosystem protection. Korean experiences of IRBM demonstrate the policy focus shift from food production and water supply for households and industries to ecosystem protection in water resources management together with effective flood control measures, as seen from the Lake Sihwa Development Project. In the Mekong River Basin, the basin-wide planning should prioritize diverse sectors depending upon demands from local communities, as well as the member countries, and consider tailor-made policies and projects. The complementary TbEIA should immediately be finalized and approved to address environmentally and socially harmful impacts resulting from water and non-water sector development projects.
- More investment and R&D are necessary in order to cope with climate change-driven impacts for South Korea and the Mekong River Basin, especially water-related disasters such as flood events and droughts. The Four Major River Project shows a good example of South Korea's efforts to tackle

climate change-driven challenges, such as water shortages triggered by long spells of drought and flood events caused by typhoons and torrential rainfall.

- Socio-Economic Implications

  - The case of South Korea implies that sustainable water resources management can be established step by step and in accordance with the growing strength and diversification of economic development.
  - As seen in [Figure 1-14], water managers focused on providing sufficient amounts of water for the agricultural and industrial users at the early phases of economic growth in South Korea. Whilst Korea's economy was gradually transformed into a heavy industry and manufacturing-centered economy, and a higher GNI per capita was realized, the policy focus was shifted towards not only achieving stable water supply, but also directing more concerns to water quality and impacts on the environment overall. Since the mid-1990s, Korea has undergone post-modernity development phases, demonstrating the emergence of diverse stakeholders in water decision-making.
  - A good degree of water security and the implementation of the Integrated River Basin Management of South Korea have been possible after the bitter, up-and-down experiences of the political economy landscape. The cases of the Sihwa Development Project and the Four Major River Project imply that there are numerous questions to be answered every time large-scale water related projects are planned, implemented, and maintained.
  - The degree of socio-economic development of each riparian country in the Mekong River Basin varies, policy priorities are diverse, and vested interests for each country's development are different. Nevertheless, it is imperative for the countries of the river basin to work together in achieving socio-economic development based on the step-by-step approach and the recognition of the contributions by sustainable water resources management. The case of Korea is a good practice that the countries of the river basin can emulate to remember the important linkage between water and socio-economic development, which paves the way for the Mekong River Basin to achieve sustainable development in the foreseeable future.

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2017/18 Knowledge Sharing Program with the MRC:
Basin-wide Strategy for Sustainable Hydropower Development

Chapter 2

Challenges and Opportunities in Sustainable Hydropower Development

1. Introduction
2. Dam Development and Water Resources Management in Korea
3. Mekong Water–Energy Security Nexus: Opportunities and Challenges
4. Policy Directive of Water Resources Development for Sustainable and Prosperous Mekong Cooperation: the Case of Hydropower Development
5. Conclusion and Recommendations

Challenges and Opportunities in Sustainable Hydropower Development

Ilpyo Hong (Korea Institute of Civil Engineering and Building Technology)

Summary

This study presents effective implications for solving the water security of river basins, such as river development, water resource management, and development of hydroelectric dams for the Mekong River. Such implications will be demonstrated by sharing Korea's policy agenda and its related experience for water resource development and management, hydroelectric power generation, and establishment of multi-purpose dams. This will also help build the development conditions for sustainable development of the countries located in the lower reaches of the Mekong River countries, which have recently achieved significant development. In particular, the trial and error experienced by Korea in the development and management of dams may be used as a good example for sustainable growth in these countries.

Applying the experience of Korea—with a land area of 99,720 km^2 and a population of about 52 million—in water resource management and dam construction to the Mekong River case might be unrealistic to some extent, as their geographical and political backgrounds are completely different. However, the aggressive development of water resources in the 1970s to the 1980s—a cornerstone of Korea's rapid economic development—and the current paradigm shift in dam construction and water management could help with the harmonious and

Keywords: Dam Development, Water Resources Management, Mekong Water-Energy Security Nexus, Hydro-power Development, Water Resources Development Policy Directive

sustainable development of the trans-boundary river and local river for each of the Mekong countries.

Although the application to discussions of dam construction and/or hydroelectric power generation in the Mekong River is difficult, Korea's experience in water resources development could help countries like Laos, Thailand, Cambodia, and Vietnam—through which the lower Mekong River runs—to develop water resources in the river.

Moreover, this study examines the development direction of the Mekong River through an overview of various projects based on sustainable development.

The annual average precipitation of Korea is 1,274mm (1973~2011), which is 1.6 times the world average of 807mm. The total amount of water resources is 134.9 billion m^3/year, but due to the high population density, the total amount of annual precipitation per person is 2,660m^3, which is only about 1/6 of the world average of 16,427m^3 (Water for Future, 2015). In terms of the coefficient of river regime, the Han River has a value of 1:393. Compared to the Mekong River (1:35), it is more difficult to manage Korean rivers and water. Additionally, Korean rivers have a higher risk of flash flooding. Despite such different characteristics, Korea's experience in general dam construction and river management may be a good example for the development of the Mekong river basins.

After the Korean War, in 1953, there was almost nothing left in Korea. There was no industrial infrastructure to build on, the unemployment rate was 25%, and the declining economy was unable to sustain itself without the aid of other countries. The GDP per capita in the Republic of Korea was only USD 70 per annum in 1953.

But following economic growth in the past 60 years, as of 2015, the Republic of Korea ranks as the 11th largest economy in the world in terms of GDP. Last year Koreans enjoyed a GDP per capita of approximately USD 27,000 per annum.[1)]

One of the primary driving forces behind Korea's economic development was the government-led, intensive investment in infrastructure. This government led initiative maximized the industrial productivity, and build-up of Korea's five major infrastructure sectors such as water, city, transport, energy and communication.

In particular, dam and river development in terms of water resources was carried out from the 1960s to the 1980s. This period focused on national economic growth, including poverty eradication, prevention and protection from disasters such as flood and drought, supply of industrial water, agricultural water, and domestic water for

1) Source: http://databank.worldbank.org/data/download/GDP.pdf

city development

However, from the mid-1980s, growth-oriented development of dams and rivers and industrial growth brought environmental problems. The deterioration of the water quality in rivers, as shown in the Nakdong River phenol accident, and environmental pollution caused socio-economic problems. Since then, the government has promoted environmentally friendly resource development and river management. It has also started to focus on water quality management through pollutant management in the river basins.

The hydropower potential of the Mekong is quite large, providing a comparable source of energy for upstream countries, particularly Yunnan China, Lao PDR, Cambodia, and parts of Vietnam. However, the development to fully capitalize on the hydropower potential of the Mekong river basin (mainstream and tributaries) with the construction of a series of big dams on the Mekong mainstream upstream in China and the Lower basins in Laos, Thailand, and Cambodia, together with hydropower in the tributaries in all countries are potentially serious threats to water security, food security, and the livelihood of riparian communities. These threats apply not only to the Mekong countries in general, but also to the countries located downstream, namely Cambodia and Vietnam.

In the Lower Mekong Basin (LMB), the construction of hydropower dams has started to increase considerably in recent years. Consequently, after the establishment of the Mekong River Commission (MRC) Initiative on Sustainable Hydropower (ISH) in 2008, there were many useful MRC studies undertaken during the period 2009-2017. Such studies aimed to help the MRC Member Countries to plan and manage effectively the increasing number of hydropower projects as the cumulative impacts from them are being felt. While some of the Guidelines, such as the Preliminary Design Guidance (PDG), have been already used by the hydropower dams developers while designing their hydropower projects, most of the ISH studies are being disseminated to the MRC Member Countries to encourage their usage.

The findings of the Council Study have further confirmed that there are significant and important opportunities to reduce trans-boundary impacts through the reconsideration of hydropower development plans.

Therefore, knowledge management and capacity building to imbed sustainable hydropower considerations in regional planning and regulatory systems for the MRC Riparian are very important tasks for the MRC. While capacity building is being conducted during the implementation of a study as a normal practice, such an approach appears to be insufficient considering that the required time for the participating Member countries is limited.

There should be coordination and support between the cooperative mechanisms (MRC, LMC, Great Mekong Subregion etc.) in the Mekong basin/region to ensure the sustainable development of water resources in the Mekong basin for water, food, and energy security. Such cooperation can be achieved through appropriate benefit sharing mechanisms in water resources development for all purposes among the upper and lower basin countries. To develop a common operating mechanism for the hydropower systems on the mainstream can ensure mutual interests, while also mitigating negative impacts.

1. Introduction

This study presents effective implications for solving the water security of river basins, such as river development, water resource management, and development of hydroelectric dams for the Mekong River by sharing Korea's policy agenda and its related experience for water resource development and management, hydroelectric power generation, and establishment of multi-purpose dams. This will also help build the development conditions for sustainable development of the countries located in the lower reaches of the Mekong River countries, which have recently achieved significant development. In particular, the trial and error experienced by Korea in the development and management of dams may be used as a good example for sustainable growth in these countries.

Water is the source of life and an indispensable resource for the survival of all living things, including humans on Earth. Water contributes to transport, trade, food production, industrial resources, national health, and welfare. As such, water is one of the essential resources required for the economic growth of a country. For the Mekong region, it is no exception that the sustainable use of water therefore is not only imperative, but a driving force for green economy and growth.

The Mekong River is 4,900km long with a total watershed area of 795,000km^2. It flows starting from Yunnan, China, through Myanmar, Laos, Thailand, Cambodia, and Vietnam, before emptying out into the South China Sea. The watershed of this trans-boundary river, flowing through six countries, is about 7.8 times South Korea's total area of 99,720km^2. Although application to discussions of dam construction and/or hydroelectric power generation in the Mekong River is difficult, Korea's experience in water resources development could help countries like Laos, Thailand, Cambodia, and Vietnam—through which the lower Mekong River runs—to develop water resources in the river.

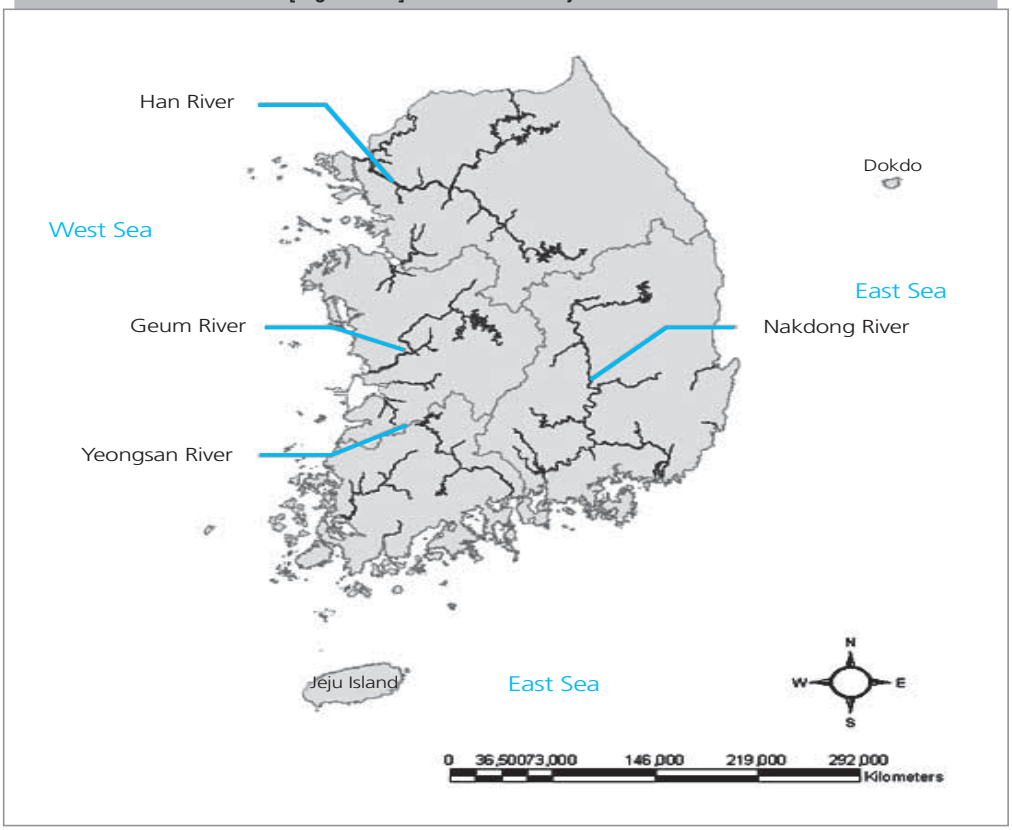
In discussing consistent and sustainable river management and water resources development from the upstream (Yunnan, China) to the downstream (Vietnam) of

the trans-boundary river, the water–energy–food nexus was central, supporting by the cooperation of interested countries.

Moreover, this study examines the development direction of the Mekong River through an overview of various projects based on sustainable development.

The annual average precipitation of Korea is 1,274mm (1973~2011), which is 1.6 times the world average of 807mm. The total amount of water resources is 134.9 billion m^3/year, but due to the high population density, the total amount of annual precipitation per person is 2,660m^3, which is only about 1/6 of the world average of 16,427m^3 (Water for Future, 2015). In terms of the coefficient of river regime, the Han River has a value of 1:393, and the Nakdong River has a value of 1:372. Compared to the Mekong River (1:35), it is more difficult to manage Korean rivers and water. Additionally, Korean rivers have a higher risk of flash flooding. Despite such different characteristics, Korea's experience in general dam construction and river management may be a good example for the development of the Mekong river basins.

[Figure 2-1] South Korea Major River Basins



Source: http://www.wepa-db.net/policies/state/southkorea.

The history of modern Korean dams started in the late 1920s, and large-scale dams were constructed the late 1940s. After 1962, many dams were constructed with advanced designs.

After the Korean War, in 1953, there was almost nothing left in Korea. There was no industrial infrastructure to build on, the unemployment rate was 25%, and the declining economy was unable to sustain itself without the aid of other countries. The GDP per capita in the Republic of Korea was only USD 70 per annum in 1953.

But after exponential economic growth in the past 60 years, as of 2015, the Republic of Korea ranks as the 11th largest economy in the world in terms of GDP. Last year Koreans enjoyed a GDP per capita of approximately USD 27,000 per annum.[2)]

One of the primary driving forces behind Korea's economic development was the government-led, intensive investment in infrastructure. This initiative maximized industrial productivity, and helped establish five of Korea's major infrastructure sectors: water, city, transport, energy, and communication.

In the 1960s, Korea had poor economic conditions, making it difficult to provide stable drinking water supply and to manage floods and droughts. Recognizing the importance of water resources development for economic growth, the Korean government established the Ten-Year Plan for Comprehensive Development of Water Resources (1965-1975), along with relevant laws and institutions for its implementation. In the 1970s, the government provided intensive support for the construction of agricultural reservoirs and made massive investments in hydropower dams and multi-purpose dams. The Korea Water Resources Corporation (currently K-Water) was established in 1967 to support the development of water resources, investigation projects, and project implementation.

In particular, dam and river development in terms of water resources was carried out from the 1960s to the 1980s. This period focused on national economic growth, including poverty eradication, prevention and protection from disasters such as flood and drought, supply of industrial water, agricultural water, and domestic water for city development. It was a time of significantly quantitative growth, including the development of multi-purpose dams. At that time, the black smoke rising from the chimneys of industrial complexes was regarded as a symbol of economic growth; no one was concerned about the environment.

However, from the mid-1980s, growth-oriented development of dams and rivers and industrial growth brought environmental problems. The deterioration

2) Source: http://databank.worldbank.org/data/download/GDP.pdf

of the water quality in rivers, as shown in the Nakdong River phenol event, and environmental pollution caused socio-economic problems. Since then, the government has promoted environmentally friendly resource development and river management. It has also started to focus on water quality through pollutant management in the river basins.

2. Dam Development and Water Resources Management in Korea

2.1. Colonial Period

The history of modern Korean dams started in the late 1920s, and the present age of large-scale dams began in the late 1940s. After 1962, the quantitative and qualitative development of dam construction was achieved.

In the early 1910s, the Japanese government used Korea as a food production base and implemented various policies to solve the shortage of food. Two of these policies promoted the construction of dams on the Korean peninsula. First, the heavy industrialization policy in North Korean regions constructed the large-scale hydro power plant. Second, the Korea food production base policy generated many dams for irrigation to increase the production of rice.

To support flood management, Japan created a river management rule for river surveying in 1914 and carried out the first river investigation project (1915~1928) for 14 years. First, it unified stream names and conducted river surveys in a modern way in all aspects including water level and flow surveying, weather monitoring, river facilities, irrigation facilities, drought and flood damage surveying, and state art of inland water navigation. A total of 22 rivers (10 in South and 12 in North) were surveyed. Among them, 14 major rivers underwent surveying, and river improvement plans for 11 rivers were implemented.

As a result of the first river survey, the "River in Chosun" and "Chosun River Survey" were published in 1923 and 1929, respectively. The second river survey was conducted from 1928 to 1940. "River in Chosun" and "Annual River Survey" were annually issued from 1928 to 1940.

Three hydropower projects were conducted from 1911 to 1939 (Table 2-1). At this time, the construction of hydropower dams such as Bujun Dam (1929), Su-Pung Dam (1931), Posong Dam (1931), Jangjin Dam (1935), Hwacheon Dam (1939), and Cheongpyong Dam (1939) started. In addition, more than 140 agricultural reservoirs were constructed by 1945.

〈Table 2-1〉 Hydropower Survey during Japanese Colonial Period

Category	Period	Hydro-power dam site	Flow Criteria	Potential Hydropower (kw)	
First	1911~1914	80	Minimum flow except ten days		56,966
Second	1922~1929	150	Six month flow	Total	2,202,539
				Domestic	1,689,233
				Transboundary	513,306
Third	1936~1943	154	Annual average flow or flow for longer period	Total	6,436,600
				Domestic	3,901,500
				Transboundary	2,535,100

Source: History of 40 years of Korea National Committee on Large Dams.

2.2. Restoration Period after Liberation (1945~1950s)

In the first and second republic period after Korea's liberation and the US army military government (before the 1960s), the foundation of Korea's water resource policy was mainly focused on the development of single-purpose dams for irrigation. This involved the development of agricultural water to expand irrigated paddy lands, supply domestic water, and hydro power generation.

In 1946, power generation facilities were destroyed due to outages of 50% of South Korea's electric power by North Korea and war. A five-year power development plan was established after the war, and Goesan Dam (1957) was constructed. Prior to 1960, the need for agricultural water supply for food production emerged, and 158 small- to medium-sized agricultural reservoirs were built nationwide. In particular, the war restoration construction was completed in 1958, and policy direction for the construction of a new land including a water resource sector was prepared (Water Resource Long-term Comprehensive Plan, 2011).

In fact, the economy and technology of the country did not reach the level of the large-scale multi-purpose dams. Rather, it was a period of irrigation-oriented water resource development in the form of agricultural water and hydro power generation until the late 1950s.

2.3. Era of Comprehensive Water Resources Development (1960s)

In 1960, the Korean government established the the first phase of a five year economic plan (1962-1966) as a measure for economic growth. As part of this plan, it started to develop plans for the development of multi-purpose dams in earnest. The basic goal of the Five-Year Plan for the First Economic Development was to build a foundation for achieving a self-sustaining economy. To do so, it presented six major projects: 1) expansion of energy sources such as power and coal; 2) the rise of farm household income by increased agricultural productivity and correction of the structural imbalance of the national economy; 3) expansion of the key industries and fulfillment of social overhead capital; 4) use of idle resources, in particular the increase in employment and conservation and development of the land; 5) improvement of the balance of payments based on increased exports; and 6) promotion of technology.

In recognition of the need for comprehensive water resource development, including the development of agricultural water, development of living and public water, construction of hydroelectric power plants, and construction of multi-purpose dams that simultaneously achieve the flood control and irrigation, the Korean government established the "Ten-Year Plan for Comprehensive Development of Water Resources (1966-1975)" in 1965 (Table 2-2).

A task force team was organized to promptly achieve the long-term vision of water resource development and complete the formulation of policy goals. The Ten-Year Plan for Comprehensive Development of Water Resources was a "long-term development plan" focused on the multi-purpose dam plans for flood control, irrigation, and energy development regarding important water systems in the areas to be developed, in order to cope with the increased demand for water resources essential for economic development. This plan was meaningful, as it helped overcome the vicious cycle of disasters such as floods and droughts caused by seasonal excess or deficiency of water and helped achieve economic development through precious water resources.

The River Act was enacted in December 1961 for efficient use of water resources. The main contents of the River Act are shown in <Table 2-3> below.

〈Table 2-2〉 Ten-Year Plan for Comprehensive Development of Water Resources (1965-1975)

Category		Status (1965)	Goal (1975)
River improvement	Important river	• Total river length: 28,000km • Important river length: 12,800km • Current goal: 5,114km • Length of the existing embankment: 3,668km (71% of the goal) • Farmland protection: 289,550km^2 • Residential area protection: 468,307 houses	• Prevent flooding of important areas including 116,605km^2 of farmland and 303,189 houses
	Special river	• Han River: Downstream in Goan Station, the 47km of coastal area near Seoul as a retarding reservoir • Nakdong River: 52km from Nam river Dam to downstream in Jungam Brid	• Han River: Development and use of separate retarding reservoirs until the construction of the upstream Soyang river dam, Chungju dam and Danyang Dam • Nakdong River: Development and use of separate flooding areas until the construction of upstream Nam River Dam
	Small-scale river	• Small river length: 15,200km • Current goal: 2,993km • Length of the existing embankment: 423km • Farmland protection: 147,805km^2 • Residential area protection: 90,677 houses	• Prevent flooding of important areas including 877,500km^2 of farmland and 387,000 houses
River management, disaster prevention		• Danger reach due to lack of maintenance: 528km • Flood forecasting communication facilities: 15 stations	• Improvement and maintenance of immediate danger reach, strengthened maintenance of river facilities, establishment of flood forecasting system
Flood storage facilities		• Flood damage status	• Reduction of planned flood discharge at reference points

Source: Korea's River Basin Management Policy, 2013.

〈Table 2-3〉 Main Content of the River Act as Enacted in 1961

Category	Main content
River management	• Manager: Head of the National Land Construction (the current Minister of the Ministry of Land, Infrastructure, and Transport; local river is managed by the city and provincial governor of the administrative district) • Determination and change of river zone • Institutional management of items during implementation of various works (development, adjunct construction, auxiliary construction, etc.) related to rivers • Creation and storage of river inventory/documents
River use	• Procedures for the use and occupation of flood plains and permission • Collection of use and occupation fees and limitation of fee collection
Conservation of river and charge in public uses	• Manager: Head of the National Land Construction (the current Minister of the Ministry of Land, Infrastructure, and Transport; local river is managed by the city and provincial governor of the administrative district) • Determination and change of river zone • Institutional management of items during implementation of various works (development, adjunct construction, auxiliary construction, etc.) related to rivers • Creation and storage of river inventory/documents
Costs and revenues for rivers	• The principle of cost burden (divided into state treasury and local autonomous entity according to the governmental authority) • Regulation on various expenses and profits for development and management of rivers • Government subsidies
Management supervision	• Supervision action on violation of statute • Supervision action for public interest (with exception of legal punishment) • Forced collection of allotment
Loss compensation	• Loss compensation through charge in public uses • Loss compensation through supervision actions

Source: Korea's River Management Policy, 2013.

The first long-term comprehensive plan for water resource development in Korea was the Ten-Year Plan for Comprehensive Development of Water Resources (1966-1975), which was drafted in September 1965. It was a macroscopic project based on major regions including three rivers (Han River, Nakdong River, and Geum River) and their watersheds. This plan established a system for research and planning in terms of water resource development and built a system for water balance. Through this plan, the water demand was systematically calculated in the "Large-scale Land Construction Plan" written in 1967. In 1970, the Four Major River Basin, including

Yeongsan River and the three rivers mentioned above, was established (1971~1981). This plan pursued consistent development of the entire water system, such as multi-purpose dam construction, river improvement, expansion of irrigation facilities, and construction of estuary banks. Thus, it devised ways to prevent repetitive droughts and floods, effectively use the land, and stabilize farming by facilitating the supply of water and preventing water pollution along with continuous industrial development (Four Major River Basin Comprehensive Development Plan, 1971). Thus, in the early stages of development, Korea politically prioritized the construction of multi-purpose dams for water supply, flood control, and power generation, rather than dams only for power generation. The first multi-purpose dam in Korea was Seomjin River Dam (completed in 1965), and the next was Namkang Dam (completed in 1971). These two dams were constructed and completed in accordance with the River Act (December 1961), which was specifically enacted for the development of multi-purpose dams. The dam that was first constructed by the Multi-purpose Dam Act was Soyang River Dam (April 1967~ October 1973), followed by Andong Dam (1976) and Daecheong Dam (1981). <Table 2-4> shows a general overview of Korea's multi-purpose dams.

To facilitate the development of water resources, the "Multi-purpose Dams Special Act" was enacted in April 1966 as a law covering special cases of the River Act. In November 1967, the Korea Water Resources Corporation was established as a body dedicated to the development of water resources.

〈Table 2-4〉 Multi-purpose Dam in South Korea

River Basin	Multi-purpose Dam	Basin Area (km^2)	Height (m)	Length (m)	Total Capacity of Reservoir (million m^3)	Active Capacity of Reservoir (million m^3)	Installed Capacity of Power station (MW)	Enterprise Effect		Construction Period
								Flood Control (million m^3)	Water Supply (million m^3/year)	
Han-River	Soyang	2,703	123	530	2,900	1,900	200	500	1,213	''67-''73
	Chungju	6,648	97.5	447	2,750	1,789	412	616	3,380	''78-''86
	Hoengseong	209	48.5	205	86.9	73.4	1.3	9.5	119.5	''90-''02
Nakdong-River	Andong	1,584	83	612	1,248	1,000	91.5	110	926	''71-''77
	Imha	1,361	73	515	595	424	51.06	80	591.6	''84-''93
	Hapcheon	925	96	472	790	560	101.2	80	599	''82-''89
	Namgang	2,285	34	1,126	309.2	299.7	14	269.8	573.3	''87-''03
	Miryang	95.4	89	535	73.6	69.8	1.3	6	73	''90-''02
	Gunwi	87.5	45	390	48.7	40.1	0.5	3.1	38.3	''00-''12
	Gimcheon-Buhang	82.0	64	472	54.3	42.6	0.6	12.3	36.3	''02-''14
	Bohyun Mountain	32.61	58.5	250	22.11	17.88	1.414	3.49	14.87	''10-''14

〈Table 2-4〉 Continued

River Basin	Multi-purpose Dam	Basin Area (km^2)	Height (m)	Length (m)	Total Capacity of Reservoir (million m^3)	Active Capacity of Reservoir (million m^3)	Installed Capacity of Power station (MW)	Enterprise Effect		Construction Period
								Flood Control (million m^3)	Water Supply (million m^3/year)	
Guem-River	Daechung	4,134	72	495	1,490	790	90.8	250	1,649	''75-''81
	Yongdam	930	70	498	815	672	26.2	137	650.43	''90-''06
Seomjin-River	Seimjin-River	763	64	344.2	466	370	34.8	32	350	''61-''65
	Juam	1,010	58	330	457	352	1.44	60	270.1	''84-''92
	Juam Regulation	134.6	99.9	562.6	250	210	22.5	20	218.7	''84-''92
Etc.	Buan	59	50	282	50.3	35.6	0.193	9.3	35.1	''90-''96
	Boryeong	163.6	50	291	116.9	108.7	0.701	10	106.6	''90-''00
	Jangheung	193	53	403	191	171	0.8	8	127.8	''96-''07

Source: https://www.kwater.or.kr/gov3/sub03/annoView.do?seq=1443&cate1=3&s_mid=54

2.4. Renaissance of Water Resources Development (1970~90s)

From the 1970s to the 1980s, large-scale multi-purpose dams were constructed for water supply and flood control, and this was a period of rapid growth of the Korean economy. In particular, during this period, large-scale multi-purpose dams such as Soyangang Dam, Andong Dam, Chungju Dam, Hapcheon Dam, and Juam Dam were constructed. Thus, it was a period of revival in terms of dam development.

The establishment of a comprehensive water resource development plan ('81-'01) in 1980 promoted the construction of Chungju Dam, Imha Dam, Hapcheon Dam, Juam Dam, and Namgang Dam, as well as that of the metropolitan area and other regional waterworks. Estuary dams were also completed in Nakdong River, Yongsan River and Geum River.

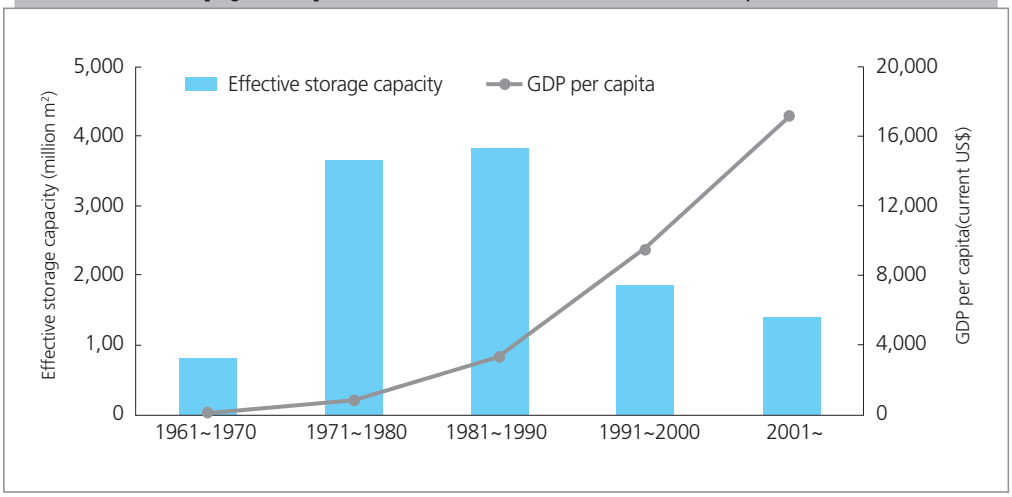
In this period, economic development increased water usage from 3.1 billion in 1960 to 15.3 billion in the 1980s, and 249 agricultural reservoirs were built to supply stable agricultural water. In addition, the need for water quality management for water resource management was magnified, and the Environmental Office was established in the Ministry of Health and Social Security in the early 1980s to start water quality management for public water bodies. Before the Asian Games in 1986 and the Olympics in 1988, the Han River Development Project ('81-'96) was launched to create the city's water-friendly environment. This led to river maintenance, which emphasized water-friendly functions (Water Resource Long-term Comprehensive

Plan, 2011).

[Figure 2-2] shows the relationship between economic growth based on the national income of Korea and the reservoir capacity of the dam. It shows that many dams were developed in the 1970s and 1980s when the national income was less than $4,000. In the period when Korea advanced from a least developed country to a developing country, it established industrialization for economic growth and infrastructure for national welfare through the development of dams that could support economic growth through water supply, flood and drought control, and power generation, thus providing the basis for high economic growth during the 1990s.

These cases show that in the early stages of a country's industrial development, investment in water resources development—including dam construction—can serve as a driving force for industrialization, agricultural growth, urban development, and infrastructure projects through the stable provision of industrial water, which can then become a foundation for smooth economic growth.

[Figure 2-2] Korea's Economic Growth and Dam Development



Source: Author.

In the mid-1980s, water resource development policies were not applied to many communities located in small and medium-sized areas, as they focused on constructing large-scale multi-purpose dams in the mainstream of large rivers.

In 1990, there were policy changes towards the development of medium-scale multi-purpose dams in consideration of the distribution to the areas that were

alienated from the benefits of irrigation, flood control, environmental conservation, and water resource development. The Korean government planned the construction of medium-scale multi-purpose dams with a basin area of 50~500km^2 and a total reservoir capacity of 2~100 million m^3. It conducted a preliminary feasibility study for 15 candidate areas for medium-scale multi-purpose dam development from December 1985 to September 1986.

The dams built in the 1990s are Buan Dam, Milyang Dam, Hoengseong Dam, and Yongdam Dam. These dams are medium-scale multi-purpose dams with a total reservoir capacity of about 74 million m^3 to 230 million m^3.

Major multi-purpose dams located in Korea's major rivers, Han River, Nakdong River, Geum River, and Seomjin River (Soyangang Dam, Chungju Dam, Andong Dam, Deacheong Dam, and Juam Dam), are summarized as follows.

2.4.1. Soyangang Multi-purpose Dam (Han River: Bukhan River / North Han River)

Soyangang Dam is the largest multi-purpose dam in Korea in terms of reservoir capacity, and it was completed in 1973 with a height of 123m and a length of 530m. The dam's power generation capacity is 200,000kW, and its total reservoir capacity is 2.9 billion m^3. The actual investigation of the construction of the Soyangang Dam began in the 1950s.

In 1960, social conditions changed drastically, thereby increasing the need for development. The validity of the development was increased due to the industrial modernization and rapid increase of water demand in the downstream regions of the Han River, including Seoul. According to the government's policy, a five-year economic development plan and a comprehensive land development plan were established. In addition, a comprehensive development plan for the four major rivers including the Han River was established.

In 1966, a joint investigation team for the Han River basin was organized to change from the development of single-purpose dams for power generation to the development of multi-purpose dams for the additional purposes of irrigation and flood control. After various investigations for the comprehensive development of water resources in the Han River basin, a comprehensive development plan for river basins including the construction plan of the Soyangang Dam was established in 1968. As part of the Five-Year Plan for the Second Economic Development, the preparatory construction commenced in April 1967, and the construction of the dam was completed in December 1973.

The Soyangang Dam supplies 1.2 billion m^3 per year to the metropolitan areas located downstream of the Han River, including Seoul. It also supplies 32 million m^3 of irrigation water to Gyeong-gi Province and 255 million m^3 of instream flow to the downstream areas of the Han River. In particular, flood control of 500 million m^3 greatly contributes to the flood control in the downstream areas of the Han River. It also copes with drought by ensuring uniform sulfur throughout the year.

In addition, in terms of hydro power of the Soyangang Dam, it has 200,000kW of facility capacity and 353GWh of annual power generation. The hydro power plants in the downstream areas, such as Euiam Dam, Cheongpyeong Dam, and Paldang Dam can annually increase 61GWh of power generation, which is equivalent to the effect of constructing a new power plant of 34,000kW. The total annual power generation of Soyangang Dam is 414GWh. The firm peak power is 159,500kW.

[Figure 2-3] Soyangang Multi-purpose Dam



Source: http://www.kncold.or.kr/

〈Table 2-5〉 Soyangang Multi-purpose Dam

Category	
River	Han River, Soyang River in the North Han River tributary
Basin Area	2,703km^2
Total Project Cost	321 hundred million KRW
Annual Average Rainfall	1,153mm
Annual Average Inflow	2,148 million m^3
Construction Period	1967. 4 ~ 1973. 12
Dam	
Type	Zone Fill Dam
Length	530m
Volume	9,600,000m^3
Height	EL 203.00m
Spillway	
Plan Discharge	5,500m^3/sec
Spillway Gate	5 Gates (13m×13m)
Power Plant	
Location	Vertical Down of the right bank of a dam
Type	Ground Power Plant (Indoor Type)
Water Turbine Generator	Francis
Installed Capacity of Power Station	200 million W
Rated Head	90m
Plant Discharge	251m^3/sec
Reservoir	
Design Flood Stage	EL 198.00m
Normal Pool Level	EL 193.50m
Restricted Water Level a Flood	EL 190.30m
Reservoir	EL 150.00m
Total Reservoir Capacity	2,900 million m^3
Effective Storage Capacity	1,900 million m^3
Reservoir Area	70.0km^2
Flood Control Capacity	500 million m^3

Source: http://www.kncold.or.kr/

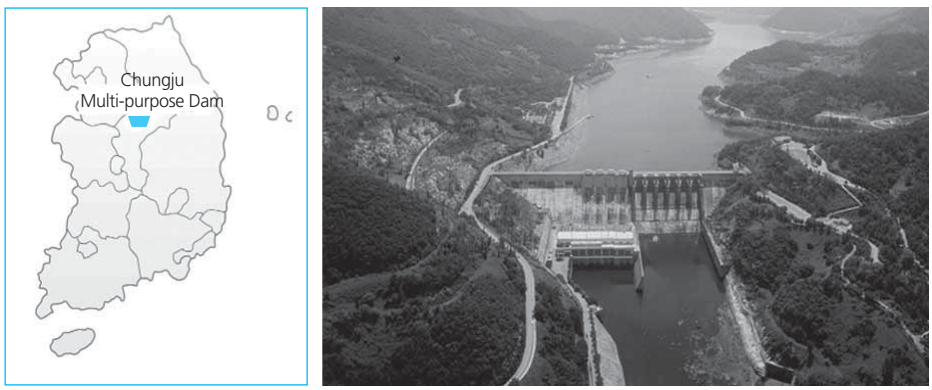
2.4.2. Chungju Multi-purpose Dam (Han River: Namhan River/South Han River)

The construction of the Chungju Multi-purpose Dam was implemented as part of the comprehensive development plan for the four major rivers. It aimed to generate power and control flood while supplying irrigation, living, and industrial water to the downstream areas of the dam (including the metropolitan areas) through the advanced development of water resources in the Han River water system.

Chungju Multi-purpose Dam is Korea's largest concrete gravity dam built on the Namhan River. It was constructed to efficiently develop the water resources of the Namhan River basin, supply various kinds of water to the downstream areas, generate hydro power energy to cope with peak power demand, and reduce flood damage in the downstream areas. It has a height of 97.5m, a length of 447m, a concrete volume of 902,000m^3, and a reservoir capacity of 2.75 billion m^3. It has a basin area of 6,648km^2 and has a balancing reservoir dam with a height of 21m, a length of 480.7m, and 20 gates at the 19.6km position downstream of the dam. Chungju Dam is the largest hydro power in Korea with a capacity of 412,000kW combined with the capacity of the first power plant and the second power plant. It also has the largest flood control capacity in Korea at 616 million m^3.

Chungju Dam supplies 3.38 billion m^3 of water per year, in particular, it includes 315 million m^3 of agricultural water and 334 million m^3 of instream flow. The hydro power of Chungju Dam has 412,000kW of facility capacity and 844Gwh of annual power generation. It contributes to the saving of foreign currency by producing a

[Figure 2-4] Chungju Multi-purpose Dam



Source: http://www.kncold.or.kr/

substitution effect of 13,000 BL/year of oil. It also contributes greatly to the power supply of Korea by being responsible for peak development.

〈Table 2-6〉 Chungju Multi-purpose Dam

Category	
River	Namhan River
Basin Area	6,648km^2
Total Project Cost	5,551 hundred million KRW
Annual Average Rainfall	1,113mm
Annual Average Inflow	4,872 million m^3
Dam	
Type	Concrete Gravity
Length	447m
Height	97.5m
Volume	902 thousand m^3
Spillway	
Plan Discharge	16,200m^3/sec
Spillway Gate	6 Gates (15.5m×17.9m)
Power Plant	
Location	Vertical Down of the right bank of a dam
Type	Semi-basement
Water Turbine Generator	Francis
Installed Capacity of Power Station	400 thousand kW
Rated Head	57.5m
Discharge Water Level	EL 71.30m
Plant Discharge	217.5m^3/sec
Annual Energy Production	844 million kW
Reservoir	
Design Flood Stage	EL 145.00m
Normal Pool Level	EL 141.00m
Restricted Water Level a Flood	EL 138.00m
Reservoir	EL 110.00m
Total Reservoir Capacity	2,750 million m^3
Effective Storage Capacity	1,789 million m^3
Reservoir Area	97.0 km^2
Flood Control Capacity	616 million m^3
Amount of Water Supply	3,380 million m^3

Source: http://www.kncold.or.kr/

2.4.3. Andong Multi-purpose Dam (Nakdong River)

Andong Multi-purpose Dam was constructed as part of the comprehensive water development project of the Nakdong River basin. It is a rockfill dam with a central shielding membrane with a height of 83m, a length of 612m, a dam volume of 4,014,000m^3, and reservoir capacity of 1.25 billion m^3. Andong Dam has a power plant available for pumping power generation with a facility capacity of 90,000kw for the first time in Korea. This dam is located at the main river, about 340 km upstream of the Nakdong River estuary. A floodgate-type re-regulating reservoir with a height of 20m and a length of 218m is located 3 km downstream from the dam.

Andong Multi-purpose Dam was first reviewed in 1961, and the direction of water resource development was only for hydro power at the time. Therefore, the scale of the project was reviewed as a dam dedicated to hydro power generation.

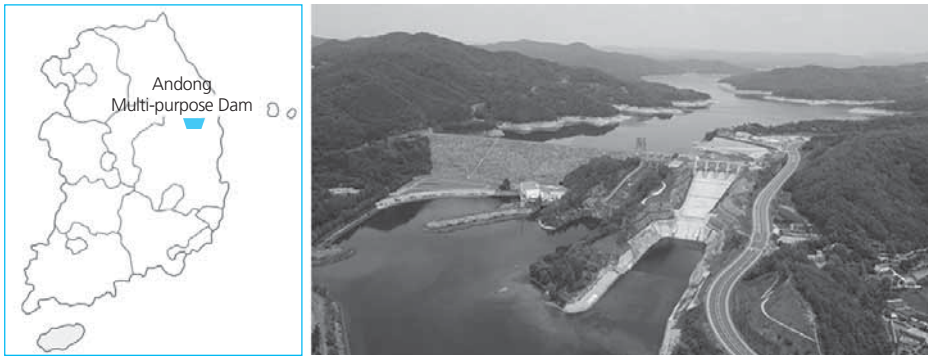
However, since the comprehensive development of land and water resources was required, according to the rapidly growing social and economic conditions, the basic survey of Andong Multi-purpose Dam was conducted in 1966 along with the basic survey of the Nakdong River basin. In addition, to meet the water shortage due to the rapid increase in water demand, Andong Multi-purpose Dam construction was determined through various surveys across various fields. The Andong Multi-purpose Dam construction project commenced on April 1, 1971 and was completed on October 28, 1976, with a domestic capital of 32,659,000 KRW and a foreign capital of US $17,150,000 as a loan business.

The annual water supply of Andong Multi-purpose Dam is 926 million m^3, of which 450 million m^3 is used as living and industrial water. This dam plays a major role as a source of living and industrial water supply for major industrial cities such as Busan, Pohang, Ulsan in the southern part of the East Sea, and Changwon, Masan, and Jinhae in the eastern part of the South Sea. It stably supplies 300 million m^3 of irrigation water and 176 million m^3 of river maintenance water to the area of about 44,000ha in the downstream of the dam.

In addition, it generates 158 million kW of electricity a year including the amount of pumping-up power generation, thus playing a role in eliminating power shortages in peak load. It was the first domestic power plant available for pumping power generation, which launched generation on October 1, 1976, and has a facility capacity of 90,000kw (45,000kw×2). The annual electric power of 158 million kWh is mainly supplied to the Yeongnam region and contributes greatly to the industrial development and the stability of the power system in the region.

The flood damage amount of the Nakdong River basin prior to the construction of Andong Multi-purpose Dam was about 6,307 million KRW (as of June 1975) per year from 1916 to 1971, and the damage of agricultural products accounted for 46.4%. The Andong multi-purpose dam protects the property and life of the Nakdong River basin by controlling the amount of flood equivalent to 110,000,000 m^3/year in the downstream area of the dam.

[Figure 2-5] Andong Multi-purpose Dam



Source: http://www.kncold.or.kr/

〈Table 2-7〉 Andong Multi-purpose Dam

Category	
River	Nakdong River, Seom River
Basin Area	209km^2
Total Project Cost	404 hundred million KRW
Annual Average Rainfall	1,469mm
Construction Period	1990 ~ 2000
Dam	
Type	Rockfill Dam
Length	612m
Height	EL 83.0m
Volume	4,014 thousand m^3
Spillway	
Plan Discharge	4,500m^3/sec
Spillway Gate	4 Gates (14m×9.7m)

〈Table 2-7〉 Continued

Power Plant	
Location	Vertical Down of the right bank of a dam
Type	Pumped-storage hydroelectricity
Water Turbine Generator	DERIAZ
Installed Capacity of Power Station	45 thousand kw × 2
Rated Head	57m
Reservoir	
Design Flood Stage	EL 162.50m
Normal Pool Level	EL 160.00m
Restricted Water Level a Flood	-
Total Reservoir Capacity	1,248 million m^3
Effective Storage Capacity	1,000 million m^3
Reservoir Area	51.5km^2
Flood Control Capacity	110 million m^3

Source: http://www.kncold.or.kr/

2.4.4. Daecheong Dam (Geum River)

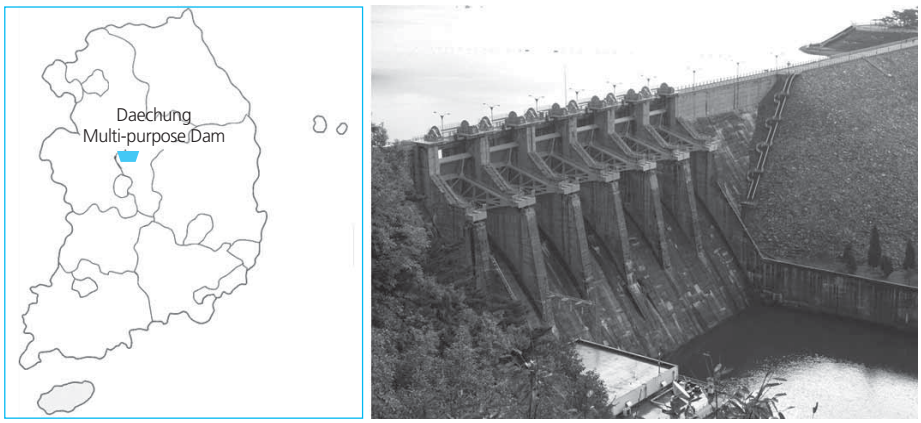
Daecheong Multi-purpose Dam is a complex type rockfill dam consisting of a gravity type concrete dam with a height of 72m, a length of 495m, and a dam volume of 1.234 million m^3. It is located 150 km upstream from the Geum River estuary. The major facilities of Daecheong Dam include the main dam with a reservoir capacity of 1.49 billion m^3 and a regulation dam. There are three auxiliary dams around the main dam to prevent the water in the reservoir from overflowing to other areas. There are also conduits for water supply to Daejeon and Cheongju and a hydropower plant with a facility capacity of 90,000kw. The construction of the dam was commenced in March 1975 and completed in June 1981. The completion of the dam resulted in the reduction of flood damage in the downstream area of the dam and in the saltwater damage in the farmland. The dam also supplies the living and industrial water to rapidly growing neighboring cities in the basin.

The annual water supply of the Daechong Multi-purpose Dam is 1.649 billion m^3, of which 1.3 billion m^3 is used as the living and industrial water. This dam plays a major role as a source of living and industrial water supply for Chungcheong areas, including Daejeon and Cheongju, and Jeonbuk areas, including Jeonju, Gunsan and Iksan. It stably supplies 349 million m^3 of irrigation water to Chungju, downstream of the Geum River and Mankyeong River district.

Due to the intensive rainfall in the summer from July to September, the Geum River basin repeatedly flooded every year, causing damage to people and property and resulting in enormous obstacles to economic activities. However, Daecheong Multi-purpose Dam trapped 250 million m^3 of flood waters, thereby greatly reducing the damage.

The hydroelectric power of Daecheong Multi-purpose Dam has a facility capacity of 90,000kW and annual power generation of 240GWh.

[Figure 2-6] Daechung Multi-purpose Dam



Source: http://www.kncold.or.kr/

〈Table 2-8〉 Daechung Multi-purpose Dam

Category	
River	Geum River
Basin Area	4,134km^2
Total Project Cost	1,557 hundred million KRW
Annual Average Rainfall	1,174mm
Annual Average Inflow	2,722 million m^3
Construction Period	1975. 3 ~ 1981
Dam	
Type	Combination Embankment and Concrete Gravity
Length	495m
Height	72m
Volume	1,230 thousand m^3

〈Table 2-8〉 Continued

Spillway	
Plan Discharge	6,000m^3/sec
Spillway Gate	6 Gates (13m×15.9m)
Power Plant	
Location	Semi-basement
Type	Francis
Installed Capacity of Power Station	90 thousand kW
Rated Head	38.7m
Annual Energy Production	240 ~ 196GWh
Reservoir	
Design Flood Stage	EL 80.00m
Normal Pool Level	EL 76.50m
Restricted Water Level a Flood	EL 72.00 ~76.50m
Reservoir	EL 60.00m
Total Reservoir Capacity	1,490 million m^3
Effective Storage Capacity	90 million m^3
Reservoir Area	72.8km^2

Source: http://www.kncold.or.kr/

2.4.5. Juam Dam (Seomjin River)

Juam Multi-purpose Dam was constructed to solve the shortage of water in the Honam region including Gwangju City, Yeosu, Suncheon, and Gwangyang. It is composed of two dams: the main dam and a regulating dam.

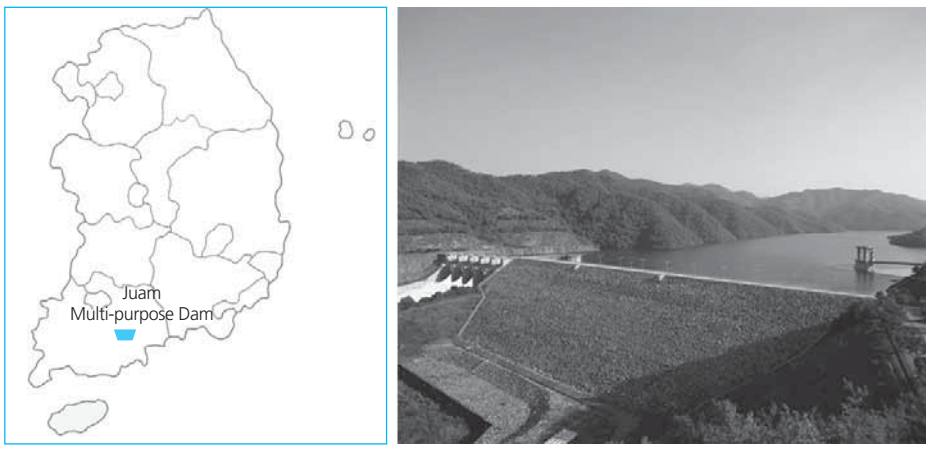
Juam Multi-purpose Dam consists of a main dam constructed in the Bosung River, which is the Seomjin River tributary, a regulating dam in the Isacheon River basin, a power generation facility and re-regulating reservoir constructed downstream of the regulating dam, and a water conveyance tunnel connecting both the main dam and regulating dam.

In particular, the dam adopted the "diversion to other basin" method. It supplies the abundant water of the Boseong River basin not only to Gwangju City, but also to the southern coastal area by drilling the water conveyance tunnel and connecting Boseong River to both water systems in the Isacheon. Thus, it is evaluated as an epoch-making water resource development project that maximizes the use of water resources.

The main dam was constructed as a rockfill dam with a central shielding membrane with a height of 57m, a length of 330.0m, and a volume of 1,573,375m^3 at the middle of the Bosung River, which is 25 km upstream from the confluence point with the main stream of the Seomjin River. The total reservoir capacity of the dam is 457 million m^3, and the basin area is 1,010km^2. It accounts for about 77.5% of the total basin area of the Boseong River. And a total 370,633 million KRW was invested in the project, including domestic and foreign capital.

The main dam stably supplied 640,000m^3 of water per day to Gwangju City and Mokpo City. The regulating dam supplied 640,000m^3 of daily, industrial, and irrigation water per day to Suncheon City, Yeosu City, Gwangyang, and Yeochun Industrial Complex. Thus, it satisfied the water demand of the region until 2010 and contributed greatly to national life and community development. As a result, the frequent flood damage was resolved in the downstream area of the Boseong River.

[Figure 2-7] Juam Multi-purpose Dam



Source: http://www.kncold.or.kr/

〈Table 2-9〉 Juam Multi-purpose Dam

Category	
River	Boseong-river (a branch of Seomjingang River)
Basin Area	1,010km^2
Total Project Cost	3,628 hundred million KRW (Include regulation dam)
Annual Average Rainfall	1,530mm
Annual Average Inflow	789 million m^3
Construction Period	1984. 9 ~ 1992. 12
Dam	
Type	Rockfill Dam
Length	330m
Height	58m
Volume	1,570 thousand m^3
Spillway	
Plan Discharge	4,145 m^3/sec
Spillway Gate	5 Gates (13m×12.5m)
Reservoir	
Design Flood Stage	EL 110.50m
Normal Pool Level	EL 108.50m
Restricted Water Level a Flood	-
Reservoir	EL 85.00m
Total Reservoir Capacity	457 million m^3
Effective Storage Capacity	352 million m^3
Reservoir Area	33.0km^2

Source: http://www.kncold.or.kr/

The water resource development projects, such as the construction of multi-purpose dams in the 1970s and 1980s, were mainly aimed to secure water for economic growth, power generation, and flood management. The Ten-Year Plan for Comprehensive Development of Water Resources (1965-1975) provided the basis for the development and management of water resources to promote economic growth through industrialization. Since then, the government's continuous commitment to and investment in water resources development have helped prevent the impact of natural disasters, such as floods and droughts, and supported economic growth by expanding the water supply to industries, agriculture, power generation, cities, and rural areas.

2.5. Paradigm Shift in Water Management Policy

Out of the total precipitation volume of 129.7 billion m^3 in South Korea, 54.4 billion m^3, which is the 42% of the total is lost due to evapotranspiration and underground penetration. Only 73.53 billion m^3, 58% of the total, is available to flow into rivers. And the 56 billion m^3, 43% of the total, is focused in the monsoon season, June to September. Only 19.3 billion m^3 of water are available for use if such precipitation cannot be stored in dams. Korea's total water use is estimated to be about 33.3 billion m^3, about 26% of the total precipitation water volume, among which 10.8 billion m^3 is provided from rivers; 18.8 billion m^3 from dams; and 3.7 billion m^3 from underground sources.

Dam construction since the 1960s has secured 558 million m^3 of flood control capacity and contributed to stable water supply and water quality improvement. At present, the country has 16 multi-purpose dams, five estuary dams, 14 water supply dams, 12 power generation dams, two flood management dams, and 29 regional or industrial water supply networks. In particular, the multi-purpose dams have the capacity to supply 18.8 billion m^3 of water, which accounts for 56.5% of the total water use of 33.3 billion m^3.

Since the 1990s, facing the opposition of environmental groups to dam construction, the policy has shifted to small and medium sized dams, taking into consideration river conditions. Although the basic purposes of the water management policy in the initial stage that focused on dam construction and river investigation included agricultural water supply, hydropower generation, and flood management, the Korean government began paying attention to environmental aspects, including water pollution, from the 1980s. River contamination caused by the pollutants discharged from industrial complexes and campaigns/activities of civil and environmental groups for water quality have raised public awareness regarding the environment. The main causes of water pollution are diverse detergents, livestock wastewater, and pesticides. In this regard, the government separated rainwater and sewage, which has led to a certain level of water quality improvement, although it is not satisfactory yet. Since the 1990s, as the national income and the public interest in the natural and residential environment have increased, water management policy has also changed.

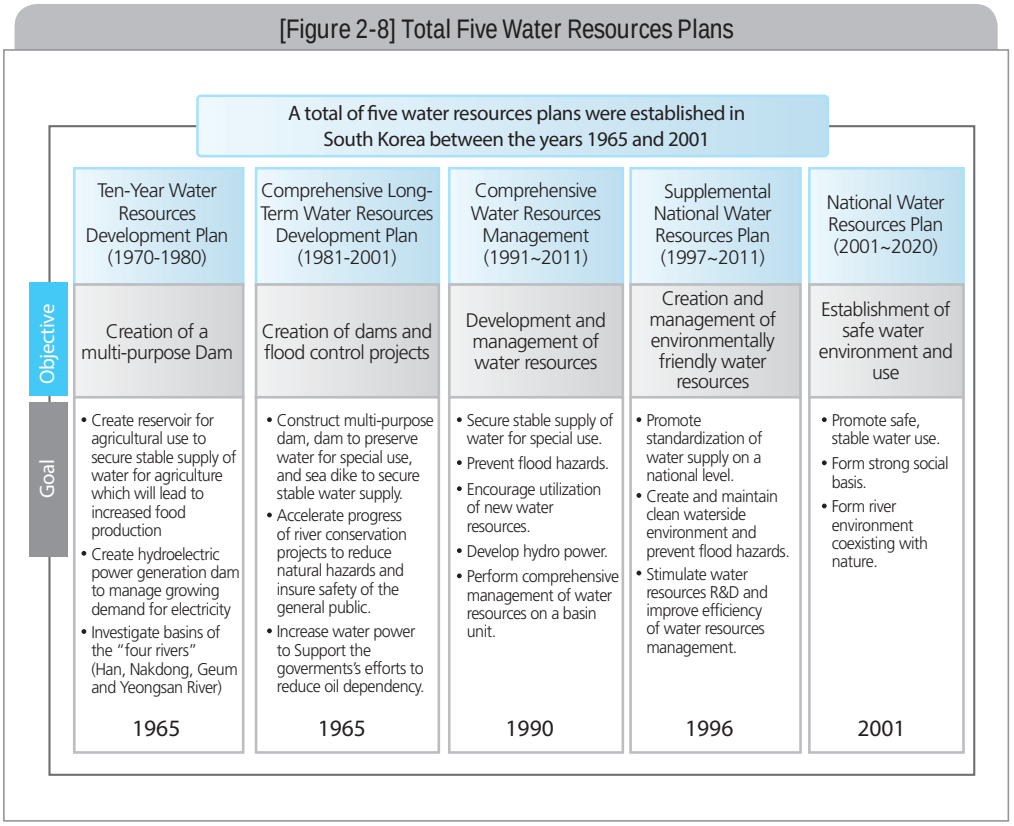
In particular, the continuous economic growth in the 1990s increased the people's desire to have a higher quality of life and the demand for leisure activities in and along rivers. The water management policy is more focused on water quality improvement and water pollutant management. The Comprehensive Water Resources Management Plan for 1991-2011 was aimed at the construction of small- and medium-sized dams and the environmentally friendly development and

management of rivers.

In addition, there was a controversy about the planned Yeongwol Dam in the upper part of the Namhan River regarding the conservation of the river ecosystem, local cultural heritage, and landscape. As a result, the dam construction plan was cancelled.

[Figure 2-8] shows the policy changes in water resources development and management in chronological order.

[Figure 2-8] Total Five Water Resources Plans



Source: Ministry of Construction and Transportation (2006).

Since the late 1990s, the northern Gyeonggi Province has been experiencing huge floods due to abnormal climate. In 2002, typhoon Maemi caused heavy rainfall exceeding 880 mm/day in Gangwon Province. After that, the government has come up with various measures to tackle climate change and has evaluated the safety of existing dams because they were constructed based on flood control capacity, which was estimated at the time of their design. However, climate change has increased the possible occurrence of floods greater than the designed capacity.

One example of the climate change countermeasures is a supplementary spillway added to the Soyangang Multi-purpose Dam, increasing its flood control capacity from 7,500m^3 to 14,200 m^3.

As described above, projects to strengthen the flood control capacity of the existing hydraulic structures have been underway in response to the recent climate changes.

3. Mekong Water-Energy Security Nexus: Opportunities and Challenges

3.1. Mekong River Basin

The Mekong River, with annual flow of 475km^3, the length of 4,900km and total catchment area of 795,000km^2, ranges from the 8th, 12th and 21th largest river basin in the world in term of water flow, catchment area, and length respectively. The Mekong River originates in the Tibetan Plateau in China and flows through land of six countries, namely China, Myanmar, Lao PDR, Thailand, Cambodia, and Vietnam before emptying into the East Sea.[3)] Lancang River is the name of the Mekong River flowing in China (Yunnan province) and Myanmar. From the point of border between China, Myanmar, and Laos to the Mekong delta and East Sea, the river is named Mekong. In this paper, the Lancang–Mekong River will be called the Mekong River basin or Mekong River. The Mekong River plays a very important role in the social-economic life of its riparian countries in general and in the water-food-security nexus in particular.

Geographically, the Mekong River basin is divided into two parts: the Upper Basin and the Lower Basin. The words Upper and Lower are capitalized to implicate specific geographical areas in the basin. The Upper part of the Mekong river basin (UMB), including the basin area located in mainland China (Yunnan province) and on Myanmar territories, has an area of 165,000km^2 (21% of the entire basin catchment area: China 18% and Myanmar 3%); the Lower Mekong basin (LMB) includes part of the area located in Laos, Thailand, Cambodia, and Vietnam, and has an area of 606,000km^2 (79% of the entire basin catchment area: Lao 25%, Thailand 23%, Cambodia 20% and Vietnam 8%). The catchment area of each riparian country and countries' contribution to the flow of the Mekong River are shown in <Table 2-10> below.

3) MRC.

〈Table 2-10〉 The Mekong River Basin and Six Riparian Countries

Riparian Country	Area in the Mekong basin		Contribution of annual flow of country to Mekong river	
	Area in basin (km^2)	% of basin	Annual flow (km^3)	% of contribution
China (Yunan)	165,000	21	76.00	16
Myanmar	24,000	3	9.50	2
Laos	202,000	25	166.25	35
Thailand	184,000	23	85.50	18
Cambodia	155,000	20	85.50	18
Vietnam	65,000	8	52.25	11
Total	795,000	100	475.00	100

Source: SAO (2011). Mekong Basin (http://www.fao.org/nr/water/aquastat/basins/mekong/index.stm).

The Mekong River is home to over 70 million people, and it is predicted that the population in the basin will be over 100 million by 2025, with over 100 different ethnic groups in six countries, making it one of the most diverse cultural regions in the world. In addition to abundant water resources, the Mekong River basin is considered as an area of biodiversity levels higher than that of many other regions of the world. The Mekong River basin produces and exports the biggest quantity of rice in the world to feed 300 million people in and outside of the basin, and it is one of the rivers with the largest production of fresh fish in the world. In the basin there are more than 1,300 fish species, and the water flow regime of seasonal fluctuations provides the environmental conditions and food for aquatics in the basin. Located in a particular geographic region, the Mekong River crosses countries that have rich cultures and long histories of coexisting and co-development.

Historically, before 1975, countries in the basin had experienced a great deal of political upheaval and fierce wars. However, after the Indochina War's end in 1975, with the peaceful and stable political condition in the region, the riparian countries, especially in the Lower Mekong basin have embarked on economic reconstruction. The region's socio-economic development has made tremendous progress.

The population is growing rapidly, and the economy is booming in the Mekong countries, with the expansion of agricultural land, especially for paddy fields in flat and delta areas in Thailand, Laos, Cambodia and Vietnam, and aquaculture that creates great pressure on the water resources of Mekong River, especially in the dry season. Together with high pressure on water resources, hydropower development in the Mekong River basin has escalated to the point where the Mekong is considered as one of the most active hydropower development in the world that challenges to

change the water flow pattern of the river and consequence the natural ecological conditions of the basin.

Although there are a number of cooperative mechanisms in the Mekong basin, such as the Mekong River Commission (MRC, 1995), the Lancang Mekong Cooperation Mechanism (LMCM, 2015), riparian countries in the Mekong River Basin still have many differences and lack of consensus in the cooperation in water resources uses in the river basin for sustainable development. Taking advantage of geography and natural conditions, each country has its own plans to promote the exploitation of water resources for its own interests, but they are less interested in seeking the agreement of the affected countries by the development. Examples illustrating this will be presented in the later analysis of this article.

It is obvious that, because of dependency on the shared river basin of riparian countries for their socio-economic developments in general especially for food and energy in particular, the Water-Energy-Food security nexus in the Mekong River basin are under significant challenges for sustainable development, not just for today, but also for the future.

3.2. State of the Water-Energy Security Nexus in Mekong River Basin

The Water-Energy Nexus describes the complex and inter-related nature of our global resources systems. It is about balancing different resource user goals and interests, while maintaining the integrity of ecosystems. In a transboundary setting, the inter-sectoral implications propagating across borders reach another level of complexity, as the trade-offs and externalities may cause friction between the riparian countries and different interests (FAO, 2014).

The countries in the Mekong Basin, especially the LMB's countries (Laos, Thailand, Cambodia and Vietnam), are heavily dependent on the common and shared water resources of the Mekong River for their socio-economic development in general, for ensuring water and food security, and for improving the energy supply in particular. With geographical advantages, natural conditions, and resources, each country has its own policy concerns and uses its resources for socio-economic development. Even in the Mekong River Basin there are already mechanisms for cross-border water resource development and management. However, as each country pursues its own strategy of exploiting its own Mekong River resources for its own benefit, and due to the lack of attention to transboundary impacts and no common voice, the Water-Energy security nexus in the Mekong region has been facing major challenges.

The state of the Water-Energy security nexus on the Mekong River basin is

analyzed on a country-by-region basis and the relation of each country across in the entire Mekong River Basin.

3.2.1. Water-Energy Security in Upper Mekong Basin Countries: China and Myanmar

Korea does not have any oil reserves, so that supply of oil in Korea depends entirely on Yunnan is located in the far southwest of the country. It spans approximately 394,000km^2 and has a population of 45.7 million (2009). The GDP of Yunnan is US $202.442 billion and GDP per Capita is US $4.430.

The Mekong River in China (Yunnan province) is called Lancang. Exploitation of water resources of Lancang for hydropower is the most important development activity of China on the Mekong basin.

The Lancang River in China lies in the territory of Yunnan province and flows in relatively narrow valleys and steep slopes. There are no big riverine plains for agricultural purposes. However, the abundant water resources with the steep slope of river terrain create a large source of hydropower potential for the China. The hydropower potential of the Lancang River in China is about 23,000MW compared with 30,300MW on the Lower Mekong Basin (Laos, Thailand, Cambodia, and Vietnam).

China plans to build 15 hydropower dams on the Lancang River from now to the year 2030 (of which 8 in 2020; 15 in 2030). Most of them are high dams with high installed capacities and big storage capacity reservoirs.

In fact, since 1992 up to now, China has built and put into operation eight hydropower dams, including extremely large plants with installed capacity of 1,000 to 5,850MW, and the total storage capacity of reservoirs is up to nearly 44 billion m^3, which is half of annual flow of 100 billion m^3 of the Lancang River. So far, China has completed 8 of 8 projects planned for year 2020, namely Manwan (1992), Dachaoshan (2003), Jinghong (2009), Xiaowan (2010), Gongguoqiao (2012), Nuozadu (2014), Miaowei (2016), and Huangdeng (2017). Total capacity of the plants has been built up to 18,090MW, with a storage capacity of about 44 billion m^3. The main figures of hydropower dams on Lancang River are shown in the <Table 2-11>.

2016 witnessed China's long strides in efforts to increase its influence in the Greater Mekong Sub-Region (GMS), as it launched the initiative of establishment of the Lancang - Mekong Cooperation Mechanism (LMC). Mainly supported by China, the LMC is seen as a forum for Beijing to promote economic cooperation and expand infrastructure with other countries in the region.

China's exploration of hydropower with mega reservoirs upstream of the Mekong for its own needs, without reference to downstream countries, has raised concerns among the communities. The mega hydropower dams have great impacts on the downstream natural flow patterns affecting water resources for humans, agriculture (food security), and the environment. In addition, one of the concerns of downstream communities in the Lancang River dams is the occurrence of dam breaks, which would be a disaster to the downstream areas. China has been taking advantage of the water control on the Lancang River to create the influence to the LMB countries for their benefits.

〈Table 2-11〉 Hydropower Projects on Mainstream of Lancang River in China

No.	Project	Purposes	Reservoir Gross volume ($106m^3$)	Effective volume ($106m^3$)	Installed capacity (MW)	Energy (GMW-year)	Completion
1	Mengsong	P (Power)		0	600	3.740	
2	Ganlanba	P			150	1.010	
3	Jinghong	P	1,230	230	1,500	7,606	2009
4	Nuozhadu	P	22,700	12,400	5,500	23,700	2014
5	SichiaGang	P	550	140	1,100	5,730	
6	Dachaoshan	P	890	240	1,350	5,931	2003
7	Manwan	P	920	258	1,250/1,500	7,870	1992
8	Xiaowan	P	15,130	9,800	3,600/4,200	19,170	2010
9	Gongguoqiao	P		120	750	4,711	2012
10	TieMenKan	P	2,150	960	1,780	8,270	
11	HyangDeng	P	2,290	1,110	1,860	8,500	2017
12	Tuoba	P	5,150	3,400	1,640	7,630	
13	Wulong Long	P	980	340	800	4,890	2018
14	JiaBi	P	320	90	430	2,650	
15	Liutan Jiang	P	500	170	550	3,360	
	Total		52,810	29,258	22,860-23,710	114,768	

Source: MRC (2017): The Council Study: The Study on the Sustainable Management and Development of the Mekong River Basin, including Impacts of Mainstream Hydropower Projects. Thematic Report on the Positive and Negative Impacts of Hydropower Development on the Social, Environmental, and Economic Conditions of the Lower Mekong River Basin. Page 85. (http://www.mrcmekong.org/assets/Publications/Council-Study/Council-study-Reports-Thematic/Impacts-of-Hydropower-Development-29-December-2017.pdf).

The historic drought and salinity intrusion event of 2016 is a testament to China's role in "water bottlenecks" and its ability to control the Mekong. During the dry season of 2015-2016, most of Lower Laos, Northeast Thailand, Cambodia, and the Mekong Delta of Vietnam were heavily impacted by extreme dry weather. Vietnam, via diplomatic missions, sent a request to China to discharge its support. China's release of the Jinghong Dam for one month to increase the downstream water flow on one side helped polish the diplomatic image of the country, but, on the other hand, signaled long-term dependence of downstream countries on roles in regulating China's Mekong waters.

At the same time, concerns about the other cumulative and transboundary impacts of existing and proposed hydropower schemes on the environment, fisheries, and people's livelihoods in the Lower Mekong Basin were brought to the forefront by Mekong River Commission Member Countries and a wide range of stakeholders. The status of hydropower projects constructed or planned in Lancang River is presented in <Table 2-11>.

China not only constructed the hydropower on the Lancang mainstream in its territory, but also signed with Laos three Memorandum to invest in the form of BOT (Build - Operate and Transfer), three hydropower projects on the mainstream Mekong in Laos (Pak Lay, Pak Bang and Sanakham), and possible structures in Cambodia (Sambor). The construction and control of an important part of water resources of the Mekong River mainstream will inevitably lead to conflicts.

Economically, China is a country with great potential compared with other riparian countries on the Mekong basin. However, concerning the use of international watercourses, China detached itself from the constraints of international laws. China has been implementing plans to fully exploit the hydropower resources of the Mekong River on its territory without any consultation with other downstream countries.

Recently, China is increasingly recognizing the mutual benefits of adopting a more open approach to the trans-boundary management of water resources in the basin and today's meeting, as well as the joint efforts that have continued throughout the year, are examples of an increasingly strong cooperation that will lead to a better understanding and awareness of both the risks and opportunities associated with upstream developments on downstream countries[4]. China and Myanmar are "Dialogue Partners" of MRC and join with MRC's Council meeting that is organized annually.

4) MRC (2010), http://www.mrcmekong.org/news-and-events/news/increased-cooperation-with-china-and-myanmar/

The water resources of the Mekong River basin are not of high priority to Myanmar for food and energy. Myanmar occupies only 3% (about 28,300km^2) of catchment area and contributes 2% (about 9.5 billion m^3) annual flow of the Mekong River, but since the Mekong River basin runs through a topographical condition of narrow mountainous area, it does not support irrigation and hydropower dams. As such, Mekong River basin does not take the role in water supply, food, and energy production of Myanmar. No dams or infrastructure are created in the Mekong River in Myanmar territory so far.

3.2.2. Water-Energy Security in Lower Mekong Basin Countries: Lao PDR, Thailand, Cambodia, and Vietnam

The Lower Mekong Basin (LMB) is named for the catchment area located in four countries, namely Lao PDR, Thailand, Cambodia, and Vietnam. The total area of countries located in the LMB is 606,000 km^2 and annually contributes 84% of Mekong flow (Table 2-11). The four countries in the Lower Mekong Basin have established a collaborative mechanism for managing water resources and related resources since 1957. Experiencing the political downstream of the Mekong, the name and structure of the Mekong cooperation have been changed over the years: the Mekong Committee (MC) with 4 members Laos, Thailand, Cambodia, and Vietnam (South Vietnam) (1957-1978); Interim Mekong Committee with three members from Laos, Cambodia, and Vietnam (IMC) (1978-1995); and the Mekong River Commission (MRC) from 1995 to the present.

Unlike China and Myanmar in the Upper Mekong basin, the Water-Food-Energy security nexus plays a very important role in the socio-economic life of the four LMB countries. At the same time, cooperation in sustainable development of the Mekong River basin is of great concern to the lower Mekong countries.

With the high population of the LMB (60 million/70 million peoples (2010) of all basins) and the need for water, food, and energy is rapidly increasing, and the dependence on each other for these resources in the LMB is high. At the same time, water resources play a critical role to ensure food and energy security.

The diverse ecosystem of the Mekong River Basin means that some areas are conducive to high yields, while others are limited by poor soil and water availability in the dry season. Due to water shortages in the dry season, agricultural productivity is low throughout Cambodia and Northeast Thailand and moderate in Lao PDR, as well as in the Central highlands of Vietnam. Vietnam's Delta is the only area in the basin where farmers can harvest up to seven rice crops every two years.

The potential of hydropower in the Mekong River Basin is about 53,000MW,

consisting of 23,000MW in the Upper Mekong Basin (China) and 30,000MW in the Lower Mekong Basin (Lao PDR, Thailand, Cambodia and Vietnam). In the lower Mekong, more than 3,235MW has been realized via facilities built largely over the past ten years, while projects under construction will represent an additional 3,209MW. An additional 134 projects are planned for the lower Mekong, which will effectively exhaust the river's hydropower generating capacity. The single most significant impact—both now and in the future—on the use of water and its management in the Mekong Region is hydropower (Mekongriver.info).

Although the Lower Mekong Basin has MRC, the co-operative mechanism is seen as a "model" for cross-border water governance cooperation. There are varying levels of economic development and social organization, as well as concerns for resource development of the watersheds in each of the different countries, yet there is no consensus on joint water resources sharing. However, it is a great challenge for the present and the future for development across the river basin, especially considering the concern of the lower basins.

(1) LAO PDR

Lao PDR has an area of 236,800km^2, of which agricultural land 23,600,000ha and forest land accounts for 18,572,240ha (FAO 2014). The population is 6,758,350 people (2016-WB). The GDP figure in 2016 is $15,768 million, and Laos is number 115 in the ranking of GDP of the 195 countries that were published. The absolute value of GDP in Laos raised $1,405 million with respect to 2015.

About 86% of country area (202,000 km^2) is located in the Mekong basin, so that the socio-economic development of Lao PDR depends very much in the natural resources of the Mekong River basin. According to the Lao National Chamber of Commerce and Industry (LNCCI), the agriculture and forestry sector saw average growth of 4.1 percent annually over the period 2005 to 2010, accounting for 30.4 percent of total GDP, while the industry sector (mining and hydropower) grew by 12.5 percent annually over the same period, and accounting for 26 percent of total GDP. Laos expects to be a regional battery by development of hydropower on the Mekong River.

Lao PDR, a lower-middle income economy with a GDP per capita of $2,150 in 2016, is one of the fastest growing economies in the East Asia and Pacific region and globally. GDP growth averaged 7.8% over the last decade, with the use of the country's natural resources – mostly water, minerals and forests – contributing around one third of this growth (WB, 2017).

The Mekong River flows through Laos and has many potential sites for

hydropower development. The Mekong River is also the most important flow throughout Laos and to make up the ecosystem and special landscape for most of this country. As such, the changes developed by the river in Laos would certainly have a major impact on the eco - landscape of the country. Wild fish, including catfish, are important sources of nutrition for the people of Laos.

Laos wants to become a rich country and Southeast Asia's batteries. The purely economic calculations will definitely push the conflict between hydropower, environment, and livelihoods of the country hydropower and both countries share the same water source.

Ten proposed mainstream projects on Mekong River across Lao and Lao – Thailand territories are shown in <Table 2-12>.

Although hydropower is considered one of the three largest resources for income in Laos (mines, timber), the construction of a series of hydropower plants on the Mekong mainstream has caused great controversy in the region. These hydropower projects will have unintended impacts on the environment and ecology of the Mekong river in Laos itself, as well as on the lower Mekong countries, Cambodia, and Vietnam. MRC and Vietnam have carried out studies on hydropower impacts on the Mekong mainstream to downstream countries.[5)]

〈Table 2-12〉 Hydropower Projects on the Mekong Mainstream in Lao and Lao-Thailand

No.	Name	Country	Investor	Install Capacity (MW)	Energy production (MWh/ Year)	Reservoir capacity (Mill. M^3)	Status
1	Pak Beng	Lao PDR	Datang International Power Generation (China)	1,230	5,517	442	To be constructed in 2018
2	Luang Prabang		PetroViet Nam Power Corporation (Viet Nam)	1,100	5,437	734	FS completed
3	Xayaburi		SEAN & Ch. Karnchang Public Co Ltd (Thailand)	1,260	6,035	225	Operation in 2018
4	Pak Lay		CEIEC and Sino-Hydro (China)	1,320	6,460	384	2016
5	Sanakham		Datang International Power Generation (China)	700	5,015	106	2016

5) ICEM (2011) Strategic Environmental Impact Assessment of the Mekong mainstream (SEA); MRC (2015-2017) MRC Council Study, Vietnam (2013-2016): Mekong Delta Study.

〈Table 2-12〉 Continued

No.	Name	Country	Investor	Install Capacity (MW)	Energy production (MWh/ Year)	Reservoir capacity (Mill. M^3)	Status
6	Pakchom	Lao PDR Thailand	N/a	1,079	5,318	12	
7	Ban Koum		Italian Thai Asia Corp. Holdings (Thailand)	1,872	8,434	0	
8	Lat Sua	Lao PDR	Charoen Energy and Water Asia Co Ltd (Thailand)	686	2,668	0	2018
9	Don Sahong		Mega First (Malaysia)	2,375	240	115	To be completed in 2019
10	Thakho diversion			50	360	0	
	Total			48,096	10,531		

Source: Peter J. Meynell & Lawrence J.M. Haas (2010). MRC SEA of Mekong mainstream hydropower MRC SEA of Mekong mainstream hydropower. Profiles of 12 proposed Mainstream developments in the LMB. (http://www.mrcmekong.org/assets/Publications/Consultations/SEA-Hydropower/3-LMB-MSD-DriversQuick-Project-profiles-4Jun10.pdf).

(2) Thailand

Thailand has a land area of 513,120km^2 of which agricultural land is 22,110,000ha, forest land is 16,369,000 ha (FAO 2014), with a population of 68,863,510 (2016-WB). The Mekong River basin plays an important role for food production in Thailand, which is also now a main importer of energy that is produced by hydropower dams in Lao PDR.

Thailand, with GDP of US $407.109 million (2016-WB) and GDP per capita of US $5.912, is the most developed country in LMB. Thailand is the country with the highest economic growth rate in the four Lower Mekong countries, and is also the country with the largest energy demand for its economy.

Thailand is the second-largest economy in Southeast Asia. While most demand for electricity is concentrated in the Bangkok metropolitan area, Thailand also has a large industrial and manufacturing base and significant amounts of tourism in its other provinces. Thailand is a rapidly growing country with a large middle class, and as a result is set to undergo a structural transition, changing the nature and shape of

electricity demand in the coming years.[6)]

As part of Thailand's Power Development Plan 2015 (PDP 2015)[7)], total installed capacity of Thailand by 2036 is 70,335MW. The role of imported hydro is also an issue. In 2015, hydro accounted for approximately seven percent of Thailand's power output. Under the plan, it will rise to 15-20 percent by 2036, and additional hydro will be imported from the Xayaburi Dam on the Mekong River and from the Hat Gyi and Mong Ton dams in Myanmar. While these sources may look clean on Thailand's balance sheets, the devastating environmental impacts to locals are cause for concern.

According to Jared Ferrie[8)], Laos has the potential to develop hydropower with a capacity of about 26.000MW, with electricity produced mainly sold to Thailand. Thailand has the advantage of direct investors from 4-5 hydropower projects on the mainstream in Laos, added power to the network, and avoids direct environmental impact (lesson Pak Mun). As major importers of hydropower from Laos, Thailand also will have one position to actively negotiate purchase prices for Laos (Lessons from Nam Ngum hydropower), and wealth being dependent on exports could cause greater risks in the future. Hydropower potential on the Mekong River in Laos is targeted to investors of energy development in Thailand.

(3) Cambodia

Cambodia has country land of 181,040km^2 of which agricultural land about 5,455,000ha (30% of country land), forest land of 9,584,400ha (52% of country land), and a population of 15,762,370 (2016-WB). Cambodia is holding the 110th position for GDP (2015) at $20,157 million and GDP per capita at $1,279 USD.[9)]

Likely Lao PDR, nearly 85% of Cambodia's country land (143,000 km^2) is located on the Mekong River basin, so that the Water-Energy-Food nexus in Mekong takes important position for the country's socio- economic development.

Cambodia's power sector is small by regional (and international) standards, but demand has been growing extremely rapidly. Between 2003 and 2014, the annual growth in electricity sales averaged almost 20% with total sales increasing by over seven times. The number of customers has grown only slightly more slowly, by 17% annually or by six times over the same period. Cambodia's national power

6) Fatih Birol (2016), Thailand Electricity Security Assessment 2016.
7) Mr. Chavalit Chavalit (2014), Thailand's Power Development Plan Thailand's Power Development Plan 2015 (PDP 2015).
8) Jared Ferrie (2010), Laos turns to hydropower to be "Asia's battery". csmonitor,com/world/asia-pacific/2010/0702.
9) https://countryeconomy.com/countries/cambodia

development master plan is currently being updated. The rapid increase is driven by the expansion of electricity supplies nationwide. From electrification rates of just 6.5% of communes ('khums') and 5% of households in 2003, coverage is estimated to have reached 85% of communes and 60% of households by 2014.

The Mekong River flows through the territory of Cambodia, and there are some locations for hydropower development. Two big hydropower projects, Sambor and Stung Treng, plan to build along the mainstream of the Mekong River (Table 2-13). However, in order to create a substantial power output hydropower dams should be long with a large reservoir, together inundating a huge area of forest and agricultural land. At the same time, the hydroelectric dams are also important factors hindering the migration of wild fish downstream and from the Great Lake, where there are risks of destruction of species habitats of rare freshwater dolphin (Irrawaddy). The problem of tradeoffs require careful consideration. Two big dams planned to build on the Mekong mainstream in Cambodia are shown in <Table 2-13>.

〈Table 2-13〉 Hydropower Dams of Cambodia on Mekong Mainstream

	Dam	Country	Install capacity	Energy production	Reservoir capacity	Investor	Status
1	Stung Treng	Cambodia	900	170.78	N/A		N/A
2	Sambor	Cambodia	2,600	465	N/A	Grid-Guodian Corporation (China)	N/A

Source: Peter J. Meynell & Lawrence J.M. Haas (2010). MRC SEA of Mekong mainstream hydropower MRC SEA of Mekong mainstream hydropower. Profiles of 12 proposed Mainstream developments in the LMB. (http://www.mrcmekong.org/assets/Publications/Consultations/SEA-Hydropower/3-LMB-MSD-DriversQuick-Project-profiles-4Jun10.pdf).

(4) Vietnam

The country area of Vietnam is 330,967km^2, of which agricultural land about 10,873,700ha and forest land 14,644,000ha (FAO 2014) and population 92,701,100 million (WB-2016). In 2016, Vietnam held the 47th position for nominal GDP: 201,309 million US$, GDP per Capita: 2,172 US$[10].

All though the area of Vietnam in the Mekong River basin is only 11% of the whole basin, but over 20 million people depend on water resources of the Mekong River, about 1/3 of the population in the entire Mekong River basin. Vietnam

10) https://countryeconomy.com/countries/vietnam

is associated with the Lower Mekong Basin (LMB) in both the upstream and downstream.

The Central Highlands of Vietnam located in the upstream eastern part of LMB is fed by the Se San and Srepok rivers that are among the biggest tributaries of the Mekong River basin. For agriculture, with a large area, mainly of fertile basalt soils and abundant water, the Central Highland is one of the biggest agricultural cash crops productions of Vietnam, mainly coffee, rubber, sugarcane, pepper and cashew. With total production of 1.7 million tons of coffee (2013/2014), 147,000 tons of black pepper (2014), and 340,000 tons of cashew, Vietnam is the second biggest exporter of coffee, first biggest exporters of pepper and cashew nut in the world, with those crops mainly produced in the Central Highland (MARD).

Meanwhile, the Mekong Delta of Vietnam located in most downstream of Mekong river basin is a large land area accounting for 12% of the area and 19% of the population nationwide. The Mekong Delta, with a dense network of rivers and canals has big advantages in agricultural development, food industry, tourism, and renewable energy. The Mekong Delta contributes 50% of rice, 65% of aquaculture production and 70% of fruits of the country. 95% and 60% of rice and fish production exported are from the Mekong Delta and it is conveniently located in trade with ASEAN countries and the Greater Mekong Subregion (GMS). Vietnam is the third largest rice exporter in the world, after India and Thailand (FAO-2017).

However, water resources for the Mekong Delta are dependent on 95% of water resources from upper Mekong countries (China, Myanmar, Laos, Thailand, Cambodia) and Central Highland of Vietnam. Upstream development has had increasing impacts on water resources in the Mekong Delta, including changes in annual flow regime and seasons and impacts on salinity intrusion from the sea and reduced sediment retention, which are the biggest challenges for the future of the survival and development of an important land of Vietnam. The Mekong Delta is also considered one of the ten largest in the world most affected by climate change and sea level rise.

The Mekong Delta is facing the risk of double impacts from changes in upstream and sea level rise. ICEM (2010) has projected that after 11 downstream hydropower dams, the amount of fine silt will decrease by 50% once again to 42 million tons, or one quarters of the old volume before 1992, will be completely retained by the dams. At that time, the landslide and bank and sea coastal area's erosion will be more intense, and there are no measures in place in the Mekong Delta, either work or non-construction, that can resist this trend.

It is clear that millions of people today and in the future clearly depend largely on

the cooperation and management of water resources of the Mekong River. With the geopolitical position of the country, Vietnam should have the appropriate policies to protect its legitimate rights and maintain mutually beneficial cooperation with the riparian countries, and compliance with international law is the way to ensure sustainable development, thus ensuring security for the region.

3.3. Hydropower Development and Challenges for Water and Food Security in the Mekong Basin

As analyzed above, at different levels, the water and related resources of the Mekong River play an important role in the overall socio-economic development and water-energy security of each country in the basin and for the whole area. At the same time, the sharing of the common water resources of the Mekong River creates interdependence among the countries in the basin. Water-Energy Security in the basin is also a factor in ensuring the political-economic security of the Mekong region.

The Mekong River has relatively large hydropower potential (Table 2-14). During the boom of the current economic development, the Mekong Basin countries have been taking full advantage of their resources to develop their resources, namely hydroelectricity in the Mekong basin.

〈Table 2-14〉 Hydropower Potential in the Mekong River Basin

Country	Hydropower potential capacity			
	Mainstream (MW)	Tributaries (MW)	Total (MW)	Percentage of whole basin (%)
China	-	-	23,000	42.7
Cambodia	3,600	2,200	5,800	10.8
Laos	8,000	13,000	21,000	38.9
Thailand	1,400	700	2,100	3.9
Vietnam	0	2,000	2,000	3.7
Total	13,000	17,900	53,900	100.0

Source: The Report of Strategy Environmental Impact Assessment of Hydropower on Mainstream, MRC-2010.

In the Upper Mekong Basin (UMB): At present, China has basically completed its plan up to 2020 to build 8 major hydropower dams on the Mekong mainstream (Lancang). By 2030, it is expected that the total number of hydropower plants on the Lancang mainstream will reach 15, with hundreds of small hydro in the Lancang

tributaries. The amount of water stored on the dams system in Lancang will reach up to 50% of the Lancang River's annual flow.

In the Lower Mekong Basin (LMB): Laos, Thailand, and Cambodia have plans to build 12 large hydropower projects, including eight in Lao, two in Lao-Thailand, and two in Cambodia. Currently, two large hydropower plants are under construction in the territory of Lao PDR, namely Xayaburi Dam (installed capacity of 1260MW - Thai investor - 90% construction works completed) and Don Sahong hydropower plant (240 MW - Malaysian Investor-under construction). Laos is preparing to build a third dam on the mainstream, Pak Beng Dam (920 MW - Chinese Investor).

All hydropower projects in Laos are invested and constructed by foreign investors from Thailand (four dams), Malaysia (one), France (one), China (three) and Vietnam (one). In Cambodia, there are investors from China, possibly others from Vietnam and Thailand.

In the Mekong tributaries, decades ago, hydro potential countries in the Lower Mekong Basin undertook research and construction of hydropower plants on tributaries. Over 120 dams are planned for the tributaries. While Thailand and Vietnam have already developed most of their tributary sites, Cambodia, Laos, and Myanmar currently possess the greatest potential for hydropower resource development, and by the year 2030, they are expected to reach a combined percentage of hydroelectric generation of 96 percent.[11)]

According to ICEM (2010)[12)] relating to the positive and negative impacts of hydropower in the Mekong basin, excluding China's hydropower projects on the Lancang River, the mainstream projects will bring additional energy and investment/ revenue sources for the entire region. Benefits are very substantial: the proposed 11 mainstream dams together would generate an extra US $ 15 billion. About 400,000 new employment opportunities would have been created during the construction and operation phases of the mainstream dams. Furthermore, the 11 LMB mainstream dams would have the potential to reduce the greenhouse gas emissions of the regional power sector by about 20 million tonnes CO_2/year by 2030. However, it can be said that for hydropower development in Lao, the foreign investors are the greatest beneficiaries, for the natural resources are undervalued and investors enjoy preferential treatment from the host country from host country.

At the same time, these projects bring many serious risks and uncertainties to the strategic, economic, social, and environmental concerns of the Mekong Basin

11) https://opendevelopmentmekong.net/topics/hydropower/
12) International Center for Environmental Management - ICEM: Strategic Environmental Assessment of the Mekong Mainstream Hydropower - Final Report Summary - Submitted to the MRC 10/201.

countries, as well as for sustainable development of the whole basin.

For the hydropower on Mekong on UMB in China, the impacts are assessed, including large changes in downstream flow regime, impacts on natural hydrological regime, and environmental conditions of the river, significantly reducing the source of downstream silt, thus triggering river bank erosion and ultimately decreasing fertility for the delta, reducing the yield of crops, and increasing the amount of chemical fertilizers used for cultivation. At the same time causing sinking in the delta (Jon, Tu-2014) would increase the risk of salinity intrusion when coupled with climate change and sea levels rising (MRC). The affected countries are five downstream countries, namely Myanmar, Laos, Thailand, Cambodia, and Vietnam.

For hydropower on the Mekong mainstream in LMB, Laos, Thailand, and Cambodia, although hydropower projects on the Mekong mainstream are run-off river hydropower dams, they boast capacities of several hundred to one billion cubic meters and mechanisms of daily regulation, thus having a great impact on the changing of the flow downstream. Large changes in river flow downstream will dramatically change the natural ecosystems and cause unpredictable consequences for cultivation, human habitation, and the environment. According to the MRC, between 1992 and 2010, Mekong sediment load fell by 50% from 160 million tons to 85 million tons per year (MRC 2010).

Although hydropower projects are expected to have huge negative impacts on downstream, particularly affecting the flow of water, sediment and nutrients, fisheries productivity and livelihoods of the millions of communities in basin in all countries. However, because of the economic benefits, the development of hydropower in the Mekong Basin is still attractive to investors and governments in exploiting this energy source.

3.4. Recommendations

Lancang -Mekong is the common river of China, Myanmar, Laos, Thailand, Cambodia, and Vietnam. The Mekong has, for thousands of generations, been the common source of water for all riparian countries. The Mekong river basin has a special position in the economic and social life of riparian states, especially ones in the lower Mekong Basin. The water resources of the Mekong guarantee the lives of over 60 million people, and in the near future there will be more than 100 million people in the basin.

The hydropower potential of the Mekong is quite large, providing a comparable source of energy for the upstream countries, particularly Yunnan China, Lao PDR, Cambodia, and parts of Vietnam. However, the development to fully exploit the

hydropower potential of the Mekong river basin (mainstream and tributaries) with the construction of a series of big dams on the Mekong mainstream upstream in China and the Lower basins in Laos, Thailand and Cambodia, together with hundred hydropower in the tributaries in all countries, are potentially serious threats to water security, food security, and livelihoods of riparian communities in the Mekong countries in general and countries located in downstream, especially Cambodia and Vietnam.

A Strategic Environmental Assessment (SEA)[13] report on the proposed hydropower dams on the Lower Mekong Basin indicates that there are many uncertainties in mainstream hydropower development, and proposed to postpone the decision on these dams for 10 years for further study and better understanding.

The analysis of the SEA shows that Vietnam does not enjoy any positive impact from the development of the hydropower ladder on the Lower Mekong Basin-economic-environment, as they are single-hydropower production purpose projects, targeting only electricity generation. As these projects are subject to day-to-day operation, they are especially detrimental to changing dry-season flows in a negative direction. The operation of these hydropower projects in the future are to be conducted by different foreign investors, so that the formation of mechanisms to regulate the interests of investors with the interests of downstream countries is a big challenge.

Recent research conducted by Vietnam with the assistance of experienced international consultants (Mekong Delta study-2013-2015) shows that, depending on the operation of upstream reservoir systems, the Mekong Delta will be affected by saline intrusion, severe impacts on reduction of sediment flow, water quality, and nutrient depletion. With such impacts, clearly the Mekong Delta faces changes in production, and, combined with climate change, these impacts will be multiplied.

There should be coordination and support between the cooperative mechanisms (MRC, LMC, GMS etc.) in the Mekong basin/region to ensure the sustainable development of water resources in the Mekong basin for water, food, and energy security. The cooperation should achieve its goals through appropriate benefit sharing mechanisms in water resources development for all purposes between upper and lower basin countries. This should be done with the goal of developing a common operating mechanism for the hydropower systems on the mainstream, ensuring the mutual interests and mitigating negative impacts.

13) International Center for Environmental Management - ICEM: Strategic Environmental Assessment of the Mekong Mainstream Hydropower - Final Report Summary - Submitted to the MRC 10/201.

4. Policy Directive of Water Resources Development for Sustainable and Prosperous Mekong Cooperation: the Case of Hydropower Development

4.1. Overview

4.1.1. History of Mekong Cooperation before 1995

At the end of the World War II, in 1945, there was little understanding on the Mekong River, and it was undeveloped. In 1947, the United Nation began to engage in the creation of the regional commission and, in 1952, with the report on Mekong flood control and river development, which was to be the first planning report to show the formation of a knowledge base and the studies for development projects on major energy and agriculture in limited areas on the tributaries. In 1957, the Mekong cooperation was finally started with the establishment of the Mekong Committee (MC) and National Mekong Committees (NMCs), and in 1959, the United Nations appointed the first Executive Agent and staff for the management as the first Secretariat.

In 1970, the 1970-2000 Indicative Basin Plan proposed tributary and mainstream development for 180 projects. This included a $2 billion short-term (to 1980) programme, with 0.7 million hectares of irrigation expansion and 3,300 megawatt (MW) of tributary hydropower, followed by a $10 billion long-term (1981-2000) programme, including 17,000 MW of hydropower, with a cascade of major dams (including the 4,800 MW Pa Mong dam). Those would also extend navigation by 800 km.

In 1975, the MC signed a Declaration of Principles, particularly on mainstream development. However Cambodia's internal dispute led to its pull-out from the cooperation activities in 1976 and, Lao PDR, Thailand, and Vietnam only established the UN Interim Mekong Committee (IMC) in the following year. That is why Cambodia was to be absent for 14 years without further involvement of actions on the mainstream.

The 1970 Indicative Basin Plan was completely revised in 1987, with a 1987-2000 investment plan. Cambodia re-engaged with the stability in the country and the Paris peace agreement of 1991. In 1994, negotiations began for a new agreement which would take the MC to separate from the UN system and establish an intergovernmental organization under international treaty law. The 1995 Mekong Agreement was the start of a new era of Mekong Cooperation.

〈Table 2-15〉 List of Hydropower Dams Built before Signing of the 1995 Mekong Agreement

Dam Name	Country Province	Built in Year	Installed Capacity (MW)	Annual Generation (GWh)	Reservoir (Million m^3)	Major Issues
O Chum 2	Cambodia Banlung, Ratanak Kiri Province,	1992	1	2.5	0.1	Water quality issues
Nam Ngum	Lao PDR Vientiane Province	1971	155	865	4,700	Some water quality issues. Fish migration blockage.
Ubol Rattana	Thailand Khon Kaen	1966	25.2	56	2,250	Resettlement issues, deforestation, erosion.
Nam Pung	Kut Bak, Sakon Nakhon	1965	6.3	17	170	Change in flow regime
Sirindhorn	Thailand Ubon Ratchathani	1971	36	90	1,970	Change in flow regime
Chulabhorn	Thailand, Khon San, Chaiyaphum	1972	40	59	165	Change in flow regime
Pak Mun	Thailand Ubon Ratchathani	1994	136	280	225	Land compensation issues; Adverse effect on fisheries.
Drai linh 1	Viet Nam Dak Lak	1990	12	94	2.9	Deforestation, Ecological disturbance.

Note: MRC (2010) provides the rationale and orientation of the MRC Initiative on Sustainable Hydropower, (ISH) for the MRC Strategic Plan Cycle (2011-2015).

Source: MRC (2010).

4.1.2. History of Mekong Cooperation after 1995: Hydropower Development

The MRC document, "Initiative on Sustainable Hydropower (ISH), 2011-2015 Document, October 2010", provides the rationale and orientation of the MRC Initiative on Sustainable Hydropower (ISH) for the MRC Strategic Plan Cycle (2011-2015).

During the period of regional preparations for the MRC Strategic Plan (2011-2015), hydropower development was considered as a challenge for the MRC's mission to implement the 1995 Mekong Agreement. In particular, at the 3rd Regional Consultation on the Basin Development Plan (BDP) Scenario Assessment in July 2010, it was further emphasized that the Mekong had reached a crossroads on decisions about hydropower in the Lower Mekong basin (LMB).

As a result, the MRC became to recognize that the challenge ahead and it was not only about informing decisions for new hydropower schemes, or their design features. It was mainly about how to proceed and make the strategic thinking for cooperation which was needed to manage the growing number of existing hydropower assets in the Mekong basin in a sustainable way. Such considerations need to be linked also to wider strategies for sustainable development of the regional power sector.

One relevant indication, immediacy and scale of the common challenge was offered in the MRC's latest Basin Development Planning (BDP) Scenario Assessment practice. Here, the Definite Future Scenario (DFS) of the BDP showed up to 41 large hydropower schemes on LMB tributary systems by 2015. This compared to 15 LMB schemes in the BDP Baseline case for 2000, an increase of 26 large dams. The BDP 20-year Probable Future (PFS) Scenario sees up to 71 large hydropower schemes operating on LMB tributaries by 2030.

To some extent, the policies and legislation of MRC Member States already were recognized the need to address hydropower sustainability challenges in their planning and regulation systems in an integrated way (i.e. across the economic, social, and environmental dimensions) at a national level through bilateral mechanisms, and at a regional level through implementing the 1995 Mekong Agreement. The BDP is a primary instrument for the implementation of that cooperation to identify, categorize, and prioritize the projects and programs to seek assistance for and to implement at the basin level.

[Figure 2-9] The LMB Countries



Source: Mekong River Commission (2016).

4.2. Review the Governance for Water Resources Development in the Mekong River Basin, Focusing Hydropower Development

The objective of this chapter is to provide an understanding over the development of river basin planning and development paradigms that would help to see the kind of policy directive of water resources development for sustainable and prosperous Mekong cooperation, with particular focus on hydropower development in a transboundary context.

4.2.1. MRC Basin Development Planning

The 1995 Mekong Agreement has framed a clear mandate for the BDP. However, it was only in late 2001, six years after the Agreement that the formulation of the BDP finally started. The MRC Member Countries (MCs) have had different perceptions on basin planning.

BDP's first phase (BDP1) focused primarily on planning processes and tools, including a knowledge base and modelling capability, on non-controversial projects, and on building relationships. These are necessary but insufficient conditions for cooperation and development, which also require products, actions, and outcomes. BDP1 ended after five years, and the following phase, BDP2, was launched at the end of 2006.

By 2006, the LMB had changed greatly, with water investments in national programmes taking place, due to rapidly growing water, food, and energy demand and growing private sector involvement, particularly in hydropower and commercial agriculture. This shift from dependence upon multilateral banks and their safeguards exposed the need for strengthened national regulatory frameworks. BDP2 had to move beyond process alone to a focus on water development at national and regional level, without returning to the earlier almost exclusive focus on water infrastructure.

Mekong development was happening and it was imperative to ensure that the move to coordinated and cooperative development took full account of transboundary, social and environmental impacts and led to substantive, positive development outcomes.

The primary product at the end of BDP2 was the Basin Development Strategy. The Strategy was a consensus product that described strategic priorities for basin development and for basin management, specifically in order to move identified development opportunities to implementation. The Strategy was adopted by the MRC in January 2011, 15 years after the Mekong Agreement was signed. This was an important milestone, re-introducing a focus on water development to support poverty reduction and economic growth, complementing and not replacing the focus on water management.

Launched in 2011, BDP3 is overseeing the implementation of the Strategy over a 4 year timeframe in cooperation with other MRC Programmes working with national line agencies, river basin organizations and others. The BDP Programme has lead the work on addressing avoidance/mitigation of adverse impacts of water resources development and designing a mechanism for the sharing of transboundary benefits,

impacts and risks of current and planned developments.

- Basin development Planning and Independent review by a Panel of Experts:

In 2010, a Panel of Experts (POE) was formed with the mandate to review the key products Scenario Assessment Report (October 2010) of the MRC Basin Development Plan Phase 2. The POE has carried out a thorough and independent review of the above mentioned reports where they have inspected the different aspects of the reports including the relevance, the suitability of their scope, the quality, the consistency, and the comprehensiveness.

In their findings described in "A Strategic Review of the Basin Development Plan, Report of the International Team of the IPOE, Don Blackmore, David Grey, Mark Halle, Mekong River Commission, Vientiane, 8 October 2010", some interesting key observations were taken from their review and shown here below:

- The POE has shown some significant concerns: "the river flows and diversions point of departure for the BDP, resulting in a primary focus on hydropower and irrigation, with other areas covered through special studies, strategic guidance and technical guidelines. While hydropower and irrigation are obviously very important for development, the relative absence of other development sectors, including fisheries and navigation, and management options, including social and environmental actions, is striking. This outcome reflects the coherence challenge faced by the MRCS and underscores the imperative of a "One MRC" approach. The BDP Strategy document is a negotiated and country-owned product that is important as the record of the BDP consultative process. Nevertheless, and perhaps because of its negotiated status, it is confusing, repetitive and difficult to read and use."
- The POE recommended the MRC to invest on more knowledge which could be in form of studies and researches is order to establish 'biophysical' objectives for the river; make sound investment decisions; design effective mitigation actions; and negotiate tradeoffs and outcomes"
- The POE also added that: "The MRCS, specifically, will need to: provide timely and objective advice; sustain the values enshrined in the Agreement; facilitate inter-country discussion and negotiation; ensure financing for transboundary dimensions; and become 'one MRCS', beyond its current silos of opinion, modeling the coherent and disciplined behavior needed across the basin for sustainable development of world-class infrastructure. The MRC can and must become a relevant, world-class institution to support the development and management of a world-class transboundary river basin."

However, beside the above concerns and recommendations, the POE consider that

the BDP has met an "extraordinary success in creating an effective and functioning platform for Mekong River cooperation is recognized and highly commended."

The MRC report "Basin Development Plan, Completion Report for Phase 2 (2007-2011)" is a Completion Report to provide information related to the performance of the Basin Development Plan Programme under its Phase 2 programme (BDP2) during 5 years of activities between 2007 and 2011. The content of this report has disclosed that:

- Basin development Planning and Programme achievements:

The BDP2's development objective was set to be: "The water resources of the MRB managed and developed in an integrated, sustainable and equitable manner for the mutual benefit of the basin countries" with immediate objectives of achieving through like-named components:

- Programme management and communication for effective engagement of stakeholders in the basin planning process;
- A rolling IWRM based Basin Development Plan produced in support of sustainable development in the MRB;
- Knowledge base and assessment tools further developed and utilized effectively in the MRCS and NMCs; and
- Capacity built at the MRC and NMC levels for IWRM planning and facilitation/ mediation in areas where trade-off management is required.

Within this framework, 16 outputs were defined to be accomplished through 34 activities.

Consequently, the report has stated that "BDP2 has achieved each of its objectives on time and within budget, bearing testament to the strong management and technical leadership and effective management within the BDP2 team." Most remarkable achievements include:

- A rolling IWRM based Basin Development Plan produced in support of sustainable development in the Mekong River Basin thanks to the findings from the assessment of basin-wide development scenarios. The results can be seen as a basin-wide cumulative impact assessment of the countries' development plans. They demonstrate the considerable inter-play between water, energy, food, environmental and climate security and how, through coordinated national planning, benefits can be realized for all countries and adverse transboundary impacts minimized.

- The IWRM-based Basin Development Strategy, which was widely acclaimed as a major milestone for the MRC, drew progressively upon the findings and understandings reached during the scenario assessment as these emerged. The Basin Development Strategy demonstrates that basin development can take place and natural systems protected if planned well. The Strategy describes how synergies between the various water related sectors (water, energy, food, environment, etc.) can be exploited, trade-offs resolved, and potential downsides avoided or mitigated by adhering to IWRM principles and addressing knowledge gaps. In doing so, the Strategy provides an integrated basin perspective against which current and future national water resources development plans can be assessed to ensure an acceptable balance between economic, environmental and social outcomes in the Lower Mekong Basin (LMB), and mutual benefits to the LMB countries, as required by the 1995 Mekong Agreement.

Since 2011, under the IWRM-based Basin Development Strategy (the Strategy), the MRC Members countries have started the implementation of its activities. At the heart of the Strategy is the move beyond cooperation primarily on knowledge acquisition towards cooperation on water development and management, and the move beyond national, sectoral planning towards comprehensive basin planning. Consequently, the M-IWRMP of the Mekong River Commission provides a coordinated and integrated planning for development and management of water and related resources, in a large and complex river basin like the Mekong. It can help maximize economic and social welfare without compromising the sustainability of vital ecosystems. It is assisting its Member Countries: Cambodia, Lao PDR, Thailand, and Vietnam enhance the adoption of this principle through the implementation of the MRC's five Procedures and their Technical Guidelines. Providing a systematic and integrated framework, these Procedures enable greater cooperation in, for example, maintenance of flows in the Mekong mainstream, exchange of critical data and information and the notification of projects that may result in significant changes to the river.

A transboundary component, supported by the World Bank, aims to implement integrated water resources management on a bilateral basis between the Member Countries, while supporting and protecting pro-poor livelihoods. This component strengthens the cooperative effort by building a common understanding of key water management issues, and sharing the benefits of the countries' experiences.

A national component, supported by the World Bank, helps the Member Countries meet their commitments to effectively implement the Procedures. It will strengthen capabilities on a national scale by assisting the countries to improve laws and regulations, as well as governance mechanisms and technical expertise.

4.2.2. The Preliminary Design Guidance (PDG)

The fact that at least eleven large hydropower schemes have been proposed on the mainstream reaches of the Lower Mekong Basin in Cambodia, Lao PDR, and Thailand. Whereas implementation of any one or all of the proposed schemes brings potential opportunities for economic development of the region, mainly through enhanced electricity supply and improved conditions for inland navigation, the projects will inevitably be accompanied by major impacts and other development risks in the four MRC Member Countries.

The impacts and risks are particularly with respect to:

- Effects on the fisheries resources of the Mekong, the world largest inland fishery, especially the barrier effect that dams could have for migratory species, fish biodiversity and the subsequent consequences for people's livelihoods;

- Effects on sediment and river morphology, with associated risks to the economic life of the mainstream impoundment of water and safe operation, and effects on long-term river bed stability, river bank erosion and channel changes in the downstream reaches;

- Potential water quality changes, especially with regard to water pollution and effects on aquatic ecosystem functions and services, as well as wetland systems, both in the mainstream channel above the dams and localized effects downstream.

There is also the potential for longer-term sediment and nutrient flow changes in the downstream Mekong system in relation to cumulative effects of dams in a cascade. These changes can add pressure to factors already affecting ecosystem functions and productivity in the Tonle Sap; as well as the long-term stability of the Mekong delta, including the influences of the large storage dams on the upper reaches of the Lancang-Mekong system in China and tributary dams in the lower basin.

This document provides preliminary design guidance in the form of performance targets, design and operating principles for mitigation measures, as well as compliance monitoring and adaptive management. Two broader aims are:

(1) To ensure that developers have timely guidance in order to adopt a consistent approach to the design of individual dams, as well as the proposed mitigation and management measures. This is important, particularly where developments have significant transboundary impacts for people or the

environment downstream.

(2) To ensure that the approach of offering performance targets allows developers the flexibility to identify and propose the best solutions.

(3) The guidance is founded on a set of basic Integrated Water Resource Management (IWRM) principles, international best practice and the relevant primary legislation of Member States, namely:

- Avoidance over mitigation
- Water as an economic good
- Adaptive management
- Good practice and safe operations

Therefore, to date the PDG has formed the basis for Prior Notification Prior Consultation and Agreement (PNPCA) submissions made by MRC Member countries and assessments made by the MRC Experts of three mainstream dams; Xayaburi (1285MW, 2011), Don Sahong (260MW, 2014), and Pak Beng (950MW, 2017).

The Xayaburi Hydropower Project (XHPP) has received a series of recommendations from the technical assessment and review made during and under the PNPCA Process. The concerns raised include potential impacts on Mekong Delta area, water flow, fish migration, sediment flow and navigation. Consequently, the project developers and the Government have implemented additional works to address all concerns. While accepting to carry out additional works, the Government of Lao has added another USD 200 Million, and on the developer side they have also provided more than 200 Million USD.

During the assessments of the above 3 Mekong Mainstream hydropower projects, it has become clear that there are certain gaps in the PDG that may need to be filled and also areas of ambiguity that need to be clarified. In addition, the question of the applicability of the Guidelines to significant tributary projects, that may have trans-boundary impacts, has been raised by member countries.

4.2.3. The Strategic Environmental Assessment (SEA)

The projects are moving forward without an overall spatial or integrated development plan for the River – either within each country or at the regional level. In the absence of such a guiding framework, the national power and environment agencies are applying their project-specific review procedures and standards, including Environmental Impact Assessments (EIA), prior to making a decision in each case. At regional level, LMB countries have adopted a protocol under the MRC

Agreement which commits them to notify their neighbors of proposed mainstream projects when they have sufficient information, then consult and reach agreement on whether or not to proceed with the project. That full Procedure for PNPCA has never been triggered. When notified by Lao PDR or Cambodia, the mainstream hydropower project proposals would be an important test for the PNPCA and regional cooperation. It is the relatively sudden revival of many proposals and MOUs (Memorandum of Understanding) at the same time and for the same shared river that led LMB countries to call for a Strategic Environmental Assessment (SEA) of all 12 proposals to be conducted under the MRC. SEAs address the broader strategic issues usually relating to more than one project. SEAs follow similar steps to EIAs but have much larger boundaries in terms of time, space, and subject coverage. The SEA is a tool to examine the broad strategic concerns which need to be resolved and decided prior to making project specific decisions. In this case, the MRC SEA was asked to provide an understanding of the implications of mainstream hydropower development and recommendations on whether and how the proposed projects should best be pursued. The SEA was intended to guide the PNPCA process, to feed into the MRC Basin Development Plan (BDP), and ultimately to support national decision.

The SEA focuses on 12 proposals for hydropower on the Mekong mainstream located in three distinct hydro-ecological zones. Impacts are assessed for five different dam groupings: (i) all proposed LMB mainstream dams, (ii) the cluster of six Upper Lao projects upstream of Vientiane, (iii) the two Middle-Lao projects immediately up and downstream of Pakse (Ban Koum, Lat Sua), (iv) the two smaller Lowe Lao projects at Khone Falls (Don Sahong, Thakho), and (v) the two Cambodian Projects upstream of Kratie (Stung Treng, Sambor).

The SEA has run in four phases over 15 months from May 2009 – (i) a scoping phase to define the key strategic issues of concern to Mekong River development, (ii) a baseline assessment to describe past trends in those issues and their projection to 2030 without mainstream hydropower, (iii) an impact assessment of the effects of mainstream hydropower on those trends, and (iv) a phase to identify ways of avoiding and mitigating the risks and enhancing the benefits. The SEA has been intensively consultative involving over 60 line agencies, 40 NGOs and civil society organizations and some 20 international development organizations in meetings and workshops. The SEA process also included the participation of China through the high level Ecosystem Study Commission for International Rivers (ESCIR). The views and opinions expressed during the consultations have guided and shaped the SEA through all assessment phases. In this report the SEA team has distilled and analyzed the views and information of government experts, line agencies, and the non government community. When a diversity of views remain on key issues such as the economic costs and benefits of the mainstream proposals, the SEA team draws its

own conclusions based on the evidence before it.

The SEA baseline and impact assessment established that 96% of power demand to 2025 stems from Thailand and Vietnam – and those two countries are targeted to purchase close to 90% of the power generated by the mainstream projects. If Thailand and Vietnam decided not to purchase mainstream power, the projects – all designed for export – would have difficulty going ahead.

The main findings of the SEA are summarized below according to what government and non-government stakeholders defined as the big strategic issues relating to mainstream development. These issues were identified by national participants in the national round tables and regional impact assessment workshop. They are:

- Power security and generation including revenue, trade and foreign investment
- Economic development and poverty alleviation
- Ecosystems integrity and diversity – aquatic, terrestrial, hydrological dynamics and sediment/nutrient transport.
- Fisheries and food security (including agriculture)
- Social systems - livelihoods and living cultures of affected communities.

4.2.4. Lessons Learnt from PNPCA

The three mainstream dams that have been reviewed under the PNPCA over the last six years have used the PDG as the primary guidance to assess the proposed design and operations of the hydropower project (Xayaburi (in 2011), Don Sahong (in 2014), and Pak Beng (in 2017)). In each case there have been useful lessons learned concerning the areas of the PDG that may need to be clarified, enhanced and improved. Detailed comments from the international and Regional Experts as well as the hydropower developers and their consultants will be gathered in the course of the finalization of the PNPCA.

Following from the PNPCA reviews, some initial areas of improvements in the DG have already been highlighted. Some major points that have arisen include:

- Guidance on minimum primary data requirements for ESIA and operations;
- Additional guidance pertaining to good social impact assessment and resettlement practices;
- Emphasis on the avoidance of impacts (through strategic planning) is preferable to the mitigation of impacts - or compensation for unmitigated impacts
- Consideration of options for joint planning, join coordination and join monitoring, particularly at trans-boundary level;

- The need to elaborate on Adaptive Management given the limited system monitoring prior to construction and limited understanding of the effects on the environment;
- Guidance as to the quality of the EIA to avoid delays in the provision of adequate information for assessment.
- Operating rules for projects are often not provided in the PNPCA documents;
- Inclusion of the need for Trans-boundary CIA requirements – with reference to the current MRC preparation of guidance for Transboundary environmental impact assessment.

4.2.5. The Council Study

The Council Study (CS) or the Study on Sustainable Management and Development of the Mekong River including Impacts of Mainstream Hydropower Project. The study has been completed recently. It has provided a series of reliable scientific environmental, social, and economic impacts of water resources development in the Mekong River encompassing cross-cutting sectors and impacts.

The CS helped to fill major knowledge gaps on the environmental, social, and economic impacts of major development in the Mekong basin in the short, medium, and long term. The CS will enhance the ability of MRC to advise MCs on the potential benefits and impacts of water resource development of the basin based on sound scientific evidence, optimise the Basin Development process, and ultimately contribute to sound decision making by the MCs in the development of the Mekong basin.

A spillover effect of the CS is to promote capacity building and ensure technology transfer to MCs during the entire study process.

The Hydropower Theme is also part of the "Cross-cutting discipline impact assessment" using modelling that is at the core of the impact assessment. The Mekong Basin is a complex system and it is not possible to analyze and quantify development impacts without computer modelling. The core tool is MRC DSF (Decision Support Framework), which simulates basin-wide hydrological, flow and water quality processes, as well as human interventions to them. The DSF has been updated with the Australian eWater SOURCE for water sediment and water quality modelling. DSF is coupled with the WUP-FIN (Water Utilization Programme, Finland Component) modelling tools for integrated impact assessment focusing on The Great Lake (Tonle Sap), Cambodian floodplains, Vietnam Delta, and the Mekong estuaries and coast (MRC Technical brief of the Council Study, 2017). The CS is a complex and comprehensive study as do the CS results. At no surprise, the most important message from the CS results and outcomes for the hydropower theme, is about the absolute

necessity to apply diligently all necessary mitigation measures in case if the MRC Member Countries wish to pursue with their aspiration in promoting hydropower development to boost both national and regional economy.

4.2.6. The Update for the Preliminary Design Guidance

While the PDG has provided the hydropower dam developer with guidance in the form of performance targets, design, and operating principles for mitigation measures, as well as compliance monitoring and adaptive management, the ultimate aims are to ensure that developers have timely guidance to adopt a consistent approach to the design of individual dams. This is in addition to the proposed mitigation and management measures on top of the performance targets approach, which allows developers the flexibility to identify and propose the best solutions.

A Concept Note was prepared in December 2017 to describe the review and update the Preliminary Design Guidance as stated in the MRC Basin Development Strategy and the Strategic Plan 2016-2020 and also to propose a methodology for the review, which will be undertaken to ensure that the guidance in the updated Design Guidance (DG2018) is more complete and covers known gaps found especially in the PNPCA reviews. Therefore, during the update process new knowledge from recent and completed MRC studies including the ones made for sustainable hydropower planning will be taken into account as they contains evidence based options for the design of impact mitigation for mainstream and tributary dams.

A Trans-boundary EIA Guideline is currently in draft form[14)] and is being discussed between member countries. The PNPCA reviews to date have highlighted the need for transboundary considerations to be more thoroughly considered in the documents submitted by the notifying country. Therefore, the inclusion of Trans-boundary impact assessment is considered particularly as an important element.

The DG2018 study is planned to start its implementation in the forthcoming month. There are various consultation process to interact with all kind of stakeholders as to listen carefully to concerns and suggestions.

The Final Draft will be submitted to Member Countries review prior to submission to the Join Committee (JC). A Regional Meeting of MRC (JC Task Group) – to seek consensus on final wording of Final DG2018; and finalize DG2018 and report to JC for consideration.

14) Guidelines for Transboundary Environmental Impact Assessment in the Lower Mekong Basin; MRC, Draft June 2017.

4.2.7. The Update for the SHDS

- Objective of the Sustainable Hydropower Development Strategy 2018:

Optimal and sustainable hydropower development pathway alternatives are designed by taking into account opportunities to enhance benefits beyond national borders and minimize adverse transboundary impacts while supporting water, food, and energy security.

The Strategic Plan 2016-2020 underlines the rising sense of urgency among stakeholders for the need to move basin development towards more "optimal" and sustainable outcomes that can address long-term needs, including environmental protection, as well as ensuring water, food, and energy security.

The Strategic Plan 2016-2020 with its basin wide perspective has provided, in the Annex A for the Output 2.1, some thoughts on the nature of the Basin-wide strategy for sustainable hydropower development:

(1) Energy from hydropower projects plays an important role in each of the LMB country's energy supply mix and also contributes to the growing regional inter-dependency from cross-border energy trading.
(2) At the same time, the reservoir storage provided by these projects helps to regulate mainstream flows from the wet to the dry season, opening up opportunities for increased dry season abstractions and potentially for flood control. However, hydropower development has adverse transboundary impacts as well, e.g., on capture fish migration, rural livelihoods and sediment movement.
(3) From a basin wide perspective, national plans are sub-optimal as they do not take into account opportunities to enhance benefits beyond national borders and minimize adverse transboundary impacts. According to MRC and other assessments, the location, number and size of mainstream and tributary hydropower have differing impacts across the basin.
(4) Taking into account regional energy needs (GMS and ASEAN integration agenda), national economic development priorities, comparative national advantages in hydropower development, the development of storage for flood and drought management, and the preservation of key environmental assets for economic, social, and environmental purposes, a basin-wide strategy is needed to address the difficult trade-offs and to design more optimal and sustainable hydropower development pathways. The basin-wide strategy will support improvement of national sector planning and contributes to the overall 'Basin Development Strategy'.

The Need for Sustainable Hydropower Strategy - Key Strategic Issues to be addressed in the SHDS 2018. Therefore, to achieve the Outcomes set out in the agreed MRC Strategy Plan 2016-2020, the strategic issues raised in the above studies must be addressed by the SHDS2018 to lead to potential measures/solutions to overcome the Basin concerns, needs and challenges :

- Support the economic development objectives of member countries (including navigation)
- Protect and enhance water, food and livelihood security
- Increase resilience against Climate Change including drought and flood management
- Ensure continued energy security for all member countries
- Protection of valued ecosystems
- Further develop transboundary cooperation

The national plans for the development of hydropower arise from the need for energy in each of the rapidly developing member countries. This is a critical strategic issue for each Member Country. These Power Development Plans will have generally been developed without full consideration of the cross sectoral benefits that arise from alternative power development pathways. In addition, alternative PDPs may have reduced impact on food security and natural ecosystems. Hydropower development strategy is only one part of the Energy Strategy of a given country. Therefore, it must be considered with all sectors in the context of national plan and ASEAN development of the power grid.

The SHDS2018 aims to provide an Interactive Planning process to allow consideration of alternative cross sectoral plans that may achieve the above Strategic Objectives of all Member Countries. External stakeholders will be also properly and timely involved where appropriate.

Consequently, it is to state that each group of stakeholder will be consulted to listen and address their concerns and recommendations.

4.2.8. ISH0306

The MRC's study on producing "Guidelines on Mitigation of Hydropower Impacts on Mekong Mainstream and Tributaries" is a special study to draw particular attention on the provision of measures, best practice and the most recent impact mitigation approaches for the sustainable development of hydropower in the LMB. While this project is arriving to its final stage, during its implementation it has thoroughly documented regionally relevant hydropower impact avoidance, minimization and mitigation options for a sustainable development of hydropower

on the Mekong mainstream and tributaries. There was specific research done with intense computer modelling to improve technical and scientific understanding towards improved mitigation options and the adaptation of existing methods to the region. The implementation of this study has been carried out through four phases, where in each phase the participants from the MRC Member countries have been informed of the results and then in return they have actively discussed and learned about:

- The baseline natural resource processes and conditions in the Mekong Basin and the nature of hydro developments proposed;
- The potential impacts of these developments as assessed by existing studies as well as the potential further research to cover significant knowledge gaps;
- The various regional researches and global experiences on mitigation options and their relevance for the hydropower developments in the LMB;
- How to undertake analysis and research into the effectiveness of these mitigation options;
- How to suggest recommendations on improvements and new approaches to impact mitigation.

Finally, the outcomes of the study have been shared recently with other stakeholders such as regional agencies and hydropower dams developers because this important study is also meant to help them understand the MRC opinion and recommendations for the avoidance, minimization, and mitigation of risks of mainstream hydropower dams in operation in the Mekong mainstream, as well as the proposed several siting, design, and operational alternatives that can reduce these transboundary impacts.

4.3. Recommendation

In the LMB, the construction of hydropower dams has started to increase considerably in recent years. Consequently, after the establishment of the MRC Initiative on Sustainable Hydropower (ISH) in 2008 there were many useful MRC studies undertaken during the period 2009-2017, to help the MRC Member Countries to plan and manage effectively the increasing number of hydropower projects as the cumulative impacts from them are being felt. While some of the Guidelines, such as the PDG, have been already used by the hydropower dams developers while designing their hydropower projects, most of the ISH studies are being disseminated to the MRC Member Countries as to encourage their usage.

The findings of the Council Study have further confirmed that there are significant and important opportunities to reduce transboundary impacts through the reconsideration of hydropower development plans.

The "MRC Basin Development Strategy 2016-2020" recognizes that national development plans are sub-optimal and thus coordinated development and effective management are crucial to contribute to continued growth with associated risks (including the transboundary impacts) properly minimized or mitigated.

Therefore, knowledge management and capacity building to imbed sustainable hydropower considerations in regional planning and regulatory systems for the MRC Riparian are very important tasks for the MRC. While capacity building is happening during the implementation of a study, such an approach appears to be insufficient as the required time for the Member countries participants is limited. They have indicated that they wish to have additional time to get to learn deeper as to enable proper and efficient use of the Tools and Guidelines. This is also a good opportunity for KDI intervention where the supplement with the Korean knowledge could also reflect the Korean experiences for sustainable hydropower planning and management particularly from the perspectives of cross sector integrated planning and cooperation.

5. Conclusion and Recommendations

Since the liberation from Japan, from 1945 to the 1960s, the Korean government managed single-purpose dams for water supply or hydropower generation. The First phase Five Year Economic Plan (launched in 1962) and the National Land Development Plan (launched in 1972) promoted the construction of multi-purpose dams to address floods and droughts. These supported the country's industrial development and food self-sufficiency until the 1980s. From the 1960s to 1980s, the water management policy was mainly focused on economic growth and industrial development. Since the 1990s, however, in addition to eco-friendly water management measures, more small- and medium-sized single-purpose dams for power generation or water supply have been constructed. Moreover, the flood control capacities of existing dams have been increased to address the impacts of climate change.

Applying the experience of Korea—with a land area of 99,720 km^2 and a population of about 52 million—in water resource management and dam construction to the Mekong River case might be unrealistic to some extent as their geographical and political backgrounds are completely different. However, the aggressive development of water resources in the 1970s to the 1980s—a cornerstone of Korea's rapid economic development—and the current paradigm shift in dam construction and water management could help with the harmonious and sustainable development of the trans-boundary river and local river for each Mekong countries.

The Mekong cooperation mechanism was established in 1957 with the Mekong Committee (MC), four countries, Laos, Thailand, Cambodia, and Vietnam agreed to cooperate for development of a common Mekong river for benefits of Mekong people. Over the past 60 years, the Mekong cooperation mechanism has been challenged and changed (Mekong Committee (MC) 1957-1975; Interim Mekong Committee (IMC) 1978-3/1995 and Mekong River Commission (MRC) 4/1995 to date) in order to adapt with political changes in the region. Particularly by signing of the Mekong River Basin Sustainable Development Agreement (1995) and forming the Mekong River Commission (MRC), Mekong cooperation has changed.

The MRC from beginning of establishment, it envisaged the challenges in the implementation of principles of reasonable and equitable uses of water addressed in Mekong Agreement 1995, Countries of MRC has long process to discuss and agree to issue concurrently 5 Procedures for implementation of Mekong Agreement. These procedures include: 1) Procedure of Information Exchange and Sharing (2001), 2) Procedures for Water Use Monitoring (2003), 3) Procedures for Notification, Prior Consultation and Agreement (2003), 4) Procedures for Maintenance of Flows on Mainstream (2006), and 5) Procedures for Water Quality (2011). In 2007 the MRC launched the Sustainable Hydropower Initiative (ISH) with the main objectives: Raising awareness and dialogue on sustainable hydropower development. Consider the sustainability of hydropower projects in the Mekong Basin; Strengthen technical capacity and support data base for sustainability assessment in hydropower development; strengthen the application of analytical tools and sustainability assessments in the basin for hydropower development; Strengthen the application of new financing mechanisms, especially Benefit Sharing Mechanisms (BSM) related to hydropower in the Lower Mekong Basin.

Recent years, under the situation of hydropower development in the basin, many studies have been conducted within the framework of the Mekong River Commission (MRC) as well as Vietnam, including the Strategic Environmental Assessment of the Mekong River Hydropower Impact (SEA) implemented by ICEM for MRC (2009-2010); The Study on the Impacts of Mainstream Hydropower on the Mekong River (MDS) conducted by Danish Hydraulic Institute Denmark (DHI) for MONRE of Vietnam (2013-2016) and most study is Study on the Sustainable Management and Development of the Mekong River Including Impacts of Mainstream Hydropower Projects (Council Study) conducted by MRC itself (MRC, 2017), the results of which have shown, to varying degrees, hydropower development in the Mekong Basin has had a great impact on the environment, ecology, livelihoods of the river and communities in the basin. There was also an impact on water and food security of some countries in the basin, especially downstream countries like Cambodia and Vietnam.

However, these cooperative solutions have not help countries come up with

solutions to limit the massive hydropower development in the Mekong Basin. Hydropower projects on the Mekong mainstream in Lao (Xayaburi, Don Shahong, or Pak Beng) continue to be developed, although there is no consensus among all MRC countries. One of the reasons for this is that there is a complex geopolitical relationship in the basin, where each of the interests and interests of the river basin differs; cooperation mechanism based on consensus and non-binding; have influence from China in political-economic relations; and countries have not found a suitable benefit sharing mechanism

The demand for economic development increases sharply, countries in the Lower Mekong Basin, recognizing the benefits of using water for hydropower development, benefit greatly in their own country, while the old mechanisms did not meet the requirements. To date, what solutions to ensuring the interests of each country in the basin but still harmonizing the sustainable development of the Mekong River Basin, ensuring the principle of reasonable and equitable uses of common of water resources of Mekong River is also a big question to be answers.

In the future, a benefit-sharing mechanism among countries in the basin, including the recognition of benefits shared from incomes of various socio-economic areas/sectors and environmental benefits of nations in the Basin, may be appropriate mode of harmonization of economic and environmental interests of all countries and ensure the development of river basins in a sustainable manner for future.

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Basin-wide Strategy for Sustainable Hydropower Development

Chapter 3

Environmental Impact Assessment on Hydropower Development

1. Introduction
2. Environmental Issues and Challenges of Hydropower Development and Measures for Environmentally Sound and Sustainable Hydropower
3. MRC's Experiences: Environmental Impacts of Hydropower Development in the Lower Mekong Region (LMR)
4. Korea's Experiences: Environmental Impacts of Multi-purpose Dams
5. Conclusion

Environmental Impact Assessment on Hydropower Development

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Summary

This chapter aims to share lessons learned from hydropower development and to explore best practices and policy implications for environmentally sound and sustainable dams by reviewing general environmental issues, challenges, and measures associated with hydropower. It also aims to do so by conducting comparative analysis on environmental impacts of dams in the contexts of the Lower Mekong River (LMR) and Korea's Major rivers. Recently, most of Korea's hydropower dams are operated for many purposes since social needs for hydropower dams have changed and expanded. Therefore, the context of Korea's multi-purpose dams incorporates the key issues and information of hydropower dams, which can provide a more comprehensive and long-term perspective for the key stakeholders of the LMR's hydropower development. Given that 263 international water basins exist across 145 countries, hydropower development in the trans-boundary context of the LMR will provide useful information and policy implications for many countries including Korea, where South-North cooperation is becoming more urgent to ensure peace on the Korea Peninsula.

This study defines the cascade relationships between environmental changes and impacts of hydropower dams, which include land-use change and disturbances during construction and hydrological and geomorphological changes during its

Keywords: Environmental Impact Assessment of Hydropower Development, Environmental Impacts of Multi-purpose Dams, LMR

operation, as well as a variety of threats to humans and other living beings whose lives depend on the river. The complex relationships between climate change and hydropower development are briefly addressed. Three key challenges, such as complexities, uncertainties, and environmental justice are also reviewed in a general context.

Environmental impacts and associated challenges should be addressed in the entire processes of hydropower's life cycle, which include planning, designing, operating, and dismantling. Five principal measures (avoidance, minimization, mitigation, compensation, and ecosystem restoration) that are proposed by the World Commission on Dams should be considered and undertaken wherever applicable. It is difficult to find the best measures to fully address different environmental problems across a variety of ecological and dam settings. As such, it is important to understand the applicability, limitations, and effectiveness of the five measures.

We have examined the environmental problems associated with dam development and the measures to avoid, minimize, mitigate, or compensate environmental damage and loss in the contexts of Korea and the LMR. Water quality, ecological losses, social justice, and climate change risks are the common key issues associated with dam development. In addition to these issues, transboundary impacts, fishery productivity, and a lack of monitoring data are particularly important to the LMR.

A variety of technical measures and institutional frameworks have been developed to deal with emerging or anticipated changes and impacts of dam development, which become more comprehensive since river-basin, integrated, and balanced approaches are applied. The effectiveness of each measure varies, so the application and/or modification of each measure should be carefully considered, and the long-term and cumulative impacts of measures should be systematically tracked.

Based on the lessons learned from the cases and practices examined here, best practices are identified as follows: transparent and inclusive procedures; integrated approach of the EIA and the SEA; incorporation of the key components of the Transboundary Environmental Impact Assessment (TbEIA) Guidelines into country EIA; institutionalization of the principle for cost-benefit sharing; prioritization of avoidance and minimization measures; combination and synergy of multiple measures; a river-basin approach; integrated watershed information management system; and rules and procedures for integrated dam operation/management.

There are two policy implications for the LMR. The first one is based on successful experiences of Korea's growth. The dam development has been effectively promoted

by integrating the dam development plans into long-term and comprehensive national plans (for economic development, water sector, energy sector, and other relevant sectors). Therefore, the LMR may consider integrating hydropower development into the key regional and national plans (e.g. sustainable development goals) where relevant. The second one is based on failed experiences in Korea. At the beginning of dam development, the Korean government applied a top-down, single-purpose (water supply oriented) approach, which could achieve short-term efficiency or effectiveness but could not address a variety of environmental and socioeconomic issues. As a result, Koreans faced negative consequences, and some of the impacts were irreversible and significant. In order to avoid such consequences, a comprehensive and balanced approach should be taken, particularly at the beginning (e.g. conceptual stage) of hydropower development in the LMR.

1. Introduction

According to the International Energy Agency (IEA, 2017), global energy demands will rise by 30% for the next 25 years (2016-2040), mainly due to the growing energy needs of developing countries in Southeast Asia, Africa, and the Middle East, as well as India and China. Various energy sources are utilized to meet growing energy needs. Driven by global agendas such as the Sustainable Development Goals (SDGs) and the Paris Agreement, affordable and clean energy coupling with renewable technologies has become key to the national agenda of many countries. Hydropower is particularly important in the renewable power sector since it supplies more than 90% of the renewable electricity worldwide[1)]. Many countries have constructed hydropower dams to support economic development, population growth, and/or urbanization by supplying energy.

Throughout the 20th century, the sizes of hydropower dams had been larger, and their functions had been expanded by including additional purposes, such as water supply, flood control, inland navigation, fisheries, environmental management, or recreation. Along with the increasing sizes of dams, there had been growing concerns regarding the associated costs and negative consequences. Many experts and related organizations (e.g. International Commission on Large Dams: ICOLD, 1997) had highlighted the importance of environmental considerations, as well as dam safety, especially in the early planning phase of dam development. However, the environmental impacts of hydropower had not been fully considered in many countries.

In South Korea, a lot of hydropower dams and multi-purpose dams have been

1) http://www.icold-cigb.net/GB/dams/role_of_dams.asp

developed since the 1960s, when long-term national plans (e.g. Five-year Economic Development Plan, Five-year plan for Power Development, and Ten-year Plan on Comprehensive Water Resource Development), regulatory frameworks (e.g. Specific Multi-purpose Dams Act, Electric Power Source Development Promotion Act and River Act), and institutional arrangements (e.g. Korea Water Resources Development Corporation and Korea Electric Company)[2] were established. Most of Korea's multi-purpose dams were large, but their environmental and social impacts were not fully addressed, and their negative consequences were significant. Increased environmental awareness of large dams led to a paradigm shift in dam development, namely towards build environmentally sound and sustainable dams, which have been reinforced by various institutional and technical measures.

According to the Mekong River Commission (MRC, 2010b), energy demands are rapidly growing, and hydropower is considered as a good energy option for the regions in the Mekong River, thus making it a prime area for hydropower development. Particularly, the Lower Mekong Region (LMR) is estimated to have a high potential for large-scale hydropower dam development, and all MRC member countries (Cambodia, Lao PDR, Thailand and Viet Nam) have plans for hydropower development in this river basin.[3] There are growing concerns regarding the risks and social or environmental impacts of hydropower development in the Mekong region, so the MRC has established institutional frameworks including the Environment Programme, Transboundary Environmental Impact Assessment (TbEIA), Initiative on Sustainable Hydropower, and other inclusive mechanisms.

This chapter aims to share lessons learned from hydropower development and explore best practices and policy implications for environmentally sound and sustainable dams by reviewing general environmental issues, challenges, and measures associated with hydropower. It also aims to conduct comparative analysis on environmental impacts of dams in the contexts of the Lower Mekong River and Korea's major rivers. Key environmental impacts of hydropower development and effective measures to address such impacts are varied, depending on their socioeconomic, environmental, technological, and institutional situations. In order to explore the best options for environmentally sound and sustainable hydropower in the specific local context, however, it is necessary to learn numerous lessons and practices from different situations.

Recently, most of Korea's hydropower dams are operated for various purposes since social needs for hydropower dams have been changed and expanded.

2) 'Korea Water Resources Development Corporation' was renamed as 'Korea Water Resources Corporation (K-water)', which is responsible for multi-purpose dams. 'Korea Electric Company' was renamed as 'Korea Electric Power Corporation' and its subsidiary (Korea Hydro & Nuclear Power Co., Ltd.) is responsible for hydropower dams.

3) Refer to Appendix I (Hydropower Development in the Lower Mekong Region).

Therefore, the context of Korea's multi-purpose dams incorporates the key issues and information for hydropower dams, which can provide a more comprehensive and long-term perspective for the key stakeholders of the LMR's hydropower development. Given that 263 international water basins exist across 145 countries,[4] hydropower development in the transboundary context of the LMR will provide useful information and policy implications for many countries including Korea, where South-North cooperation is getting more urgent to enhance the peace on the Korea Peninsula.

2. Environmental Issues and Challenges of Hydropower Development and Measures for Environmentally Sound and Sustainable Hydropower

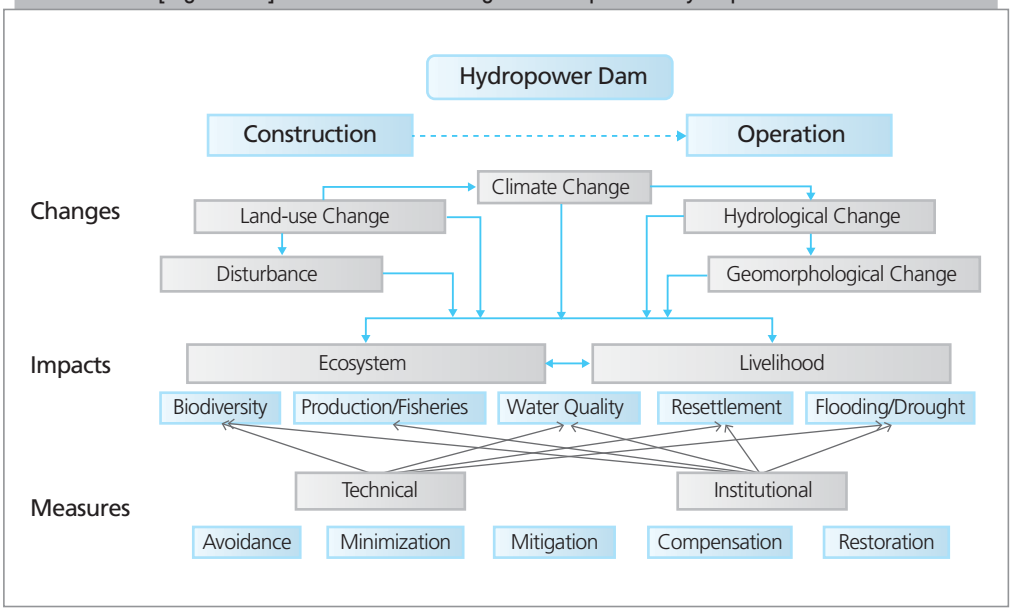
2.1. Environmental Changes and Impacts of Hydropower Dams

[Figure 3-1] presents the cascade relationships between environmental changes and impacts of hydropower dams. During construction, land-use change and a variety of disturbances are inevitable, which directly interrupt or destroy the continuity of ecosystems and livelihoods of the people. During the operation, some disturbances caused by construction activities remain, but the most noticeable changes are hydrological and geomorphological. Such changes alter the physical, biological and chemical characteristics of aquatic environment, which cause a great threat to humans and other living beings whose lives depend on the river.

The relationships between climate change and hydropower development are complex. Hydropower is considered as a low-carbon energy source, so hydropower development is often promoted in the context of climate change mitigation. However, land-use change in the dam area can result in the increase of greenhouse gas (GHGs) emissions, the variations of local climate (such as precipitation patterns), and the intensification of weather-related disaster risks. Hydropower dams have positive or negative impacts on climate change, while global climate change generally has negative impacts on the operation and management of hydropower dams.

4) http://www.unwater.org/water-facts/transboundary-waters/

[Figure 3-1] Environmental Changes and Impacts of Hydropower Dams



Source: Author.

2.1.1. Land-Use Changes and Disturbances

According to the International Hydropower Association[5], there are four types of hydropower: run-of-river hydropower; storage hydropower; pumped-storage hydropower; and offshore hydropower. A storage or pumped-storage hydropower dam is generally accompanied with a reservoir to impound enough volume of water for electricity generation, which triggers land-use and land-cover changes in the vicinity of the dam. Hydropower dams in a flat area create wide (rather than deep) reservoirs, so they flood more land to generate electricity than those in a hilly area. One of the extreme examples shows that 2,000 acres were used to generate 1 MW while 0.25 acres were used to generate the same amount of electricity.[6]

Many studies verify the impacts of large artificial reservoirs on the patterns of local climate, focusing on evaporation, precipitation, or temperature, and some studies reveal the variations of heavy rainfall in terms of its spatial redistribution and intensity (Woldemichael *et al*., 2012). Land-use and land-cover changes directly cause the resettlement, alternation, or loss of livelihoods and ecosystems, and they also have significant influences on people, cultures, animals, and plants indirectly through the alternations of scenic landscapes, local climate, or socio-economic situations in

5) https://www.hydropower.org/types-of-hydropower
6) https://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/environmental-impacts-hydroelectric-power.html#references

local communities.

Construction activities cause many disturbances associated with land-cover changes, including erosion, sediment, noise, vibration, air pollution, water pollution, traffic, waste, wildfires, or invasive species in the vicinity. Some disturbances are temporary, but vulnerable wildlife can be significantly affected by exposure to pollutants and other risks or interruption on feeding and reproduction. For local communities, public health and safety are concerns, but increased local employment, property values, and other economic gains associated with construction can be beneficial.

2.1.2. Hydrological Changes and Geomorphological Changes

The operation of a dam alters the patterns of the river flow. It is required to release a certain amount of water in order to maintain the minimum flow in downstream at all times of year. Such continuous uniform release from the upstream dams causes hydrological changes in terms of volume and timing. Dry-season flows are expected to increase, and wet-season flows are expected to decrease, with impacts more significant in the downstream area of the low-flow regime (ADB, 2013). Smoother hydrographs can reduce the occurrence of minor floods or droughts, but some case studies reveal that annual/inter-annual changes of the river flow caused by hydropower dams are not associated with the occurrence of extreme floods, or that narrowing the channel can increase flooding risks in upstream areas during heavy rainfall (MRC, 2016).

Sediment transport or bank erosion is affected by the flow changes, so there are annual and seasonal variations of sediment yield. A dam blocks the flow of sediment, reduces sediment supply in downstream and increases erosion or deposition at tributary junctions (MRC, 2016). Due to the trap efficiency of a dam, the amount of accumulated sediment is gradually increasing, which reduces reservoir storage capacity and also facilitates the abrasion of turbine blades.[7] While seasonal variations in the water level can be low, daily fluctuations in flow discharges can be high due to hydropeaking, which is also associated with frequent temperature changes in downstream and increased erosions of riverbanks (Locher, 2004). Hydrological and geomorphological changes can increase the vulnerability of aquatic ecosystems, water pollution, and weather-related disaster risks.

2.1.3. Impacts on Ecosystems and Livelihoods

As described above, when a hydropower dam is developed, land-use changes, disturbances, hydrological changes, and geomorphological changes are inevitable,

7) https://www.internationalrivers.org/sedimentation-problems-with-dams

resulting in significant impacts on ecosystems and livelihoods of the people in the vicinity of the dam. Particularly, biodiversity, fisheries, and water quality are the key concerns. A dam blocks fish to move up and down a river and limits the availability of food sources, so it affects fish species and fish production. The long-distance migrants are particularly vulnerable to dams. For migratory fish, it is necessary to find different environment that is suitable for each phase (e.g. breeding, growth or maturation) of their life cycle, so fish movements should be safeguarded along the river connectivity.[8] Dams, spillways, and turbines built in many rivers become one of the most critical threats to fish migration and even their survival.

Depending on the location, design, and operation of dams, the effect of dams on fish production varies. According to ADB (2013), dams built on the mainstream have greater impacts because floodplains in the middle and lower parts of the basin are important for fish production. Floodplain wetlands are very important habitats for fish, plants, and animals, but their ecological functions and dynamics are changed or destroyed due to reduced flooding or permanent flooding to the wetlands, triggered by large-scale reservoirs (Kingsford, 2000). Other important functions of wetlands, such as pollution removal and carbon capture, are also weakened.

Dams change water quality by altering thermal, biological, and chemical characteristics of reservoir water, which is often deteriorated by increasing human activities and pollution sources in the vicinity of the dams. Reservoir water generally has more sediments and nutrients (such as nitrogen and phosphorus) and slower flow velocity, so it has high risks of algal growth or eutrophication during the summer. Blooms of smelly phytoplankton or algae reduce water clarity, light penetration, and dissolved inorganic carbon but raise pH, which is eventually associated with microbial decomposition, resulting in dissolved oxygen (DO) depletion and anoxic 'dead zone' in reservoir water (Chislock *et al*., 2013). Water temperature of a reservoir is relatively low, so the release of this cold water can have negative impacts on aquatic lives in downstream.[9]

2.1.4. Greenhouse Gases (GHG) Emissions

GHG emissions are produced not only during the construction and dismantling of hydropower dams, but also during the operation of reservoirs due to decomposing organic material. Generally, GHG emissions from technologies powered by renewable resources are less than from those powered by fossil fuel-based resources. According to the IPCC (2014), the median value of life-cycle GHG emissions associated with hydropower is 24g CO2eq/kWh, but some other studies calculate higher estimates of GHG emissions, which are generally associated with large reservoirs in tropical

8) http://www.fao.org/docrep/004/Y2785E/y2785e03.htm
9) http://www.fao.org/docrep/004/Y2785E/y2785e03.htm

regions (NAS, 2010). There are growing demands for reporting of hydropower's carbon footprint in a new era of climate action, but it is still difficult to estimate net GHG emissions of freshwater reservoirs due to a lack of scientific consensus on the calculation methods (REN21, 2017).

2.2. Challenges in Hydropower Development

2.2.1. Complexities

Hydropower reservoirs are often used for multi-purposes. Recently, hybrid technologies such as floating photovoltaic solar panels are applied in hydropower reservoirs (REN21, 2017). When hydropower development is considered, therefore, competing uses over water, land, and energy should be identified and various stakeholders' interests should be considered in political, economic, social, and environmental contexts (ICOLD, 1997). When it comes to international rivers, the processes for hydropower development are more complex due to dynamic international stakeholders, ecological interdependencies, different regulatory frameworks, and asymmetric information. As seen in [Figure 3-1], the cascade relationships between environmental changes and impacts of a hydropower dam are complex. Combinations of multiple changes directly and/or indirectly cause different impacts, so there are growing technical difficulties of dam management (e.g. sedimentation management), as well as dam development.

2.2.2. Uncertainties

In the energy sector, hydropower is one of the most cost-effective, reliable and secured options (IPCC, 2012). However, due to climate change risks and unstable electricity prices, uncertainty of hydropower operation is getting greater, particularly in terms of power generation capacity. The capacity is designed, based on the probable maximum flood (PMF) and a probable maximum precipitation (PMP) event, but the standard calculation methods and data sources of PMP have a high level of uncertainties in a changing climate context (Woldemichael *et al*., 2012). Cumulative environmental impacts of hydropower dams in the long-term are poorly understood, so more data and evidence are needed to reduce uncertainties of environmental impacts associated with hydropower. Gaudard *et al*. (2016) analyze the uncertainty of hydropower in statistical and ignorance dimensions and propose to modify business and regulatory strategies for variability.

2.2.3. Environmental Justice

People of the vulnerable communities often depend more on natural services, so hydropower dams can alter their livelihoods and intensify socio-economic inequity.

Rai (2005) provides empirical evidence on social inequality enhanced by dam development, focusing on the socioeconomic dynamics and distributional outcomes. It is a challenge to implement sharing concepts of dam development in terms of responsibilities and benefits/costs and adopt a pro-poor agenda. If democratic engagement processes are not established, it is more difficult to incorporate the interests and needs of local communities or vulnerable groups (e.g. indigenous groups or women) in political decisions on the allocation. When multiple users compete for water resources or a river basin, therefore, very inclusive political processes should be established to allocate the resources.

A case study (Zeitoun, 2013) on transboundary rivers and global environmental justice demonstrates that apparently fair processes do not necessarily lead to equitable outcomes, that injustice at the sub-national level is unlikely to be noticed in the international negotiations, and that integration between environmental issues and social justice is often ignored. According to Wolf (2015), environmental injustice to basin countries are significant in despite of international cooperation, so he highlights the importance of institutions such as treaties or river basin organizations. Environmental costs and benefits are distributed inequitably among affected countries and communities, whose results are highly associated with intergenerational injustice. Therefore, it is important but challenging to clearly analyze and properly address environmental justice implications of dam development in a broader temporal and regional context.

2.3. Measures for Environmentally Sound and Sustainable Hydropower

In order to ensure environmentally sound and sustainable hydropower, environmental impacts and challenges and other key issues, such as safety and institutional capacity, should be addressed in the entire processes of hydropower's life cycle, which include planning, designing, operating, and dismantling. World Commission on Dams (WCD, 2016) proposes five principal measures to address environmental impacts of dams: i) "avoidance" measures should be considered where anticipated negative impacts on the environment are significant and irreversible, which calls for alternative options (e.g. site change or cancelation) at the planning stage; ii) "minimization" measures should always be applied by optimizing design features for a dam and the environment; iii) "mitigation" measures are widely undertaken to reduce anticipated or identified impacts to acceptable levels based on environmental limits; iv) "compensation" measures should be considered for unavoidable ecological or biodiversity losses to sustain the total ecological functions in the whole river basin; and v) "ecosystem restoration" measures can be performed generally through dam removals to restore key ecological functions.

It is difficult to find best measures to fully address different environmental problems across a variety of ecological and dam settings. Thus, it is important to understand the applicability and limitations of the five measures: avoidance, minimization, mitigation, compensation, and ecosystem restoration. These measures are further developed by being incorporated into policy and institutional frameworks, along with technology innovation.

2.3.1. Policy and Institutional Measures

According to the WCD (2016), avoidance and minimization measures are very effective, which can be realized through policy and institutional measures. In most countries, regulatory frameworks and participatory or transparent processes for (hydropower) dam development are established, which call for credible information to make good decisions. The Environmental Impact Assessments (EIA) can provide important information of various measures by identifying and addressing key environmental issues of hydropower development at the planning stage. Ongoing monitoring plans are required to identify both cumulative and emerging environmental changes, and monitoring should be undertaken against the hydropower dam's plan and the environmental baseline.

There are some limitations of the EIA in terms of its scope and methodologies. The EIA is conducted within a limited timeframe, so it generally focuses on specific targets (e.g. endangered species or water quality) and does not fully consider comprehensive and long-term transformations or interactions of the ecosystem's functions. Through the EIA process, decision-makers have opportunities to further explore minimization, mitigation, and compensation measures, but they rarely consider avoidance measures because the site selection is predetermined and alternative options are not often provided for the EIA. To overcome the limitations of the EIA, the Strategic Environmental Assessment (SEA) is developed, which is a similar evaluation approach of the EIA applicable to policies, programmes, and plans. The SEA can promote more environmentally sensitive decisions and sustainable development (Alshuwaikhat, 2004), and an integrated approach of the EIA and the SEA should be applied (Abaza *et al*., 2004).

Mitigation measures are widely applied but their effectiveness varies depending on dam's size and type as well as circumstances of the dam site. Legal and compliance frameworks, cooperative processes, monitoring, knowledge base, financial resources, and institutional capacity can improve the effectiveness of mitigation measures (WCD, 2016). Hydropower development results in social conflicts, so more transparent, coordinated and inclusive processes and institutional arrangements are needed. It is required to involve communities and ecosystems not only in the vicinity of hydropower dams, but also in downstream. If involved in the early

stage (e.g. planning or design stage), stakeholders can participate in the decision-making process and explore more various measures to avoid, minimize, reduce, and compensate environmental and socioeconomic impacts. Strategies and methods of sharing benefits and costs are important to reduce social conflicts, but it takes time to reach a consensus on its institutional frameworks.

2.3.2. Technical Measures

Monitoring techniques are fundamental to identify environmental issues and to make more environmentally sensitive options for sustainable hydropower. Real time sensors and regular monitoring schemes improve sustainability of hydropower operations. Given that case-specific data and modeling are needed to assess or predict environmental impacts, monitoring data will contribute to fill the knowledge gaps and reduce the uncertainty of modeling associated with hydropower development.

Eco-friendly dam design and construction technologies are well advanced. Jager *et al*. (2015) propose several spatial design principles for ecological sustainability, which include disperse dams/reservoirs, channels between dams, and river basin approach. Through modeling and optimization of hydropower, location impacts can be avoided or minimized. Environmental flow requirements are often established to ensure ecological health. There are many methods available to define environmental flows, which includes look-up tables, desktop analysis, functional analysis, and hydraulic habit modelling (Acreman and Dunbar, 2004). Erosion and sediment control systems such as check dams are designed to prevent erosion and trap sediment and routine site inspections followed by corrective action can improve the sediment balance.[10)]

A variety of mitigation measures are available: to reduce the number of fish and other organisms that are injured or killed by turbine blades (e.g. screens and fish exclusion devices); to increase dissolved oxygen (e.g. artificial destratification); to control water quality released from the reservoir; or to stabilize soils and vegetative cover. Where fishery is an important industry, fish passage technologies (e.g. pool-type fish passes, bypass channels, fish locks, fish lifts or navigation locks) are widely applied, but fish entrance should be designed in accordance with fish behavior, and the operation of the dam should maintain the appropriate entrance slot velocities and flow volumes by taking into account hydro-morphological conditions.[11)] [Figure 3-2] presents fish pass technologies applied in the LMR and Korea, respectively.

10) https://stormwater.pca.state.mn.us/index.php?title=Sediment_control_practices_-_Check_dams_(ditch_checks,_ditch_dikes)

11) http://www.fao.org/docrep/004/Y2785E/y2785e03.htm

When lost ecological resources (e.g. wetland or forest) or functions (e.g. fish spawning or habitats) are significant, compensation measures or ecosystem restoration measures are considered. Compensation measures including efforts to establish a fish hatchery, protect watershed and restore forest can be undertaken within or out of the river basin and should be integrated with long-term monitoring and evaluation schemes for the consequences of replaced functions (WCD, 2016). According to Hart *et al*. (2002), growing concerns on environmental impacts and evolving new socioeconomic needs, as well as dam security, call for ecological restoration measures through dam removals. They review challenges and opportunities associated with dam removals by focusing on various ecological responses to dam removals and relationships between environmental impacts and dams' characteristics.

[Figure 3-2] Fish Passage at Lower Sesan 2 Dam, LMR (Left) vs. Gongju Weir, Korea (Right)



Sources: Radio Free Asia (https://www.rfa.org/english/multimedia/lowerSesanII-slideshow-07142017160537.html), K-Water.

3. MRC's Experiences: Environmental Impacts of Hydropower Development in the Lower Mekong Region (LMR)

According to the MRC (2016), 11 hydropower dams have been proposed in the Lower Mekong Mainstream, of which two dams are being constructed in Lao PDR. More than 70 hydropower dams have been operated or under the construction in the tributaries of the Lower Mekong Basin. Hydropower development have been promoted by all Member Countries to stimulate their economies, alleviate poverty, and contribute to SDGs. Hydropower development has always caused environmental and socioeconomic impacts, so the MRC has been applying a holistic approach to fully assess risks and opportunities of hydropower development in the LMR, which includes technical advice services, strategy-setting, regional coordination, and communication with stakeholders.

3.1. Environmental Changes and Impacts Associated with Hydropower Development in the Lower Mekong Region

3.1.1. Environmental Changes and Impacts in the LMR

The MRC's Initial Sustainable Hydropower Study (2016) identifies five key common changes triggered by hydropower development:

a. Annual/inter-annual changes to flow
b. Daily/short-time scale changes to flow and water level
c. Loss of river connectivity
d. Impoundments
e. Diversion or intra basin transfers.

<Table 3-1> summarizes the key risks, impacts and vulnerabilities on (i) hydrology and downstream flows; (ii) geomorphology and sediments; (iii) water quality; (iv) aquatic ecology and fisheries; and (v) biodiversity, natural resources and ecosystem services. The MRC's focuses are the hydrological and geomorphological changes and the impacts on ecosystems and fisheries. The MRC's study presents the relationships of various changes and impacts in an analytical matrix. Such complex relationships can be recategorized into the cascade relationships presented in [Figure 3-1].

〈Table 3-1〉 Key Risks, Impacts, and Vulnerabilities Arising from the Hydropower Development Projects in the LMR

Changes		Risks, Impacts & Vulnerabilities				
		Hydrology & Downstream Flows	Geomorphology & Sediments	Water Quality	Aquatic Ecology & Fisheries	Biodiversity, Natural Resources & Ecosystem Services
Annual / inter-annual changes to flow	Changes in seasonality & continuous uniform release	- floods & low flows (timing & duration)	- bank erosion - downstream sediment supply	- seasonal temperature patterns in downstream	- habitats - migration & spawning triggers - productivity - flood pulse	- flow to wetlands & floodplain riparian habitats
	Modification of flood intervals	- peaks in flow& smoother hydrograph				- Dispersal of species
	Bank scour focused over limited range		- channel narrowing - flooding risk in upstream			
	Change in relationship of flow & sediment transport		- decoupling of tributary & mainstream flows - Erosion or deposition at tributary junctions	- decoupling of tributary & mainstream flows - Erosion or deposition at tributary junctions		- wetlands' functions, dynamics & ecosystem services
	Change inundation/ exposure of downstream floodplains & wetlands					- wetland & floodplain habitats
Daily / short-time period changes in flow	Hydro-peaking	- safety & navigation	- water level fluctuations - wetting & drying of banks - erosion - stress during flow changes	- water quality downstream discharges		
	Fast increase of flow velocity				- drifting rate of fish & macro-invertebrates - migration triggers - food sources	- wetlands & riparian habitats

〈Table 3-1〉 Continued

Changes		Risks, Impacts & Vulnerabilities				
		Hydrology & Downstream Flows	Geomorphology & Sediments	Water Quality	Aquatic Ecology & Fisheries	Biodiversity, Natural Resources & Ecosystem Services
Daily / short-time period changes in flow	Fast decrease of flow velocity				- stranding of fish and macro-invertebrates	- wetlands' functions, dynamics & ecosystem services
	Morphological alterations				- habitat degradation	
	Thermo-peaking				- stress, disturbance - migration triggers	
Loss of river connectivity	Disconnect between flow and sediment delivery		- deposition & erosion - seasonal sediment 'pulse'		morphological alterations & habitat loss	
	Changes to nutrient transfer			- nutrients within impoundment		- wetlands' functions, dynamics & ecosystem services
	Habitat fragmentation				- spawning & feeding migrations - isolation of sub-populations	
	Turbine passage				-fish damage and kills	
	Spill flow passage				-fish damage and kills	
Diversions or intra basin transfers	Decreased flow in donor basin		- channel - beds and bars - frequency & impacts of high flow events			
	Increased flow in receiving basin		- bank erosion & bed incision			

〈Table 3-1〉 Continued

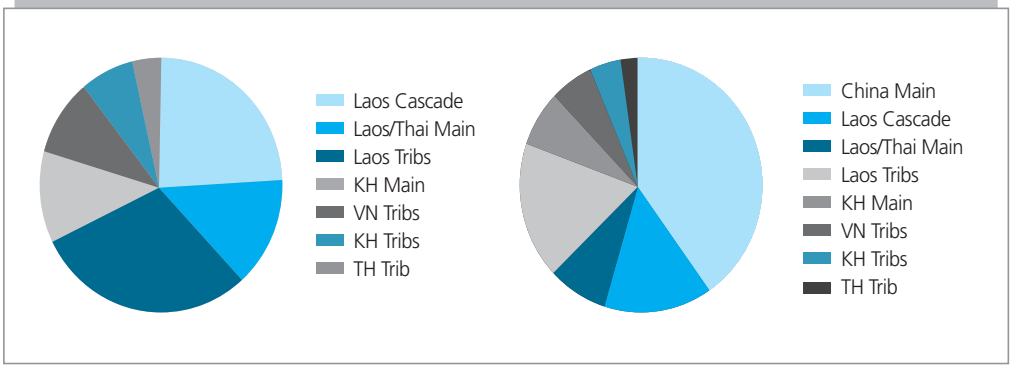
Changes		Risks, Impacts & Vulnerabilities				
		Hydrology & Downstream Flows	Geomorphology & Sediments	Water Quality	Aquatic Ecology & Fisheries	Biodiversity, Natural Resources & Ecosystem Services
Diversions or intra basin transfers	Diversion of water from one catchment to another			- nutrient & other water quality parameters		
	Reduction of river dimension				- productivity - species	
	Homogenization of flows				- habitat loss	
	Water quality changes				- stress	
	Alternation of flow regime of contributing & receiving catchments					- flow to wetland & floodplain
Diversions or intra basin transfers	Decreased flow in donor basin		- channel - beds and bars - frequency & impacts of high flow events			
	Increased flow in receiving basin		- bank erosion & bed incision			
	Diversion of water from one catchment to another			- nutrient & other water quality parameters		
	Reduction of river dimension				- productivity - species	
	Homogenization of flows				- habitat loss	
	Water quality changes				- stress	
	Alternation of flow regime of contributing & receiving catchments					- flow to wetland & floodplain

Source: MRC (2016).

Based on the latest monitoring data of sediment, multiple scenarios, and economic modeling, the MRC's case study report (2018) verifies: that sediment trapping rates are high in the tributary dams; that an erosion wave occurs (an extreme example: downstream of Sanakham at a rate of 20 km per year); that the Laos cascade dams have lower influence on the seasonal flow changes than Lancang[12] and tributary storage dams do; that power peaking causes the sub-daily flow variations; and that sediment trapping in the Lower Mekong Basin is smaller than in the Lancang and Mekong rivers (Figure 3-3).

The MRC's modeling (MRC, 2018) reveals that the risks of algal blooms in the cascade are high, while the risks of stratification are low or moderate. Since water quality is related to a reservoir's water quality and catchment inflows, adaptive watershed management and catchment management are highly recommended. The MRC's report (2018) also provides empirical evidence for ecological losses in the Mekong river: due to the loss of river connectivity or habitat fragmentation, fish productivity in terms of fish biomass has declined; migratory fish is threatened by turbine or spillway passage and interruption of larval drift; and flushing puts stress on aquatic ecosystems within the reservoirs and downstream.

[Figure 3-3] Sediment trapping in the Lancang and Mekong Rivers (Left) and in the Lower Mekong Basin (Right)



Source: MRC (2018).

3.1.2. Case Study of the Don Sahong Dam: Environmental and Socioeconomic Impacts of a Mainstream Dam

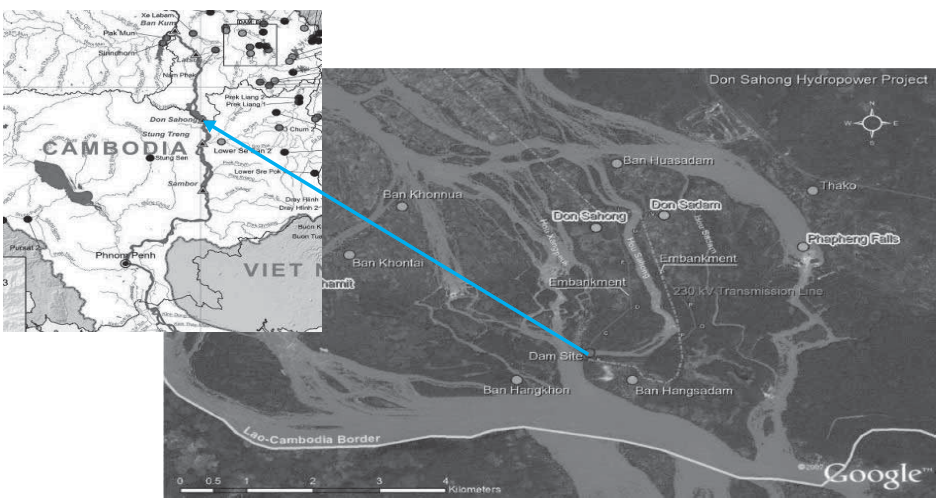
According to MRC's technical review report (2015) on prior consultation for the proposed Don Sahong Hydropower Project (DSHPP), the DSHPP is designed as a run-of-river plant in the Hou Sahong channel of the Mekong mainstream in Southern Lao

12) Lancang river is located in China, upper half of Mekong river.

PDR (Figure 3-4). The DSHPP's capacity is 260 MW (small-size) and requires a design flow of 1,600 m^3/s. One of the anticipated changes is the flow reduction in the other channels, which will affect the efficacy of these channels for fish passage. Another anticipated change is the increase of sediment discharge through the Hou Sahong, which will be resulted from the increased flows in the mainstream channel and will increase the rate of sedimentation in the head pond. Sedimentation in the excavated inlet to the Hou Sahong can cause significant impacts on the flows into that channel.

The location of the DSHPP is close to (< 1 km apart from) the Mekong Irrawaddy Dolphin Site that is designated as "Critically Endangered" by the International Union for Conservation of Nature (Smith and Beasley, 2004). According to Ryan (2014), dolphins in this Site will experience stress by noise disturbances and damage though direct contact with the machinery or rock debris associated with the DSHPP. Excavation during the construction will significantly increase sedimentation in the transboundary deep pool, resulting in the degradation or loss of dolphin habitats. There are growing concerns on fisheries, the availability of prey for the dolphin population, geomorphological changes, aquatic habitats, tourism potential, and hydrological changes, particularly in the dry season. In order to minimize hydrological changes and negative impacts on this Dolphin Site, the developer proposes underwater blasting. The DSHPP is currently under construction, but the key information of necessary minimization, mitigation or compensation measures is not fully communicated.

[Figure 3-4] Location of Don Sahong Dam and Its Vicinity

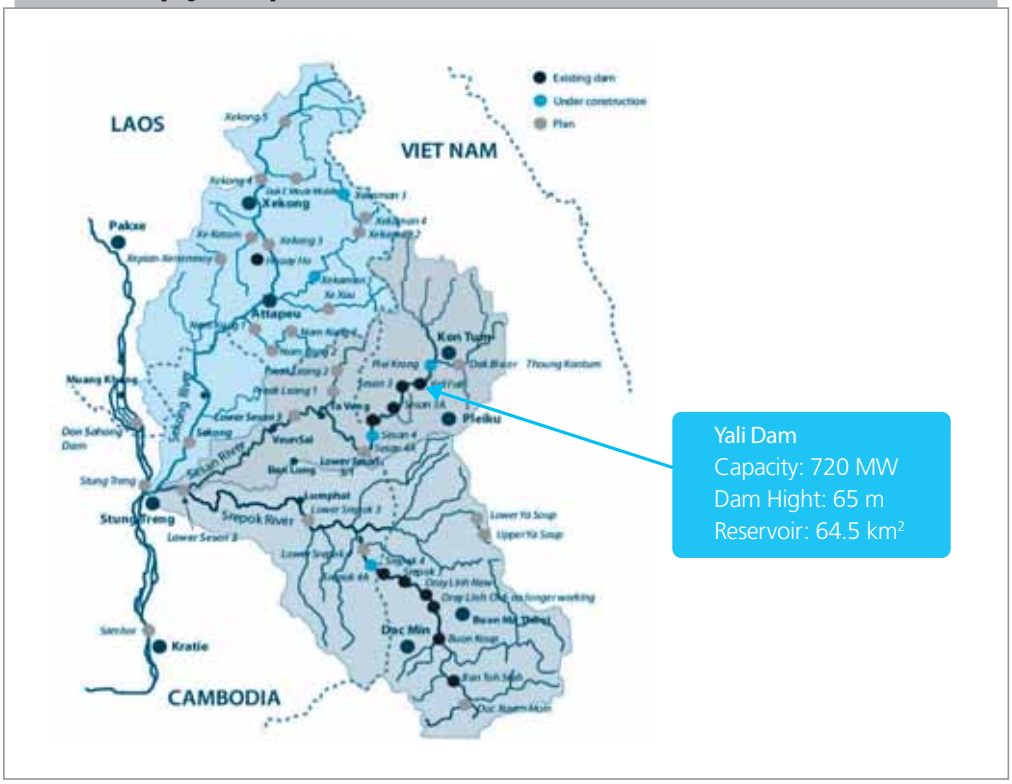


Sources: MRC (2015).

3.1.3. Case Study of the Yali Falls Dam: Environmental and Socioeconomic Impacts of a Tributary Dam

The Se San river is one of 3S[13] river basins that are large tributaries in the LMR, which flows through Vietnam's Gia Lai and Kon Tum Provinces and enters northeast Cambodia in Rattanakiri and Stung Treng Provinces (Figure 3-5). In 1993, the 720 MW Yali Falls Dam was built on the headwater of the Se San river in Viet Nam, 70 km upstream of Cambodia's border. A total of 1,658 families with 8,475 people were relocated and 6,480 hectares of land was inundated. An EIA undertaken in 1993 did not include the downstream areas in Cambodia. Since 1996, people living in downstream part (Ratanakiri Province) in Cambodia have experienced unusual or extreme flooding events and deteriorated water quality due to water releases from the dam. The growing concerns on transboundary impacts of Yali Dam triggered the establishment of the Se San Working Group (renamed as Se San Protection Network) in 2000 and the Cambodia-Vietnam Joint Committee for the Management of the Se San River.

[Figure 3-5] Location of Yali Dam and other Dams in the 3S River Basin



Sources: Mark (2012).

13) 3S indicates the Sesan, Sekong and Srepok river watersheds located in tributaries of the Mekong River.

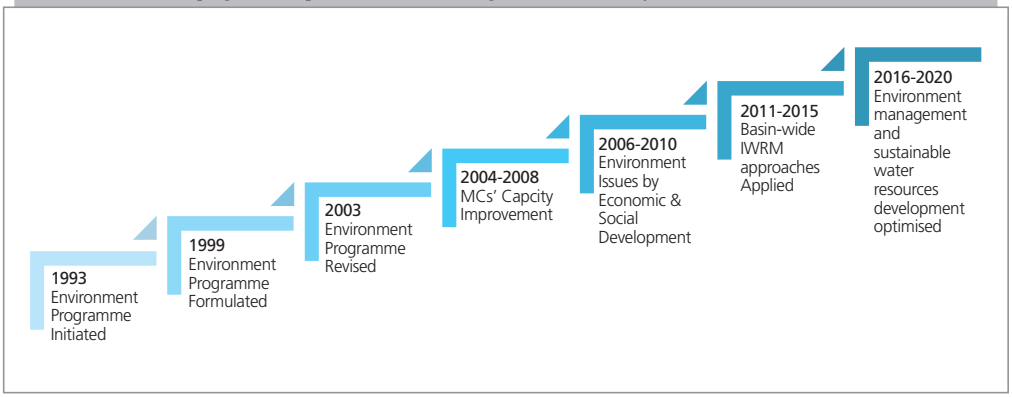
In 2007, additional EIA report focusing on the Cambodian part of the Se San River was produced by Electricity of Vietnam and communicated with the Cambodian government. The report includes impact assessment, mitigation measures, and monitoring programmes for the Se San River. However, the EIA was not carried out through a due consultation process with Cambodia agencies or with full coverage of environmental and socioeconomic impacts (Andrew and Ian, 2007; Linuma, *et al*., 2013). No monitoring reports are available to track and evaluate mitigation measures.

3.2. Environmental Programme for Hydropower Dams in the Lower Mekong Region

3.2.1. MRC Environment Programme Development

Since the initiation of the MRC Environment Programme in 1996, the MRC has continuously improved the Environment Programme to effectively secure a balance between economic development and ecological protection (MRC, 2010a). It supports cooperation among the Member Countries and is aligned with the 1995 Mekong Agreement, the MRC Strategic Plan and other key MRC programmes or initiatives, such as the Information and Knowledge Management Programme (IKMP), the Fisheries Programme (FP), the Water Utilization Programme (WUP), the Basin Development Plan (BDP) Programme, the Initiative for Sustainable Hydropower (ISH), the Climate Change and Adaptation Initiative (CCAI), and the Mekong-Integrated Water Resource Management Project (M-IWRM). [Figure 3-6] summarizes the development history of the Environment Programme in the LMR.

[Figure 3-6] Environment Programme Development in the LMR



Source: Author.

The Environment Programme has been primarily executed by the Environment Division of the MRC Secretariat. To ensure the effective implementation of the Environment Programme, the Secretariat provides coordination, guidance, regional synthesis and supports for capacity-building. International and national experts are available to provide technical assistance as needed. The implementation is integrated through means of shared outputs or activities. The four National Mekong Committees (NMCs) promote the integrated implementation by providing the coordination and management of the Environment Programme activities at the national level.

In 1998, the Joint Committee (JC) endorsed the MRC Environmental Policy and the Methodology for Environmental Impact Assessment (EIA), resulting in the establishment of an EIA and Strategic Environmental Assessment (SEA) system for the LMR in 2002. One of the major outcomes of the Environment Programme is Transboundary Environmental Impact Assessment (TbEIA) Guidelines. The Procedures for Notification Prior Consultation and Agreement (PNPCA) promote regional cooperation on Mekong development, which do not fully take into account transboundary impacts on neighboring countries. TbEIA framework has been proposed to complement the PNPCA and focus on conflict resolution and environmentally sensitive decisions for hydropower development in transboundary environmental settings.[14] There is no consensus over its legal and institutional arrangement (voluntary vs. mandatory), which calls for further negotiations, pilot studies, and improvements.

3.2.2. EIA in the MRC Member Countries

Since the TbEIA is not yet adopted by the JC, the Member Countries have applied only their national legal instruments. National EIA is the key instrument for environmental planning and management of economic development projects, such as hydropower dams. <Table 3-2> presents the main contents of national EIAs implemented in the four Member Countries. Although the EIAs in Lao PDR and Cambodia seem to include more details of principles and rules, most key contents and procedures for national EIAs are similar in all Member Countries.

14) http://www.mrcmekong.org/about-mrc/completion-of-strategic-cycle-2011-2015/environment-programme/transboundary-eia/

〈Table 3-2〉 Contents of EIA in the MRC Member Countries

Cambodia	Lao PDR[1)]	Thailand[2)]	Vietnam[3)]
1. Executive summary 2. Introduction 3. Legal framework 4. Project description 5. Description of existing environment 6. Natural environment 7. Public participation 8. Environmental impacts and mitigation measures 9. Environmental management plan 10. Economics analysis and environmental value 11. Conclusion and recommendations	1. Executive summary 2. Context of the project 3. Policy, legal, and institutional framework 4. Project description and alternatives 5. Description of the environment 6. Impact assessment and mitigation measures 7. Risk assessment 8. Cumulative impact assessment 9. Environmental and social management and monitoring plan 10. Public consultation and disclosure 11. Development plans	1. Executive summary 2. Introduction 3. Project description 4. Present environmental condition 5. Environmental impacts 6. Impact preventive and correct measures and compensation to damage incurred 7. Consideration of alternatives 8. Coordination with other government agencies 9. Monitoring programme	1. Executive summary 2. Introduction 3. Description of the project 4. Environmental status at the project location 5. Environmental impact assessment and mitigation measures 6. Environmental alternatives 7. Conclusion and recommendations

Note: 1) MONRE, EIA Guidelines, 2012 (Appendix 6).
2) ONEP, EIA in Thailand, 2012 (Section 2: General Guidelines in Preparing EIA Report.
3) The Environmental Law Institute, 2009.
Source: Author.

3.2.3. Mitigation Measures for Hydropower Development in the LMR

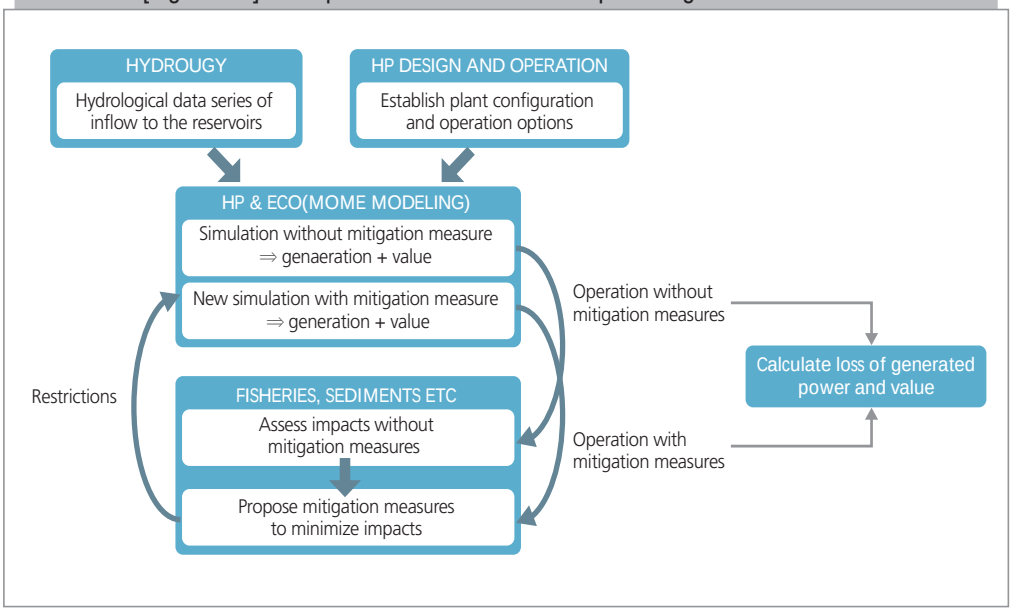
National EIAs of the all Member Countries require to consider mitigation measures. The Preliminary Design Guidance (PDG) was developed in 2009, which is supplemented by the MRC's Hydropower Mitigation Guidelines and related manual, case study report, and knowledge base documents. The MRC's updated case study report (2018) assesses the effectiveness, sustainability, and operational flexibility of selected mitigation options, focusing on energy revenues (USD), fishery productivity (USD), sediment and nutrient transfer, river connectivity, and biodiversity losses. [Figure 3-7] presents the conceptual framework for the impact mitigation assessment.

Mitigation measures such as the identification of pathways for sediment movement, the hydropeaking with restrictions on ramping rates, and timely and coordinated sediment flushing through joint operation of multiple hydropower dams are recommended (MRC, 2018). It also proposes avoidance, minimization, and ecological restoration measures to sustain sediment connectivity. Minimization

measures (e.g. smaller reservoirs, optimized designs for pumping stations and auxiliary turbines, or identification of pathways for fish migration) and mitigation measures (e.g. fish pass or operational modifications) have positive effects, but the effectiveness of measures vary (MRC, 2018).

The MRC's case study provides important information on existing or anticipated environmental impacts and the effectiveness of various measures associated with hydropower development. However, more detailed long-term monitoring data and baseline data are lacking, and minimum standards of some technical measures are not established yet.

[Figure 3-7] Conceptual Framework for the Impact Mitigation Assessment



Source: MRC (2018).

3.3. Lessons Learned from the MRC's Experiences

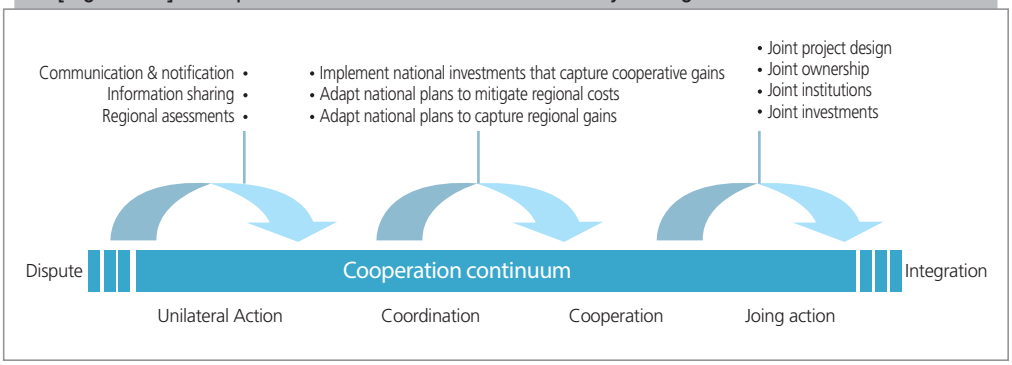
3.3.1. Transboundary Impacts and Regional Cooperation

The economic development in the LMR has been rapidly growing, and there are many plans for hydropower development to meet their increasing energy demands. By conducting national EIAs, environmental and social impacts associated with hydropower development have been assessed. However, national EIAs fail to fully consider transboundary environmental impacts. The experiences and lessons learned from the hydropower development, such as Don Sahong dam and the Yali Falls dam,

demonstrate that the transboundary environmental and social impacts can be serious and intensify social conflicts. Given that the proposed TbEIA technical guidelines are not yet approved, it is important for the Member Countries to explore the effective way to consider transboundary impacts into their national EIAs.

The MRC (2018) highlights the importance of the long-term regional cooperation (or cooperation continuum) and promotes joint action towards integration (Figure 3-8). The PNPCA has been implemented particularly for notification and information-sharing, but the shared information does not include transboundary impacts. The TbEIA has been developed to undertake regional assessment, maximize cooperative gains and share regional costs and benefits, which is not yet implemented. Given that some joint mitigation measures (e.g. coordinated flushing) are proven to improve the effectiveness of measures in the LMR, transboundary responsibilities are critical to ensure environmentally sound and sustainable hydropower development. In what way can the cooperation continuum be facilitated? How can institutional integration between MRC's and national frameworks be enhanced? These questions are important for the MRC Members Countries to reduce social conflicts and to promote regional cooperation over this international river.

[Figure 3-8] A Cooperation Continuum for Transboundary Management of Water Resources



Source: MRC (2018).

3.3.2. Climate Change

MRC's Climate Change Adaptation Programme identifies the increased climate change risks on the temperature and hydrology of the Mekong River, so the MRC has developed the "Mekong Adaptation Strategy and Action Plan (MASAP)", which sets out the strategic priorities and actions at the basin level to reduce climate change risks and strengthen basin-wide resilience. The MASAP states that hydropower production (particularly on the mainstream) can increase the occurrence or intensity of drought, so it recommends that adaptation measures should be considered at the

planning stage of hydropower development (CCAI, 2017).

One of the biggest challenges in addressing climate change is a lack of information and knowledge. In the LMR, the availability of monitoring data associated with hydropower dams is limited, so it is difficult to identify cumulative impacts or emerging environmental problems and even track the progresses and performance of adaptation/mitigation measures that have been applied. It is crucial to establish cost-effective and integrated monitoring systems to combat climate change and to promote environmentally sound and sustainable hydropower development.

3.3.3. Fisheries and People's Livelihoods

[Figure 3-9] A Mean Predicted Change for a Scenario as Percentage of 2007 Baseline

BioRa zones		1		2		3	4		5		6	7	8
Impact zones		Upper cascade				Middle reach	Lower cascade				Tonle Sap		Delta
R = river, I = impounded		R	I	R	I	R	R	I	R	I	R	R	R
Percentage of I/R per zone		59	41	12	88	100	68	32	50	50	100	100	100
Main channel resident	Migratory	-100	-100	-100	-100	-100	-100	-100	-100	-100	-85	-70	-80
Main channel spawner		-100	-100	-100	-100	-80	-100	-100	-90	-100	-55	-60	-80
Floodplain spawner	Floodplain		-80		-80	-20	-20	-80	-40	-80	-45	-65	-65
Floodplain resident						-15	-30	-30	-65	-65	-55	-50	-55
Eurytopic	Generalist	10	80	40	80	55	35	80	-5	100	5	-5	15
Rhithron resident	Others	0	-100	0	-100	10	-5	-100	-30	-100			
Estuarine resident								20		-50	-55	-50	-50
Anadromous						-100	-100		-55		-35	-20	-35
Catadromous			-100		-100		-95	-100	-25	-100	-25	-20	-30
Marine visitor										-80			-10
Non-native	Non-native	115	50	110	50	85	75	100	80	100	55	55	80
Biomass		-55		-75		-65	-40		5		-30	-35	-25

Colours indicate the degree of changes, bold and black numbers highligth guilds with > 10% contribution to the catch in the respective BioRA zone (based on BioRA Technical Report Vol 1, Appendix G).

Note: based on a scenario of 2040 without mitigation.
Source: MRC (2018).

The LMR is one of the regions that have the highest fish biodiversity and the largest inland fishery. Due to the wide distribution (because over 85% of fish are migratory) and abundance of fish species, fish is an important healthy protein source and sustainable income source for almost 60 million people in the LMR (Baumgartner *et al*., 2017). Fisheries account for 12% or 7% of the national GDP in Cambodia or Lao PDR, respectively (MRC, 2016). Fisheries resources in the LMR have the long-term sustainability. However, hydropower development has threatened their sustainability because dams block migrant fish movements and destroy their spawning or nursery habitats (Baumgartner *et al*., 2017). According to a scenario modeling (MRC 2018), the fish biomass in 2040 will be dramatically reduced in most selected river basins (25%~ 75% losses, compared to 2007) if no mitigation measures are implemented (Figure 3-9).

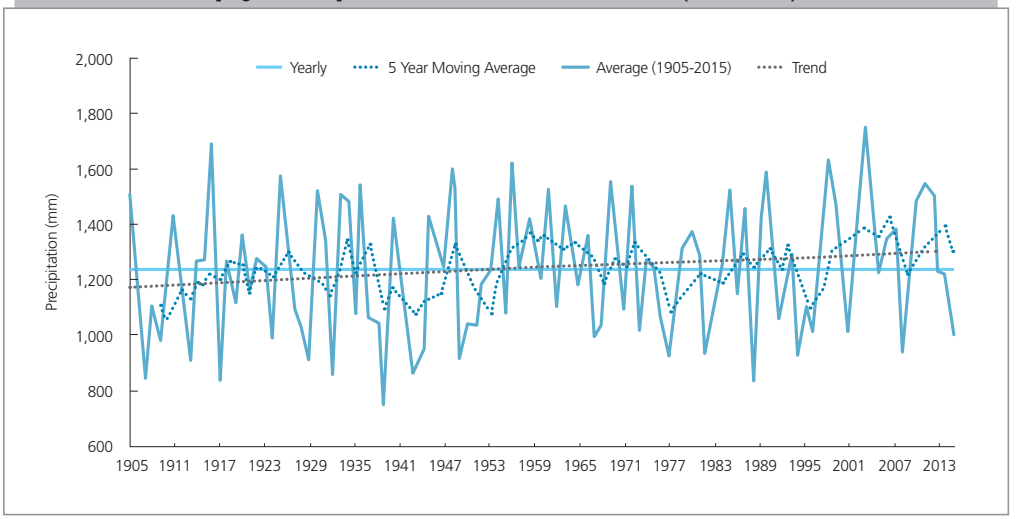
A variety of avoidance, minimization, mitigation, and compensation measures have been applied to improve the productivity of fisheries, which are further promoted through the integration of Environmental Programme and Fisheries Programme. Fisheries' benefits are associated with biodiversity, ecological services, livelihoods and food security, so it is difficult to fully calculate its benefits, while hydropower's benefits are easily calculated. Hydropower's costs cannot be fully calculated due to cumulative impacts or joint effects with other dams. As such, the benefits of hydropower development are often overestimated, while its costs are often underestimated. For fair trade-offs between fisheries and hydropower, it is necessary to establish reasonable calculation methods and procedures.

4. Korea's Experiences: Environmental Impacts of Multi-purpose Dams

In Korea the average annual rainfall per capita is quite small (16% of the world average)[15], and seasonal or regional variation of rainfall is significant. Therefore, dams and reservoirs are considered as good options to ensure water security. [Figure 3-10] demonstrates the yearly fluctuations and trends of annual rainfall in Korea (1905-2015), and [Figure 3-11] shows the average monthly precipitation in major cities (1981-2010).

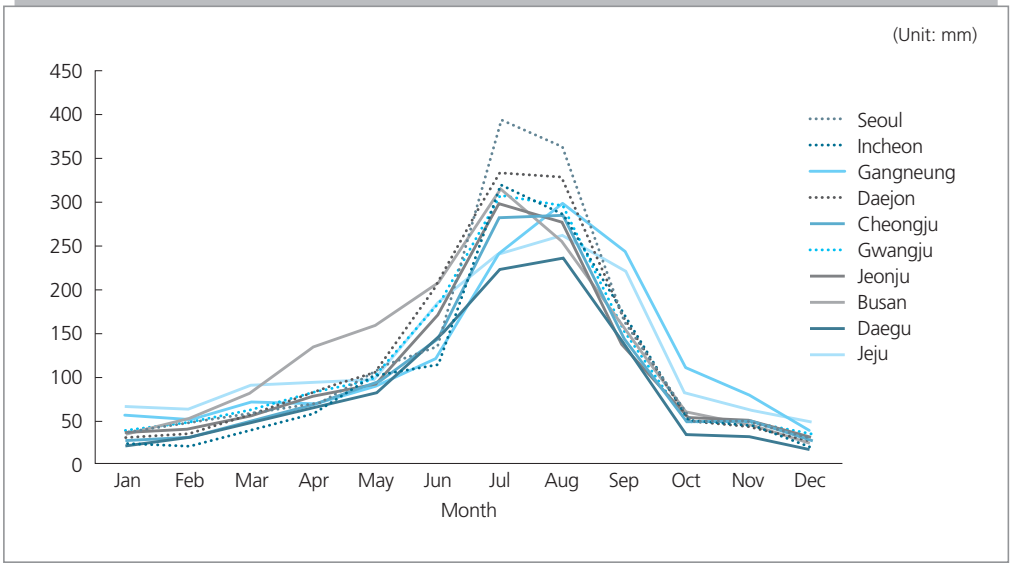
15) http://www.kogga.or.kr/eng/korea/korea.asp

[Figure 3-10] Trend of Annual Rainfall in Korea (1905-2015)



Source: Korea's Ministry of Land, Infrastructure and Transport (2016).

[Figure 3-11] Average Monthly Precipitation (1981-2010)



Source: Korea Meteorological Administration (2011).

4.1. Dam History and Environmental Impacts

4.1.1. Dam History

Before 1960, dams and reservoirs were developed for one specific purpose, such as irrigation or electricity generation. In the 1960s, multi-purpose dams were constructed. Since then, water resource development focusing on dam infrastructure has been integrated into national plans for economic or power development. The first prominent multi-purpose dam was Soyang dam, the largest dam in Korea. Its construction was completed in 1973, and it is considered as one of the key drivers for "the Miracle on the Han River"[16].

In the 1970s~1980s, the capacity of multi-purpose dams became larger to meet ever-growing demands for water and water-related services. Large dams caused more significant changes and impacts on ecosystems and livelihoods of the people. In the 1990s, as a result of the increasing environmental incidents and damage, environmental awareness, and regulatory frameworks were improved, which called for the environmental considerations for dam development, so environment-friendly dams were introduced.

In the 2000s, various options for more eco-friendly dams and the concepts of "Environmentally Sound and Sustainable Development (ESSD)" were mainstreamed in dam development, and also community involvement in the early planning phase of dam development was enhanced (Choi, 2012). There was a limited potential or feasibility for further dam development in Korea, so the dam size became smaller. Due to the ever-increasing climate risks in the 2010s, climate change adaptation action and integrated management at a river basin scale have been promoted. To improve the efficiency and effectiveness of dam management against the current institutional fragmentism, coordination has been enhanced. <Table 3-3> summarizes Korea's dam history and identifies key achievements and environmental impacts.

16) "The Miracle on the Han River" is a phrase that refers to the period of the dramatical economic growth accomplished by South Korea soon after the Korean War.

〈Table 3-3〉 Dam History, Key Achievements and Environmental Impacts in Korea

Dam History	Key Achievements	Environmental Impacts
Before 1960: Dams for Irrigation, Hydropower Dams	- Food production - Electricity generation	- Not monitored (n/a)
In the 1960s: Multi-purpose dams	- Urbanization - Comprehensive plans (long-term) - Integration of water sector and national development plans	- Drought - Flooding
1970s-1980s: Large dams (Multi-purpose dams)	- Economic development - Urbanization (fast) - Increased water capacity - Pumped storage hydropower	- Poor water quality - Loss of habitats - Resettlement
In the 1990s: Environment-friendly dams & Multi-purpose dams	- Water quality management - EIA - Water demand management	- Social conflicts - Fragmented ecosystems - Environmental injustice - Poor water quality
In the 2000s: Environmentally sound and sustainable dams, Smaller dams	- Community involvement - IWRM - SEA - Growth of tourism	- Climate risks (drought/ flooding) - Structural insecurity - Poor water quality
In the 2010s: Rehabilitation of dams	- Integrated management - Climate change adaptation - Coordinated operation/ management	- Climate risks - Algal blooms - River restoration (environmental flow)

Source: Author.

<Table 3-4> demonstrates the capacity of hydropower dams in Korea. There are only 16 pumped storage power plants in Korea, but they represent 72.6% of the total hydropower capacity. The capacity of a small hydropower plant is generally 10MW or lower. Since hydropower's role in generating electricity is relatively small, social needs and values for hydropower dams have been changed, thus requiring the roles and functions of existing hydropower dams in Korea to be redefined. That is, multi-purpose functions of hydropower dams are desired and the roles of hydropower dams become important, particularly in dealing with flooding and water quality.

〈Table 3-4〉 Capacity of Hydropower Facility in Korea

Category		No. of Units	Capacity (MW)	Ratio (%)
General hydropower plant	Korea Hydro & Nuclear Power Co., Ltd	21	595.2	9.2
	K-Water	20	986.6	15.2
	subtotal	41	1,581.8	24.4
Pumped storage power plant	Korea Hydro & Nuclear Power Co., Ltd	16	4,700	72.6
Small hydropower plant	Korea Hydro & Nuclear Power Co., Ltd	14	11.3	0.2
	K-Water	81	85.1	1.3
	KEPCO and subsidiary companies	23	37.6	0.6
	Others	122	55.7	0.9
	subtotal	240	189.7	3.0
Total		297	6,471.5	100

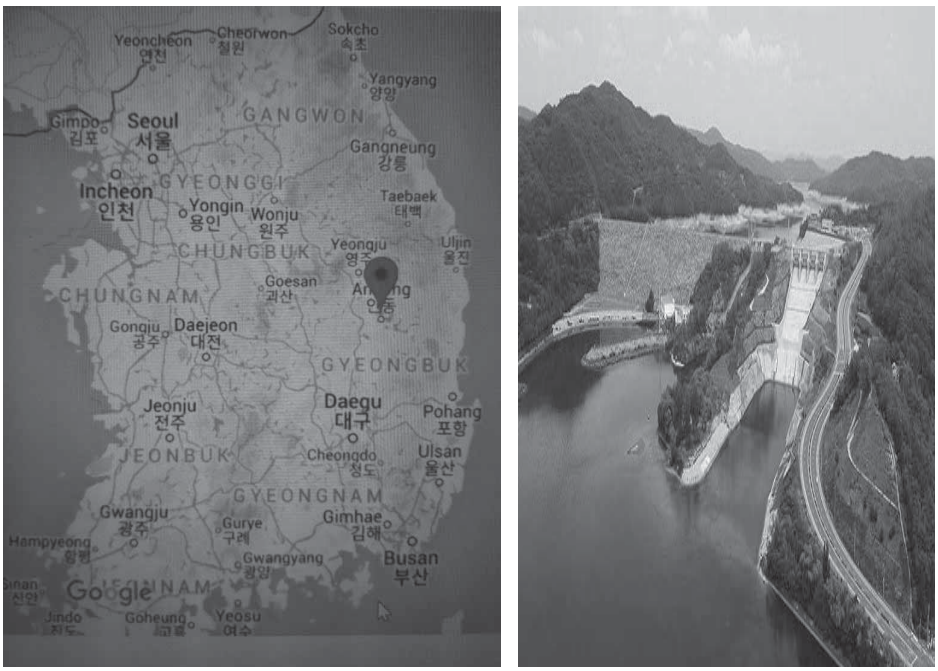
Source: Korea Hydro & Nuclear Power Co., Ltd (http://www.khnp.co.kr/eng/content/765/main.do?mnCd=EN040204).

4.1.2. Case Study of the Andong Dam: Environmental and Socioeconomic Impacts of a Multi-purpose Dam

The Andong Dam is a multi-purpose dam on the Nakdong river in Gyeongsangbuk-do province (Figure 3-12). It has a 90 MW pumped-storage power station and a large reservoir. Since 1976, it has been operated and responsible for up to 39.6% of water supply in the Nakdong River basin (Song, 2001). When this dam was developed, the EIA was not established, so environmental impacts and socioeconomic impacts were not considered. This large dam has changed the patterns of local climate in terms of fog occurrences, daylight hours, air temperature, which influenced food production and health of the local people.

After the Andong dam was constructed, the average foggy days per year (1982~1986) in the dam area were increased by 63%, compared to the baseline foggy days (1972~1976) (Table 3-5). The increased foggy days were associated with the decreased daylight hours and the solar radiation. <Table 3-6> demonstrates that the average daylight hours per year were reduced by 520 hours, compared with the baseline daylight hours. Furthermore, the local temperature became colder. The average of annual coldest temperature had dropped from -9.06° C to -12.02° C. Such environmental changes damaged crop productivity and public health. Due to the dam, water flows in downstream declined, so downstream became more vulnerable to water pollution.

[Figure 3-12] Location and Photo of Andong Dam



Source: Google, K-Water.

〈Table 3-5〉 Change of Fog Occurrence Days before and after Dam Construction

Before Dam Construction	Year	1972	1973	1974	1975	1976	Total	Average
	Foggy Days	35	29	46	64	46	219	43.8
After Dam Construction	Year	1982	1983	1984	1985	1986	Total	Average
	Foggy Days	73	69	66	77	72	357	71.4

Source: Song (2001).

〈Table 3-6〉 Change of Daylight Hours before and after Dam Construction

Before Dam Construction	Year	1972	1973	1974	1975	1976	Total	Average
	Daylight Hour	2,654.40	2,998.10	2,720.80	2,580.00	2,675.00	13,528.90	2,705.80
After Dam Construction	Year	1986	1987	1988	1989	1990	Total	Average
	Daylight Hour	2,268.00	2,217.00	2,318.30	2,317.20	1986.8	10,928.00	2,185.60

Source: Song (2001).

Socioeconomic damages were also observed. Property values in the vicinity of the dam were declining because other development was strictly restricted to protect the water resources in that watershed. Consequently, livelihoods of the local people were threatened. The local communities established a committee that aimed at mitigating the negative impacts of the Andong Dam by claiming compensation for the social, economic, and environmental losses and also by filing an administrative appeal against the government. The local people failed to receive the direct (monetary) compensation because there were no regulatory frameworks that ensured the implementation of mitigation measures to the environmental impacts and compensation options for the inevitable damages or losses. According to Song (2001), however, it was not easy to take compensation for their losses triggered by a dam even after relevant regulatory frameworks were established.

After the adoption of the "Act on Dam Construction and Assistance, etc. to Neighborhood Area" (1999), institutional and financial compensation has been finally paid to the residents. Currently, the grant is made for the residents in the vicinity of the Andong dam, which consists of 6% from the sale of electricity and 20% from the sale of water in accordance with the Act.

4.2. Institutional Frameworks for Dams in Korea

4.2.1. Water Policy Development in Korea

Since hydropower or multi-purpose dams have been developed in the water policy context, it is necessary to review the development pathways of water policy. In the 1960s, water supply was one of the national top priorities to boost economic development and urbanization. Through the integration of the water sector into the national economic development and a comprehensive National Water Resource Plan, the investment for water infrastructure was fully supported and justified. The expenditure for water resource development represented 19% of the total expenditure for the first Economic Development Plan (Koun, 2013).

The water policy could meet ever-growing water demands by focusing on supply, but few effective measures were implemented to deal with water pollution, ecological losses, flooding damage, and drought before the 1990s. The focus of water policy was changed from supply to flooding control, water efficiency through demand management, ecosystems' protection, and water quality management. That is, comprehensive management was implemented.

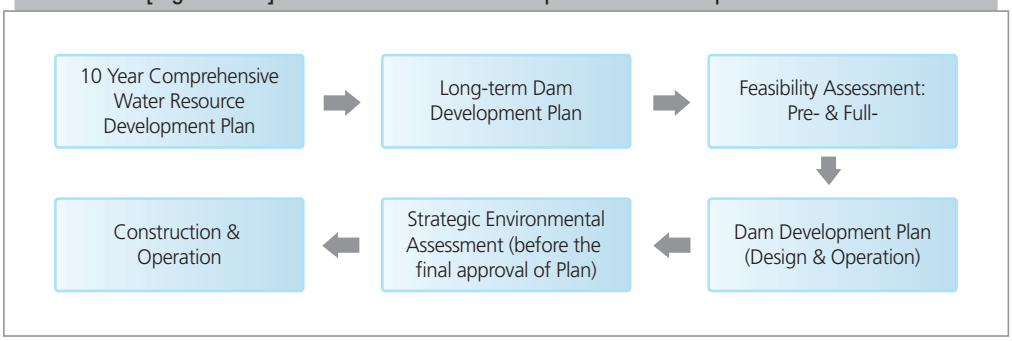
Since the 2000s, the key approach to water policy is river-basin management, which requires due considerations of local-specific circumstances, and, consequently, enhanced roles and partnerships of local governments and communities are

highlighted. In Korea, Local Agenda 21 movements were active, which contributed to empower local stakeholders and establish inclusive institutional arrangements and processes. A number of local water partnerships were established since Local Agenda 21 movements and institutional capacity was improved through co-governance among multiple stakeholders. By taking an integrated approach such as "Integrated water resources management (IWRM)", water policy becomes more comprehensive, participatory, and coordinated.

4.2.2. Regulatory Frameworks and Institutional Arrangements for Dam Development

In Korea, the EIA and the SEA has been jointly applied to assess and address the environmental impacts of policy, plans, program and project in a proactive and systematic manner. The EIA and the SEA analyze environmental implications of decisions and promote environmentally sensitive decision-making. Before the final decisions are made, the EIA and the SEA can facilitate the development of various avoidance, minimization, mitigation and compensation measures. [Figure 3-13] presents the process of the multi-purpose dam development. The dam development plan includes a basic plan, design plan, and operation plan. The SEA is carried out at the stage of administrative planning or before the finalization of the basic plan, while the EIA should be carried out before the approval or finalization of the operation plan.

[Figure 3-13] Processes of the Multi-Purpose Dam Development in Korea



Source: Environmental Impact Assessment Guidelines for Construction of Eco-friendly Dams (2016).

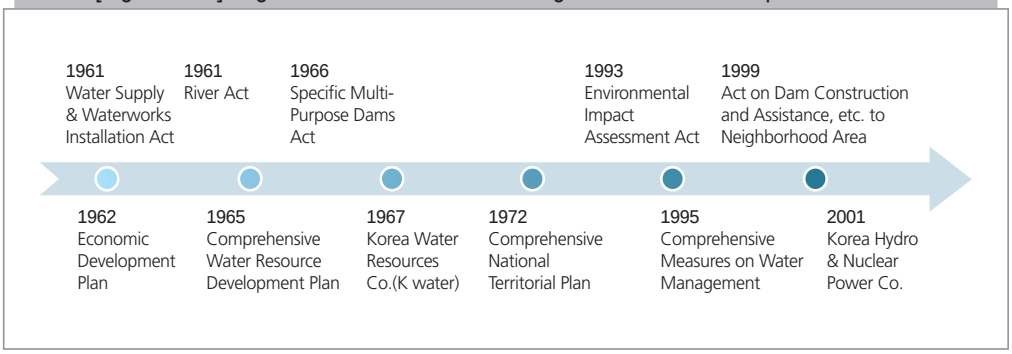
In 2006, the Korea's Ministry of Environment (MOE) enacted the Environmental Impact Assessment Guidelines for the Construction of Environmentally Friendly Dams jointly with the Korea's Ministry of Land, Infrastructure and Transport (MLIT) to carry out more efficient and systematic assessments of the dam impact, which improved the objectivity, reliability, and predictability of the environmental impact assessment in dam development.

The Specific Multi-Purpose Dams Act (1966) and the Act on Dam Construction and Assistance, etc. to Neighborhood Area (1999) were adopted to provide support and guidance for dam construction, human livelihood in communities, and conflict resolution. Other water laws (e.g. the River Act and Water Supply & Waterworks Installation Act) were also related to dam development; the Korea Water Resources Development Corporation (K-Water) and Korea Hydro & Nuclear Power Co., Ltd. (KHNP) are responsible for multi-purpose dams and hydropower dams/pumped storage power dams, respectively. [Figure 3-14] presents the key regulations and institutional frameworks related to dam development.

The River Act enforces the river maintenance flow to maintain the normal function of the river. However, only 10.7% of water in multi-purpose dams, 6.9% of water in hydropower dams (6.9%) and four out of the total agricultural reservoirs (17,649 total) are required to perform the maintenance flow purpose (MOE, 2013). Recently, the MOE has introduced the minimum ecological flow of river to prevent runoff and degradation of the ecological environment in downstream, which is considered as an effective mitigation measure for dam management.

After the adoption of the Act on Dam Construction and Assistance, etc. to Neighborhood Area, it is possible to promote the economic development (such as nature sites for environmental education, ecological parks or water sports facilities) of the regions around the multi-purpose dams as long as the Total Maximum Daily Loads (TMDLs) of pollution is controlled in accordance with the related law. This Act specifies compensation procedures for environmental or socio-economic losses and also financial supports for community development projects in the vicinity of the dam by presenting the cost and benefit sharing principles and methods.

[Figure 3-14] Regulations and Institutional Progress for Dam Development in Korea



Source: Author.

4.3. Lessons Learned from the Korea's Experiences

4.3.1. Evolving Integrated and Balanced Approaches to Dam Development

As seen the above, the dam development processes do not include only administrative, technical, and financial considerations, but also national resources management plans or environmental considerations. Within the Korean institutional frameworks, the dam development is highly associated with water resources management. In 2017, the Korean government announced a decision to unify the water management, and the Ministry of Environment launched the Sustainable Integrated Water Management Vision Forum to promote the balanced and sustainable management of water quality, ecosystem, water quantity, climate risks, and watershed democracy. This forum aims at realizing watershed democracy and establishing integrated water governance, through nation-wide consultations and active participation.

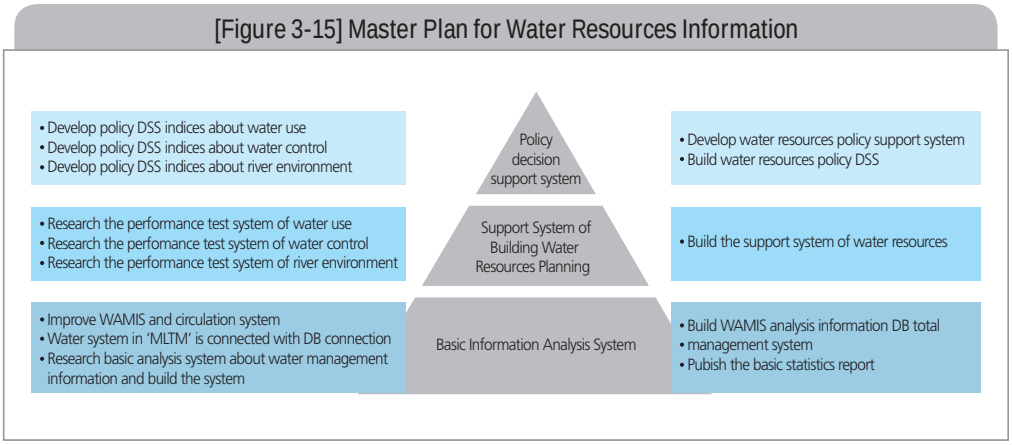
In the 2000s, local ownership of community assets such as water resources has been enhanced by implementing a community-based approach and river-basin approach. Through enhanced transparent and participatory institutional frameworks, social conflicts over dam construction and operation have been resolved. The river-basin management incorporates all dams located in the river and all players related to the dams or the river (e.g. dam operators, central government agencies, local governments and other public entities) and applies a balanced approach to meet the primary purposes of each dam and public interests. Although the main purpose of hydropower dams is to generate electricity in an economically feasible manner, they are also required to optimize water use, supply water resources, control floods, and manage the environment, which are similar to the primary functions of multi-purpose dams in Korea. In fact, hydropower dams and multi-purpose dams are highly interlinked functionally and managed through integrated operation rules and procedures, as well as a coordination council. Due to the overlapped roles of two operational entities (K-Water and KHNP), however, institutional tensions remain over the dam management, which calls for institutional rearrangement or more enhanced coordination.

4.3.2. Information and Communication Technology (ICT) for Water Management

In Korea, remote monitoring and data transmission technology are widely used in water resources management. Based on the National Water Quality Monitoring Program, comprehensive data platforms for water quality (e.g. water information system) have been operated with monitoring systems in various sites such as the

rivers, lakes, agricultural reservoirs, and urban water infrastructures. Real-time data collection and processing systems are also established. There are 70 automatic monitoring sites in the four major rivers to collect real-time data on water quality, which are useful to detect pollution incidents, to operate predictive/warning systems for water quality, and to complement the general monitoring network of water quality by providing water quality index.[17] The real-time tele-monitoring systems (so-called 'SOOSIRO' system) are established to prevent water pollution by monitoring and analyzing water pollutants from wastewater discharging facilities, public sewerage treatment facilities, and wastewater treatment plants.

[Figure 3-15] Master Plan for Water Resources Information



Source: WAMIS (http://wamis.go.kr/eng/Overview.aspx).

Based on a broad partnership among water-related public entities, the Water Resources Management Information System (WAMIS) consists of three data systems for information analysis, operation support, and decision support (Figure 3-15). The WAMIS provides scientific information for water policy makers, academic experts, and the public in a comprehensive framework that includes 10 fields (e.g. hydro/meteorology, basin, river, dam, groundwater, water use, environment and ecology, topography and event) and 300 items.

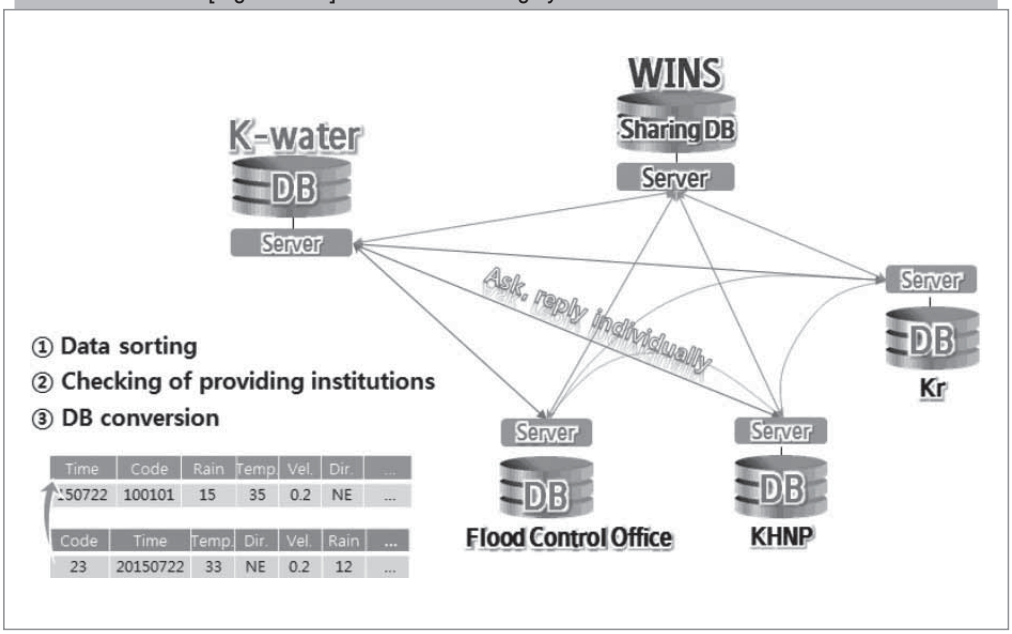
According to the MOE[18], the sediment monitoring network was operated in 177 locations (as of December 2013) to analyze the environmental impacts of sediments, particularly focusing on the changes of water quality and aquatic ecosystems triggered by the geomorphological changes. A variety of water data are available, including water quality, green algae blooms, pollution sources, total water pollution load, water flow, aquatic ecosystem (e.g. the Aquatic Ecosystem Health indicator), floodgate monitoring data, and dam operation data (e.g. discharge flow,

17) http://www.koreawqi.go.kr/wQSSTmsPurposeLayout_D.wq?MENU_GUBUN=311
18) http://eng.me.go.kr/eng/web/index.do?menuId=255

water consumption, power generation, and meteorological data). Geographical information system (GIS) is often utilized to monitor the basin and riverbed sediment in dam reservoirs.

Recently, water information systems have been integrated, based on ICT. The Water environmental geographic information service was launched, which provides comprehensive information on the water environment. According to Hong and Jang (2017), the Water management Information Networking System (WINS) operated by the Ministry of Land, Infrastructure and Transport (MLIT) is one of the integrated management systems for water information, but information-sharing is not active yet. As such, they suggest further integrations (e.g. combining GIS and real-time data), which results in the establishment of big data-based water information portal: My water. River Information Management GIS (RIMGIS) is a system that supports the river-related work in a more efficient and timely manner by providing various river-related information, which aims at the standardization and digitalization of river information.

[Figure 3-16] WINS Data Sharing System of the Korea's MLIT



Source: Hong & Jang (2017).

In Korea, monitoring schemes were developed primarily to control water quality, but their importance has been recognized and their roles have been expanded. To strengthen the competitiveness of the water sector, the efficiency and transparency of water management, and public awareness, monitoring schemes have been

incorporated into comprehensive and long-term information systems. Along with the advanced monitoring techniques and ICT, the water information systems have been more user-friendly and integrated.

4.3.3. Measures for Water Quality Improvement

According to Choi *et al*. (2017), poor water quality is one of the key challenges for sustainable water governance, and there have been recursive social conflicts between local communities/governments over poor water quality in Korea. Many large dams had been constructed before the institutional frameworks (e.g. EIA) were adopted. Although a variety of measures for water quality improvement have been applied, pollution incidents continuously occur and water quality remains as one of the key issues associated with the dam development. The increased sanitation coverage and intensive management of point source pollution result in water quality improvement. While point source pollution in the vicinity of the dams is managable by institutional measures and monitoring systems, non-point source (NPS) pollution from unidentified sources (e.g. agricultural fields, roads or urban areas) can significantly deteriorate water quality.

Based on a river-basin approach, Total Maximum Daily Loads (TMDLs) and NPS management are introduced, which are further elaborated in the Master Plan for Water Environment Management (2006~2015) and the Second Comprehensive Plan on NPS Management (2012–2020). One of the effective minimization measures for water quality is to promote low-impact development in the vicinity of the dams by designing hydrological characteristics for runoff similar to the natural state. Technology elements of low-impact development can be designed for in-situ (runoff reduction directly on site) or out-situ (runoff reduction off site). Types of technology elements include storage, penetration, filtration, or stop-over functions.

Dam development resulted in ecological losses. There is increased awareness on wetlands' functions associated with water quality, so ecological compensation measures focusing on wetlands have been undertaken to improve water quality. However, the effectiveness of artificial wetlands cannot be fully assessed within a short-term framework, so a long-term monitoring scheme is needed to track their progress.

4.3.4. Challenges

Climate change is a critical risk to water systems, including multi-purpose dams, because of increasing uncertainty and variability in weather patterns and water resources. The high level of uncertainty and variability will cause negative impacts on the effectiveness of dam development and also the optimization of dam operations.

Climate change becomes the most urgent issue in Korea's water sector (Choi *et al*., 2017). The water sector has implemented adaptation measures to climate change in accordance with national and sector-specific climate change adaptation plans. As shown in the Four Major River Restoration Project that was proposed as one of the adaptation measures, however, national strategies of climate adaptation focus on building artificial infrastructure (e.g. dams or weirs) or riverfront parks/facilities and do not fully incorporate measures to enhance natural capacity for resilience.

Climate change adaptation measures are often confused with measures for other primary purposes (e.g. disaster risks management, public health or water resources management), so it is necessary to coordinate adaptation governance or collaboration frameworks with similar measures, which can support achieving multiple purposes efficiently.

5. Conclusion

5.1. Summary of the Lessons and Experiences

In the LMR, the total installed capacity of operational hydropower is 6,398MW, which are on the Mekong tributaries (MRC, 2016). In Korea, the total installed capacity of operational hydropower is 6,471.5MW, which are on the four major rivers (Table 3-4). Currently, their installed capacities of hydropower in two regions look similar and some associated environmental impacts are similar. However, a lot of the plans for hydropower development are proposed in the LMR, so the Member Countries in the LMR may face more serious environmental problems and challenges in the future. Lessons learned from Korea's experience can be useful for the Member Countries to avoid, minimize, mitigate, or compensate anticipated problems.

5.1.1. Environmental Impacts

The key environmental changes and impacts caused by dam development that have been observed in the LMR and Korea are identified as follows:

- Land-use changes and land-cover changes were inevitable and often influenced a wide area. The created impoundments triggered hydrological changes (e.g. water level and flow) and geomorphological changes (e.g. sediment transfer), which directly or indirectly destroyed the continuity of ecosystems and livelihoods of the local people.
- Disturbances occurred during the construction of dams, and reservoirs were temporary, but the negative consequences remained for a relatively long period of time, particularly in ecologically sensitive places. In the LMR, several

hydropower projects are under construction at the same time, so their cumulative impacts and consequences can be significant.

- A dam was a barricade, which resulted in the loss of river connectivity. Habitat fragmentation was observed. Sediment and nutrient transfer, as well as fish migration, became restricted.
- Hydrological changes included both long-term (e.g. seasonal) and short-time (e.g. daily) changes to water flow and water level. Dams and reservoirs reduced loss and damage caused by drought or flooding. However, when extreme weather conditions continued, dams and reservoirs did not work properly or even intensified loss and damage in downstream or upstream.
- Geomorphological changes varied in accordance with the dam sites' conditions and the degrees of hydrological changes. The patterns and degrees of erosion and deposition were changed, which particularly influenced ecosystems in downstream.
- Changes in the patterns of local climate often observed in a large dam site. As described in the above Korean case study, the changes of local climate influenced socioeconomic conditions of the local people as well as ecological productivity.
- Water quality was one of the key concerns associated with dam development. In Korea, harmful algal blooms have occurred in four major rivers almost every year because many dams created good conditions (e.g. temperature, DO, nutrients and water flow) for algal growth.
- The negative impacts on ecosystems were the most important issue. Critical habitats such as floodplain wetlands were destroyed or reduced. Changes in ecological conditions resulted in loss of biodiversity and fish production. In the LMR, fishery is important for living and the increasing hydropower dams can be a significant threat to fisheries.
- Relocations were required particularly for the development of large dams or multi-purpose dams, which affected livelihoods of the local people in the vicinity.

5.1.2. Challenges

The key challenges related to dam development in the LMR and Korea are identified as follows:

- Climate change is an emerging risk factor for dam development and operation. The LMR and Korea both are vulnerable to climate change risks. There are various efforts to enhance resilience to climate change, and many dam development projects are proposed as one option of such efforts. However, it should be noted that artificial dams and reservoirs may reduce or destroy ecological resilience.

- Transboundary impacts are more obvious in the LMR, so the Member Countries have made efforts to address the transboundary environmental impacts through enhanced coordination, cooperation, and transparency. In Korea, the power of local autonomy has been increased by Local Agenda 21 movements and seems strong when it comes to the development and management of natural resources. Therefore, regional conflicts over dam development were severe in some cases. Regulatory and institutional arrangements have been developed or modified in order to resolve such conflicts at the early stage of dam development.
- A lack of information can be the most significant challenge. Particularly in the LMR, reliable and comprehensive information is not generated or communicated properly (in an efficient, effective and timely manner). In Korea, good information systems are established, but further integration and user-friendliness should be enhanced.
- Environmental justice was not fully elaborated here due to a lack of relevant local data and information. Vulnerable groups such as children, women, elderly, the poor, the disabled, or indigenous people do not have enough capacity to avoid damage of dam development, so it is crucial to consider measures to meet their needs and interests. Generally speaking, people living in urban areas have enjoyed benefits of dam development, while people living in the dam sites have suffered from the negative environmental impacts, which should be further addressed for social integration and justice.

5.1.3. Measures for Environmentally Sound and Sustainable Dams

A lot of measures have been developed and implemented for environmentally sound and sustainable dams. Avoidance or ecological restoration measures have not been widely applied in the LMR or Korea, while a variety of minimization, mitigation, or compensation measures have been implemented. Several important measures for the LMR and Korea are identified as follows:

- Environmental Impact Assessments (EIA) and Strategic Environmental Assessment (SEA) have been developed. In Korea, an integrated approach of the EIA and the SEA has been applied since the 2000s. In the LMR, EIA has been independently implemented by each Member Country.
- The involvement of stakeholders is important, so transparent and inclusive participation processes and institutional arrangements have been developed in the LMR and Korea.
- In the LMR and Korea, institutional frameworks have been more comprehensive by taking river-basin, integrated and/or balanced approaches and by taking into account emerging issues and problems.
- Social compensation measures have been implemented in Korea. The scope of

compensation is expanded and methods of sharing benefits and costs become more reasonable.

- Ecological compensation measures have been applied in the LMR and Korea. A variety of technical measures have been implemented, but their effectiveness should be further evaluated with a long-term monitoring scheme.
- Monitoring techniques are widely applied in Korea, while the applications of monitoring techniques in the LMR are limited.

5.2. Conclusion and Recommendations

We have examined the environmental problems associated with dam development and the measures to avoid, minimize, mitigate, or compensate environmental damage and loss in the contexts of Korea and the LMR. Water quality, ecological losses, social justice, and climate change risks are the common key issues associated with dam development. In addition to these issues, transboundary impacts, fisheries productivity and a lack of monitoring data are particularly important to the LMR. A variety of technical measures and institutional frameworks have been developed to deal with emerging or anticipated changes and impacts of dam development, which become more comprehensive since river-basin, integrated, and balanced approaches are applied. The effectiveness of each measure varies, so the application and/or modification of each measure should be carefully considered and the long-term and cumulative impacts of measures should be systematically tracked.

Based on the lessons learned from the cases and practices examined here, best practices are identified as follows:

- Transparent and inclusive procedures: Equal participation of all stakeholders from the early stage of dam development should be ensured. Particularly, the strengthened preliminary review process including intensive consultations is important to increase social acceptability of dam development. Wherever applicable, transparent and inclusive procedures should be developed from the conceptual stage of dam development to its dismantling stage, the entire processes of hydropower's life cycle.
- An integrated approach of the EIA and the SEA: national EIA and regional SEA are not fully integrated in the LMR. The SEA should ensure a long-term, holistic assessment of dam development. Clear procedures are needed to incorporate the outputs (e.g. recommendations) of the SEA into the EIA process. Assessment techniques should be further developed to improve the reliability of the outputs.
- Incorporation of the key components of Transboundary Environmental Impact Assessment (TbEIA) Guidelines into country EIA: Given that a consensus over

its legal and institutional arrangements for TbEIA is not made in the LMR, a stepwise approach is more applicable, which requires the intensive review and identification of TbEIA's components compatible with their national EIAs. For example, when national EIA is conducted, the transboundary scopes are considered wherever applicable, which can be promoted by empirical data on benefits and costs of the TbEIA and transparent communications. For Korea, the TbEIA Guidelines can be useful to facilitate the cooperation of local parties over the shared water resources.

- Institutionalization of the principle for cost-benefit sharing: Social compensation measures are important to realize environmental and social justice. Although the sharing methods can be varied, the principle should be coherent. Since all costs and benefits cannot be explicitly identified, it is recommended to establish evaluation processes for regular review and modifications of the compensation practices and outcomes.
- Prioritization of avoidance and minimization measures: In Korea and the LMR, avoidance measures are rarely undertaken. It should be noted that avoidance and minimization measures are generally the most effective, so priority should be put on these measures.
- Combination and synergy of multiple measures: Since many issues and stakeholders are associated with dam development, various measures should be considered in the entire project cycle to increase synergy and maximize benefits. It should be noted that unexpected negative relationships among measures may be identified months or years later, so long-term monitoring systems will be needed.
- A river-basin approach: Due to the interdependencies of a river basin, Korea and the LMR have incorporated a river-basin approach in their institutional and technical frameworks. The implementation can be further promoted by applying the TbEIA or other comprehensive frameworks.
- Integrated watershed information management system: Korea government has developed multiple comprehensive water information management systems (e.g. WAMIS, RIMGIS and WINS), based on comprehensive monitoring schemes. While the compatibility and linkage between the information systems should be further enhanced to improve their user-friendliness, Korea's systems are very useful to support good decision-making on water policy or dam development/operation. For the LMR, it is urgent to develop information management systems equipped with monitoring schemes, which should be developed within a watershed, rather than within a country. It will be very expensive to develop a comprehensive system or cover all areas, so a step-wide approach will be needed to establish the system, which can target the key indicators and the most vulnerable sites in the LMR.
- Rules and procedures for integrated dam operation/management: the Korean government has established institutional frameworks to minimize the

environmental impacts of dams' operation by enhancing coordinated functions of a river-basin council, as well as by connecting all dams/stakeholders in the river basin. For public interest (e.g. biodiversity, water quality, or flooding control), the operation of each hydropower dam should be controlled within a certain level and in a coordinated manner. That is, the rules and procedures should ensure that hydropower dams are not operated only to generate electricity in an economically feasible manner, but also to optimize water uses/flows in accordance with communities' and environmental needs.

There are two policy implications for the LMR. The first one is based on successful experiences of Korea's growth. The dam development has been effectively promoted by integrating the dam development plans into long-term and comprehensive national plans (for economic development, water sector, energy sector, and other relevant sectors). Therefore, the LMR may consider integrating hydropower development into the key regional and national plans to ensure coherence among relevant policies and action and also promote sustainable development goals (SDGs). The second one is based on failure experiences of Korea. At the beginning of dam development, Korea government applied a top-down, single-purpose (water supply oriented) approach, which could achieve the short-term efficiency or effectiveness but could not address a variety of environmental and socioeconomic issues. Thus, Koreans had experienced negative consequences, and some of the impacts were irreversible and significant. In order to avoid such consequences, the comprehensive and balanced approach should be taken, particularly at the beginning (e.g. conceptual stage) of hydropower development in the LMR.

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Appendix

Hydropower Development in the Lower Mekong Region

〈Appendix Table Ch 3-1〉 Mainstream Hydropower Schemes

No.	Name	Country	Status	Installed Capacity (MW)
1.	Pak Beng	Lao PDR	Planned	1,230
2.	Luang Prabang	Lao PDR	Planned	1,410
3.	Xayaburi	Lao PDR	Under Construction	1,285
4.	Pak Lay	Lao PDR	Planned	1,320
5.	Sanakham	Lao PDR	Planned	660
6.	Pak Chom	Lao PDR	Planned	1,079
7.	Ban Khoum	Lao PDR	Planned	2,000
8.	Pou Ngoy (Lat Sua)	Lao PDR	Planned	651
9.	Don Sahong	Lao PDR	Under Construction	260
10.	Stung Treng	Cambodia	Planned	980
11.	Sambor	Cambodia	Planned	1,703
	Total			12,578

Source: MRC (2016).

〈Appendix Table Ch 3-2〉 Operational Hydropower Projects on Mekong Tributaries (2014)

No.	Catchment	Project Name	Country	Installed Capacity (MW)
1.	Nam Ma	Nam Long	Lao PDR	5
2.	Nam Tha	Nam Nhone	Lao PDR	3
3.	Nam Ou	Nam Ko	Lao PDR	2
4.		Nam Ngay	Lao PDR	1
5.	Nam Khan	Nam Mong	Lao PDR	1
6.		Nam Dong	Lao PDR	1
7.	Nam Ngiep	Nam Ngiep 3A	Lao PDR	44
8.	Nam Mang	Nam Mang 3	Lao PDR	40
9.		Nam Leuk	Lao PDR	60
10.	Nam Ngum	Nam Ngum 1	Lao PDR	155
11.		Nam Ngum 2	Lao PDR	615
12.		Nam Ngum 5	Lao PDR	120
13.		Nam Lik 2	Lao PDR	100
14.		Nam Song	Lao PDR	6
15.	Nam Kading	Nam Theun 2	Lao PDR	1,080
16.		Theun-Hinboun	Lao PDR	220
17.		Theun-Hinboun Expansion	Lao PDR	280
18.	Xe Bang Hieng	Tad Salen	Lao PDR	3
19.	Xe Done	Xe Set 1	Lao PDR	45
20.		Xe Set 2	Lao PDR	76
21.		Xe Labam	Lao PDR	5
22.	Xe Kong	Houay Ho	Lao PDR	152
23.		Xe Kaman 3	Lao PDR	250
24.	Se San	O Chum 2	Cambodia	1
25.		Plei Krong	Viet Nam	100
26.		Yali	Viet Nam	720
27.		Se San 3	Viet Nam	260
28.		Se San 3A	Viet Nam	96
29.		Se San 4	Viet Nam	360
30.		Se San 4A	Viet Nam	63

〈Appendix Table Ch 3-2〉 Continued

No.	Catchment	Project Name	Country	Installed Capacity (MW)
31.	Sre Pok	Sre Pok 3	Viet Nam	220
32.		Sre Pok 4	Viet Nam	80
33.		Sre Pok 4A	Viet Nam	64
34.		Hoa Phu	Viet Nam	29
35.		Dray Hinh 1	Viet Nam	12
36.		Dray Hinh 2	Viet Nam	16
37.		Buon Kuop	Viet Nam	280
38.		Buon Tua Srah	Viet Nam	86
39.	Nam Kan	Nam Pung	Thailand	6
40.	Nma Mun	Pak Mun	Thailand	136
41.		lam Ta Khong P.S.	Thailand	500
42.		Sirindhorn	Thailand	36
43.	Nam Chi	Chulabhorn	Thailand	40
44.		Huai Kum	Thailand	1
45.		Ubol Ratana	Thailand	25
46.	Unknown	Nam Ken	Lao PDR	3
	Total			6,398

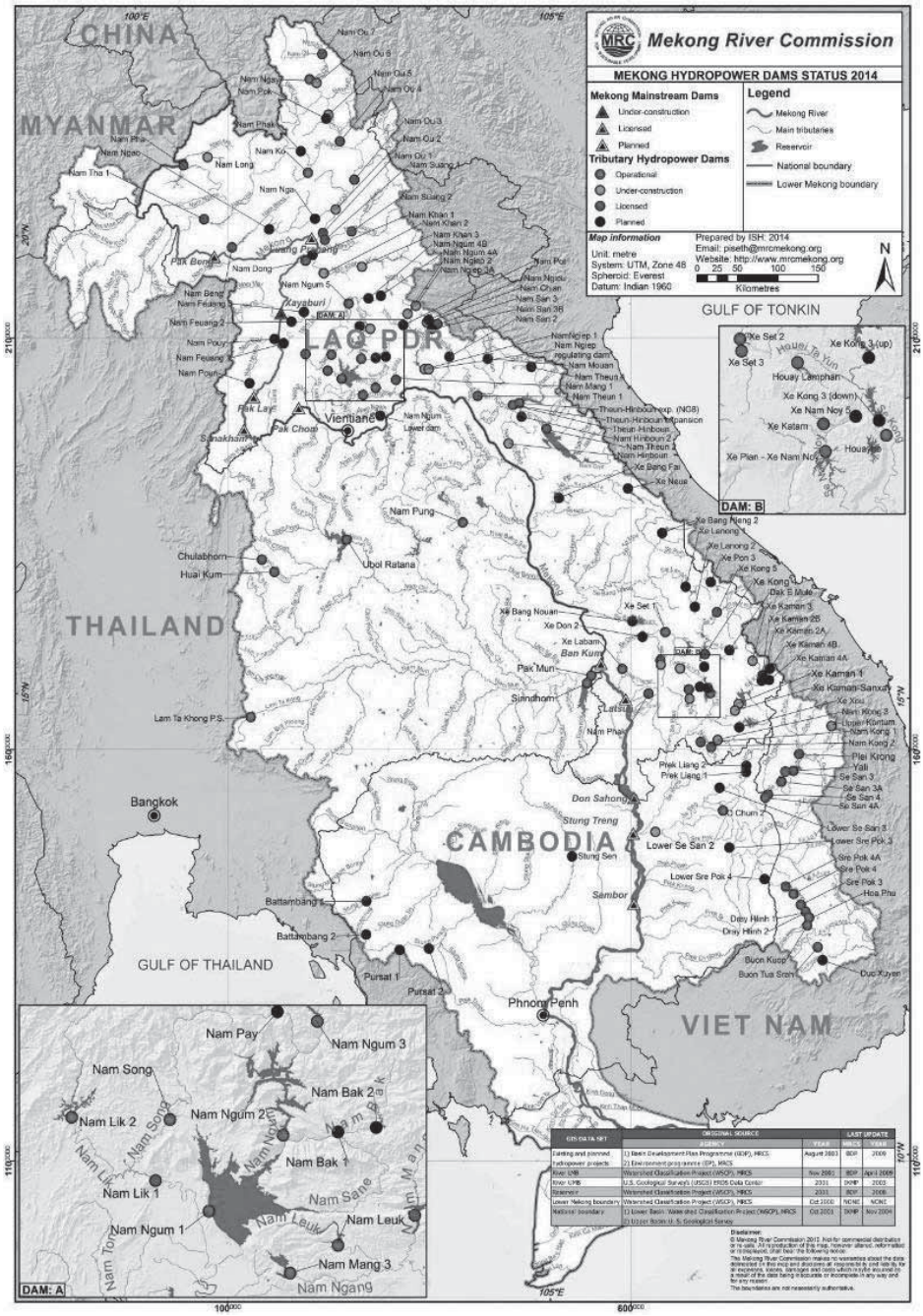
Source: MRC (2016).

〈Appendix Table Ch 3-3〉 Hydropower Projects Under Construction on Mekong Tributaries (2014)

No.	Catchment	Project Name	Country	Installed Capacity (MW)
1.	Nam Pho	Nam Pha	Lao PDR	130
2.	Nam Tha	Nam Tha 1	Lao PDR	168
3.	Nam Beng	Nam Beng	Lao PDR	34
4.	Nam Ou	Nam Phak	Lao PDR	45
5.		Nam Ou 2	Lao PDR	120
6.		Nam Ou 5	Lao PDR	240
7.		Nam Ou 6	Lao PDR	180
8.	Nam Khan	Nam Khan 2	Lao PDR	130
9.		Nam Khan 3	Lao PDR	95
10.	Nam Ngiep	Nam Ngiep regulating dam	Lao PDR	0
11.		Nam Ngiep 1	Lao PDR	290
12.		Nam Ngiep 2	Lao PDR	180
13.	Nam Mang	Nam Mang 1	Lao PDR	64
14.	Nam Ngum	Nam Bak 1	Lao PDR	163
15.		Nam Lik 1	Lao PDR	61
16.		Nam Phay	Lao PDR	86
17.	Nam San	Nam San 3A	Lao PDR	69
18.		Nam San 3B	Lao PDR	45
19.		Nam Chien	Lao PDR	104
20.	Nam Hinboun	Nam Hinboun	Lao PDR	30
21.	Se Kong	Xe Pian & Xe Namnoy	Lao PDR	390
22.		Xe Kaman 1	Lao PDR	322
23.		Nam Kong 1	Lao PDR	150
24.		Nam Kong 2	Lao PDR	66
25.	Se San	Lower Se San 2	Cambodia	400
26.		Upper Kontum	Viet Nam	220
27.	Unknown	Nam Sim	Lao PDR	8
	Total			3,790

Source: MRC (2016).

[Appendix Figure Ch 3-1] Hydropower Dams on the Lower Mekong Mainstream and Tributaries



Source: MRC (2016).

2017/18 Knowledge Sharing Program with the MRC:
Basin-wide Strategy for Sustainable Hydropower Development

Chapter 4

Future Direction of Sustainable Hydropower Development

1. Sustainable Dam Management in Korea
2. Integrated Hydropower Dam Management Case Study in Han River Basin
3. Future Direction of Hydropower Development in the Mekong River Basin
4. Implications and Recommendations

Future Direction of Sustainable Hydropower Development

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Summary

In the past, construction projects for water resource infrastructures such as dams greatly contributed to advancing the national economy, both directly and indirectly. However, due to increased climate change impacts, persistent floods that last over long periods of time, river pollution, and increased environmental awareness among citizens, we are living in a time where a new paradigm of policies is necessary, such as water demand management and effective use of water resource infrastructures, rather than the construction-oriented water resource management policies of the past.

Japan is pushing forward water resource management that involves flexibility, localization, and multi-layered safety, while the UNESCAP (United Nations Economic and Social Commission for Asia and the Pacific) is emphasizing the significance of eco-efficient water resource management for sustainable growth. As such, there is a recent, clear paradigm shift in terms of water resource planning and management. The paradigm shifts in water resource management that are currently in discussion around the world can be summarized into sustainability, integrated water resource management (IWRM), basin oriented management, and establishing a mechanism for increased participation and mediation of interests between governance and stakeholders.

Keywords: Sustainable Dam Management, Integrated Hydropower Dam Management, Reassessing Existing Dam, Hydropower Development in the Mekong River Basin

Countries of the Mekong River Basin have some similar objectives as Korea, which are to build hydropower dams for several purposes, mainly electricity power generation, flood control, and water supply. The monsoon climate provides distinct weather characteristics such as the rainy season and dry season.

However, many of the water resource infrastructures that have been built around the world through water resource development projects that have continued over an extended period of time are nearing or have already passed their life expectancy. In Korea, it has been over 40 years since most of the multi-purpose dams were built, considering that large-scale dam construction began early starting from the 1970s, and many small to mid-sized agricultural dams and, as such, many hydropower dams are over 70 years old.

Therefore, for the construction of hydropower dams and multi-purpose dams that have been in operation over a long period of time in Korea, their operation, management technology, and relevant dam development experience can provide useful insight for developing sustainable hydropower generation in the Mekong River Basin and resolve water security issues. These can also promote sustainable development of hydropower through remodeling by re-evaluating existing dams instead of building new dams to satisfy the demand for power.

The purpose of this research is to assess the status of hydro power energy supply and demand in the Mekong River Basin, and to provide support, so that sustainable hydropower development strategies can be established for the Mekong River Basin in consideration of the water resources and environment (droughts, floods, hydropower development, biodiversity, socioeconomic development strategies) of member countries of the Mekong River Commission.

Therefore, in order to derive upon a future direction for sustainable hydropower generation at the Mekong River Basin, this study analyzes Korea's advanced dam management policies. It also proposes technical alternatives for methods and procedures that involve storage reallocation through 1)the re-evaluation of the flood control storage, water conservation storage, and hydropower generation of dams that were built long time ago and through 2) the reassessment of existing dams to completely change their operation purposes.

Dam reassessment entails reassessing the effectiveness and capabilities of an installed dam by taking into account changes in runoff and the hydrological environment in comparison to when the dam was first designed, if there are any changes. Items for review for the reassessment include an evaluation of the dam's operational performance and construction effects after completion of its construction, analyzing water usage environmental changes, dam hydrological

analysis, estimation of water demand by purpose, and an evaluation of the dam's ability to supply water.

The US Army Corps of Engineers (USACE) conducted a reassessment of flood control dams located across the United States in 1988 and performed a technical review on storage reallocation, so that flood control dams can take on water supply functions. To this end, reassessments of existing dams in the United States regarding flood control dams that are managed by the USACE were analyzed, and the storage reallocation plan that was proposed by the USACE by reviewing storage reallocation scenarios that occurred through this reassessment of existing dams were reviewed.

Korea established a general plan for the reassessment of existing dams and for optimal storage reallocation through the Ministry of Land, Infrastructure and Transport in 2010, and a reassessment study was conducted in 2014 to review the impact of reassessments on water resource facilities such as dams according to climate change. A reassessment is being conducted on large-scale multi-purpose dams that are managed by K-water through the above two previous studies, and the reassessment results are being prepared for each basin.

In another dam related issue, this study conducted an analysis on dam management policy in the Han River Basin and diagnosed the problems and issues that followed management and operational dualization of three multi-purpose dams that are managed by K-water and five hydropower generation dams that are managed by the Korea Hydro-Nuclear Power Co. (KHNP) in the Han River Basin. If the hydropower generation dam was operated in conjunction with multi-purpose dams, the results of case studies on the effects of integrated joint operation of hydropower generation dams and the negotiation process for integrated operation were presented through analyzing the flood control and water use effects.

Lastly, the main current issues related to the construction and management of hydropower generation dams at the Mekong River Basin were analyzed, along with the alternatives that have been proposed thus far for sustainable hydropower development at the Mekong River Basin.

Through the above research, the efficiency of dam management policy through revaluation of existing dams has been proposed as an alternative to the construction of new dams. In addition, the importance of the change of the water resources management policy that has shifted from construction-centered and water supply-oriented water resources management policy to the management of existing facilities and the water demand oriented policy will be presented.

Managing entities are become more and more diverse for countless dams at the

Mekong River Basin, which is causing various conflicts and issues. A review on the issue of dam management unification at the Han River Basin may be proposed as a technical alternative that can resolve the difference in opinions among those who manage dams at the Mekong River Basin.

1. Sustainable Dam Management in Korea

1.1. Overview

A dam is a key hydraulic infrastructure that is used to block water flowing from rivers in order to store large amount of river flow in the reservoir, and supply that water as municipal, industrial, and agricultural water, as well as for the purpose of hydropower generation and flood control. Countries of the Mekong River Basin, similarly to Korea, require dam construction for hydropower generation, which is necessary for flood control, water supply, and generating insufficient power since the rainy season and dry season are very distinct as monsoon climatic characteristics.

Based on recent statistics that are solely based on Korea, 20 large-scale multi-purpose dams, three estuary banks, three flood control dams, and 14 water supply dams were built and are being managed by K-water. There are also eight hydropower generation dams managed by Korea Hydro & Nuclear Power Corporation and 3,400 agricultural dams managed by the Korea Rural Community Corporation, which makes for a large number of dams just in the nation of Korea alone. Moreover, there are over 14,000 small to mid-sized agricultural reservoirs that are managed by local governments.

The demand for water has continuously increased as a result of rapid industrialization and urbanization since the 1960s, and there is expected to be a shortage of water in the future even after taking into account the reservoir storage of dams that are already constructed. Moreover, flood damage is only expected to increase due to abnormal floods from the recent changes in climate, hence there is an urgent need to secure emergency water that can be used in case of extreme droughts that last over an extended period of time.

Although there is a constant demand for new dam construction for these reasons, this is an incredibly difficult due to issues such as securing a dam site that is adequate for new dams, rising construction costs, and environmental problems. Therefore, the Korean government is changing their priorities in policies regarding new dam construction to focus on dam re-development policies where dams that have already been constructed can be used more efficiently.

Redeveloping existing dams involve completely changing the purpose of an existing dam that no longer functions for a specific purpose, but for multi-purpose dams, redevelopment also involves storage reallocation through a reassessment on the flood control storage, water supply storage, and hydropower generation of an existing dam that was constructed long ago. In other words, a reassessment of existing dams consists of an evaluation on the effects and capacity of a currently installed dam in consideration of various changes that have occurred (climate change, hydrological changes, changes in water and energy demand), such as climate changes, compared to when the dam was first built due to the passing of time.

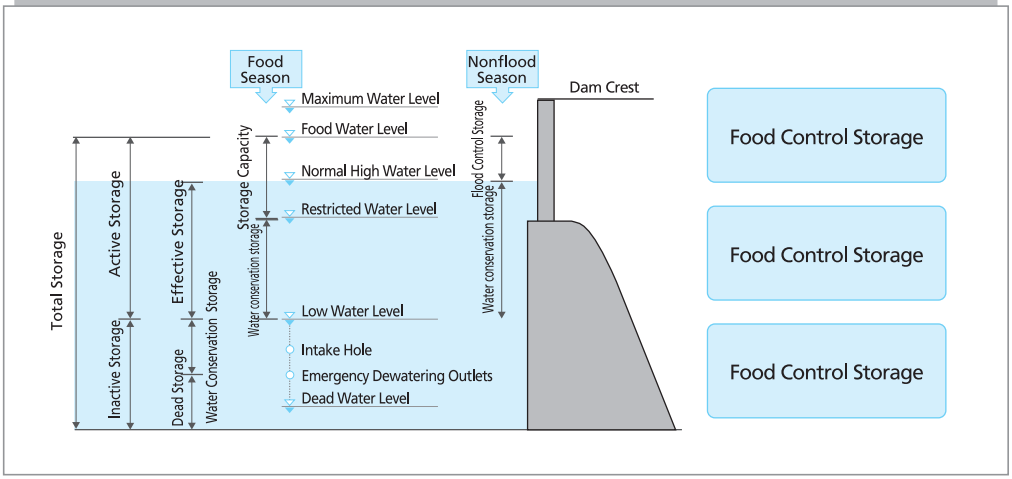
Since effects that are similar to new dam construction can be obtained by reusing the reservoir storage of existing dams rather than building new dams through this process of dam reassessment, it is seen as a valuable technique that can be fully used in countries with many dams that have already been constructed and are in use.

1.2. Reassessment of Existing Multi-purpose Dams

1.2.1. Concept of Reassessing Existing Dams

Dam reassessment means to reassess the effectiveness and capabilities of an installed dam by taking into account changes in precipitation, runoff, and the hydrological environment in comparison to when the dam was first designed, if there are any changes. Items for review for the reassessment include an evaluation of the dam's operational performance and analyzing water usage environmental changes, hydro-meteorological change, estimation of water demand, and an evaluation of the dam's ability to water supply.

[Figure 4-1] Concept of the Reservoir Storage of Multi-purpose Dams



Source: Author.

Dams typically store water and require storage reallocation according to purpose by dividing the water into water conservation storage and flood control storage. Storage reallocation is indicated by water level and reservoir storage. In other words, sediment yield is used to determine dead storage level (DSL), hydropower generation for low water level (LWL), instream flow, and environmental flow and water conservation storage for normal high-water level (NHWL), flood control storage (design flood discharge) for restricted water level (RWL), and flood water level (FWL).

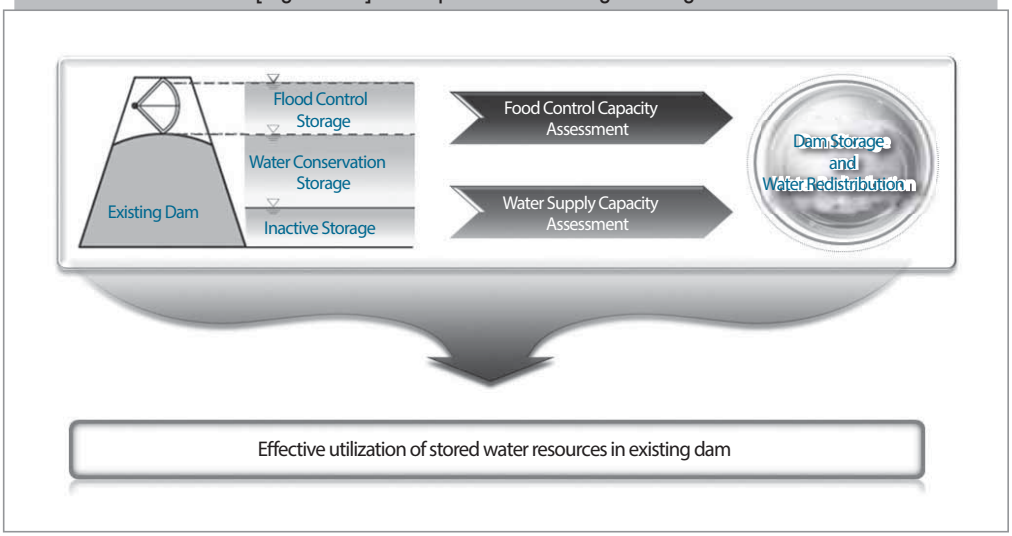
The reservoir storage is determined according to its purpose and functions, and it is allocated from the bottom of the dam to the dam crest and divided into inactive storage that includes dead storage, active storage, and excess storage. Furthermore, active storage is divided into water conservation storage and flood control storage.

Therefore, the subjects of dam reassessment are inactive storage, water conservation storage, and flood control storage to determine whether or not the current storage and specifications are adequate.

Ultimately, the dam reassessment is a review on the appropriateness of the flood control storage, water conservation storage (agricultural water, municipal water, industrial water, power generation water), and inactive storage that were allocated when the dam was first designed for the current point in time.

In addition, storage reallocation according to dam reassessment means resetting allocations by reviewing the adequacy of the inactive storage (dead storage + emergency storage), water conservation storage, and flood control storage that were established when the reservoir's total storage was designed according to its purpose and functions. Storage reallocation through dam reassessment refers to resetting the water supply amount for each respective purpose, such as municipal water, industrial water, agricultural water, and instream flow for the current time based on the water supply capacity.

[Figure 4-2] Concept of Reassessing Existing Dams



Source: Author.

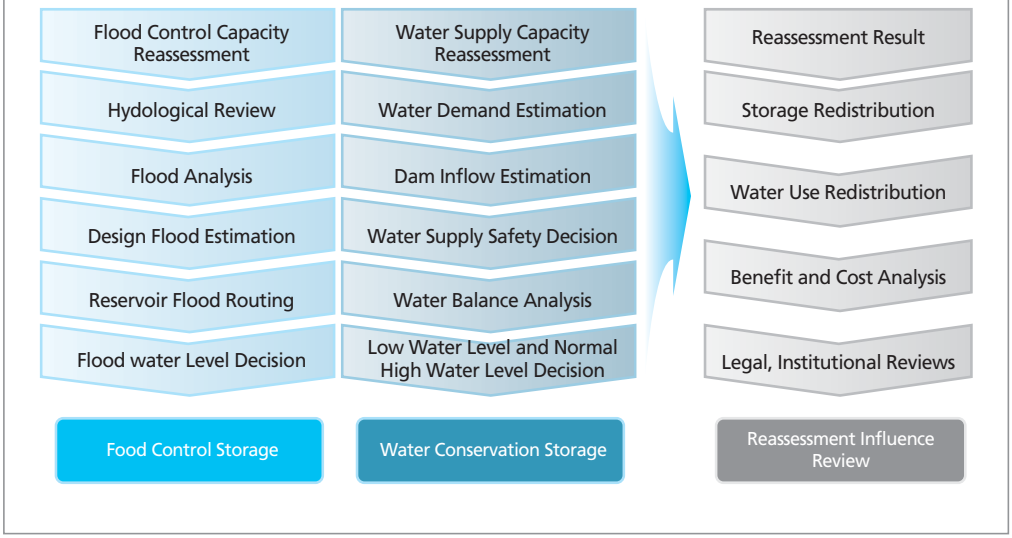
1.2.1. Reassessment of Existing Dams

Dam reassessment involves assessing the status of existing dams and collecting analysis data from when the dam was first designed, then analyzing the details of investigations related to the reassessment of existing dams, such as the design flood discharge, water supply, and hydropower generation at the current state. In the past, dams only served the three different roles of water supply, hydropower generation, and flood control. However, due to the various benefits that have been added recently, such as recreation, tourism, and water quality and environment improvements, it is also important to determine whether or not all these benefits will be quantified and taken into account.

This process of reassessment will only be realistically applicable if it is established systematically through technical rationality and societal consent.

Reassessing existing dams means to reassess the flood control capacity and water supply capacity (municipal water, industrial water, agricultural water, river instream water, hydropower generation water) of dams that were built in the past from the current perspective and follows the procedure below.

[Figure 4-3] Process of Reassessing Existing Dams



Source: Kwater (2014).

1) Reassessment of Flood Control Storage

(1) Hydrological Analysis

- The hydrological analysis in the reassessment of existing dams is identical to the hydrological analysis process when the dam was first designed
- Dam Basin Survey: Topography information, population, agricultural land, etc.
- Meteorological Data Analysis: Climate, precipitation, evaporation, relative humidity, etc.
- Precipitation Data Analysis: Average basin precipitation, probable precipitation, and probable maximum precipitation (PMP)
- Flow Data Analysis: Observed runoff (inflow), flow regime analysis.

(2) Analyze Flood and Determine Hydrograph

- Runoff Analysis: Precipitation-Runoff modeling method, analysis of measured dam inflow
- Design Flood Discharge: Calculate design flood discharge for each frequency by applying the daily precipitation of each frequency to the Precipitation-Runoff Model
- Probable Maximum Flood(PMF): Calculated using the probable maximum precipitation and Precipitation-Runoff Model

- The dam's design hydrograph is determined through the above flood analysis.

(3) Reservoir Flood Routing and Determine Flood Water Level

- Apply the estimated design inflow hydrograph and spillway conditions, then use the simulation method of optimization method to perform reservoir flood routing.
- Reassess the flood control capacity through reservoir flood routing and determine the restricted water level (RWL) or flood water level (FWL).

2) Reassessment of Water Conservation Storage

(1) Estimate Water Demand

- Survey usage status according to municipal water, industrial water, agricultural water, and instream flow.
- Determine the amount of change in the water demand that was reflected when the dam was first designed.

(2) Determine Dam Inflow and Water Supply Reliability

- Analyze the inflow that was observed in the past from the existing dam.
- If there is not enough observation data, use the Precipitation-Runoff Model to determine this figure.
- 95-97% is used for water supply reliability, which is a reliability that typically permits water shortage 1 time in 20-30 years, but the standard that was applied when the dam was first designed was used as is.

(3) Determine Low Water Level (LWL) and Normal High Water Level (NHWL) through the Water Budget Analysis

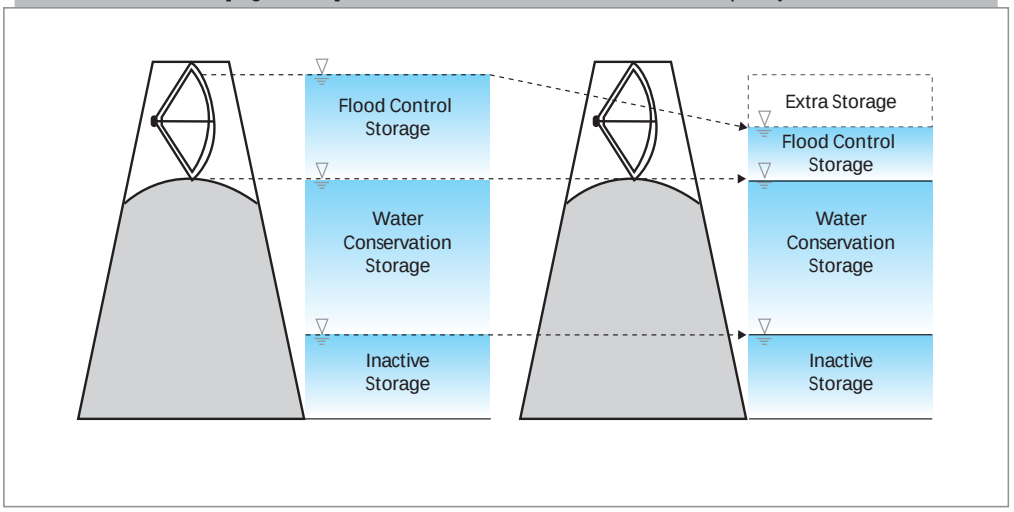
- Water budget analysis predicts excess shortage by comparing the observed dam inflow with future water demand in order to plan for the basin's future water supply and demand.
- Reassess the water supply capacity in consideration of the water budget analysis and the low water level and normal high-water level when the dam was first designed.

1.3. Storage Reallocation for Existing Dams

1.3.1. Reassessment Results for Existing Dams

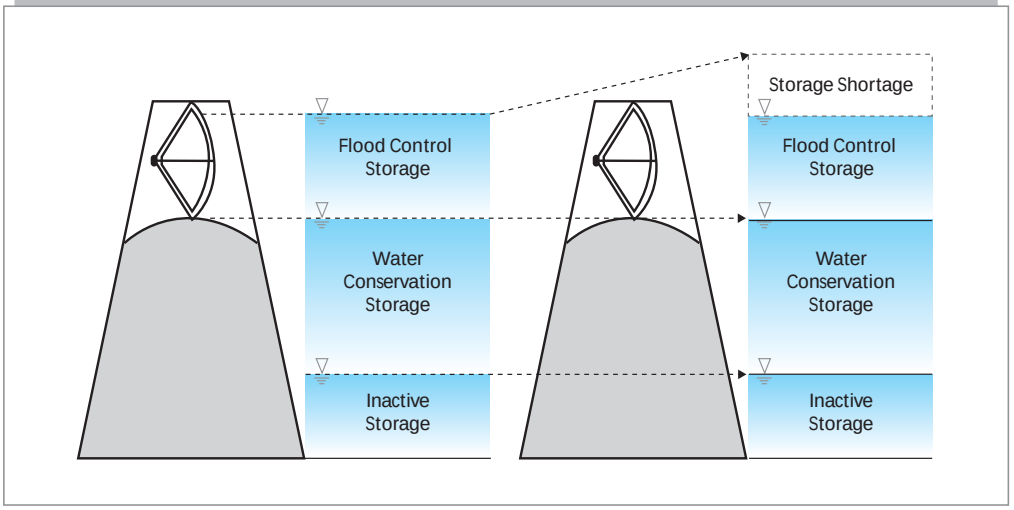
The results that may be derived through a reassessment on the flood control capacity and water supply capacity of multi-purpose dams can be summarized into the following four scenarios.

[Figure 4-4] Scenario 1: Increased Flood Control Capacity



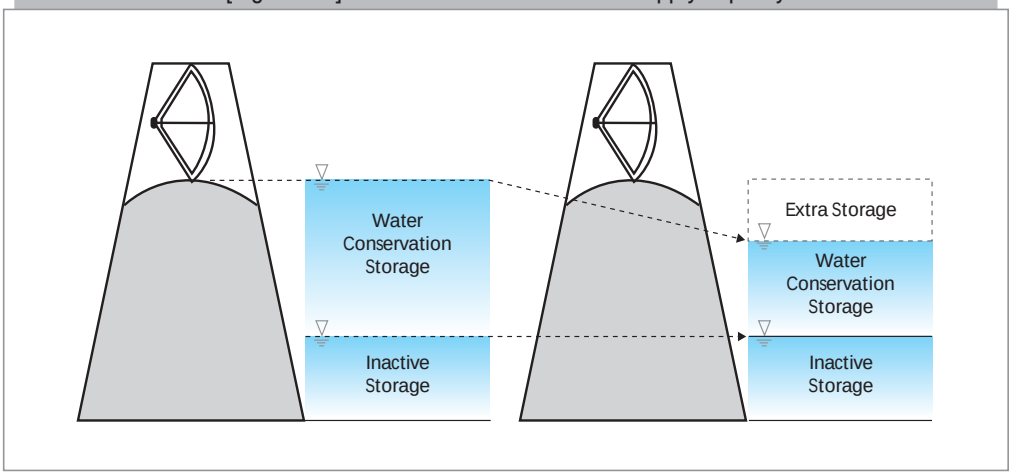
Source: Author.

[Figure 4-5] Scenario 2: Decreased Flood Control Capacity



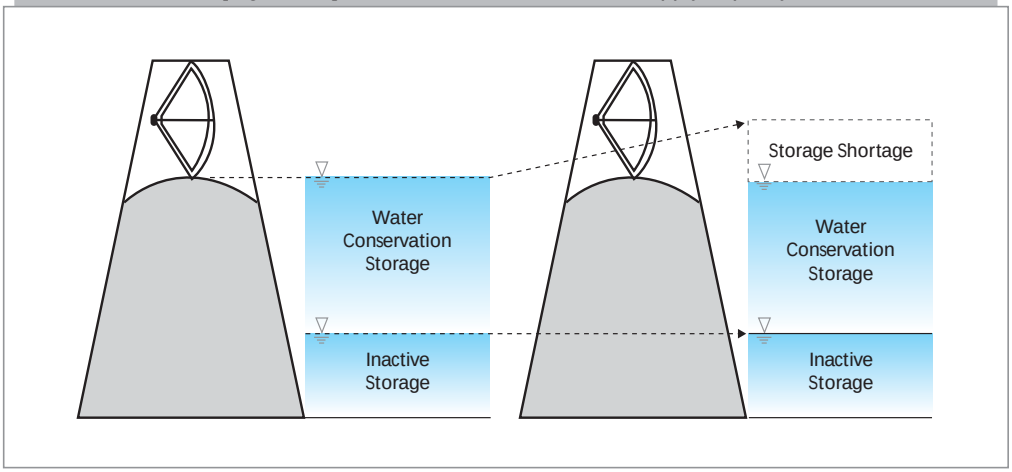
Source: Author.

[Figure 4-6] Scenario 3: Increased Water Supply Capacity



Source: Author.

[Figure 4-7] Scenario 4: Decreased Water Supply Capacity



Source: Author.

1.3.2. Storage Reallocation

In the dam reassessment results, if the flood control capacity increases, the current flood control capacity may decrease and a decreased flood control capacity may be converted into water conservation storage. However, at the current point in time where climate change is exigent, reducing flood control capacity is unfavorable from the perspective of flood defense under the increasing climate change impact.

If the flood control capacity decreases in the dam reassessment, this implies that the current flood control capacity must be improved. In such cases, if there is

no surplus in the water conservation storage, raising the dam and other structural means will be the only other alternative.

If water supply capacity increases in the dam reassessment results, the water conservation storage may decrease, and a decrease in water conservation storage can be converted into flood control storage. If there is no need to increase the flood control storage, there must be a reallocation of the surplus in the increased water conservation storage (municipal water, industrial water, agricultural water, hydropower generation water, river instream flow). To reallocate water effectively, a target year must be set for the future to evaluate water supply capacity, then water supply and demand can be tracked in consideration of climate change for practical water reallocation.

Water supply capacity typically decreases when dam inflow and natural runoff decreases according to climate change. In such cases, this may be converted from the increased flood control storage, but if there is no surplus in the flood control storage, the water shortage can be minimized through storage reallocation.

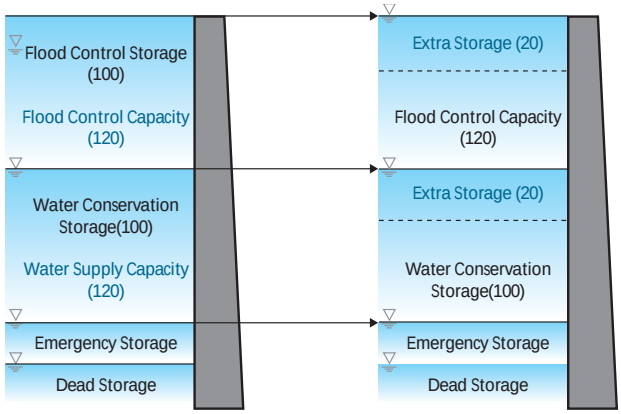
To reallocate dam storage, institutional, economic, legal, political, and technical factors must be complexly taken into account. From the technical perspective, even if storage reallocation is possible according to the reassessment results, because the water supply amount for each purpose, such as municipal water, industrial water, agricultural water, or river instream flow, and the reservoir storage for each purpose, such as flood control storage and water conservation storage, are mutually supplementary, there must be a discussion between stakeholders in order for reallocation to actually occur. These processes must be established legally and institutionally in order to be implemented.

When the above four dam reassessment results are combined, the following storage reallocation scenarios can be expected.

1) Storage Reallocation Case #1

- Reassessment Results: Increased Flood Control Capacity + Increased Water Supply Capacity

〈Table 4-1〉 Storage Reallocation Case 1

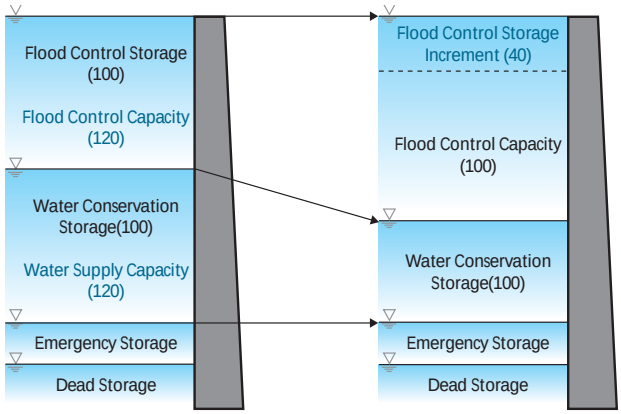
Reallocation Concept	
Reallocation	No reallocation (secure surplus for increased flood control storage(FCS) and potential water supply storage)

Source: Author.

2) Storage Reallocation Case #2

- **Reassessment Results: Increased Flood Control Capacity + Increased Water Supply Capacity**

〈Table 4-2〉 Storage Reallocation Case 2

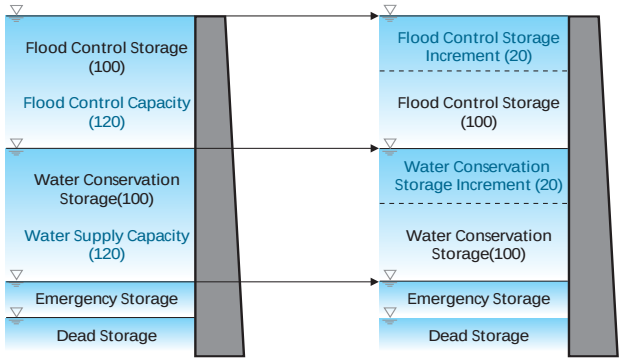
Reallocation Concept	
Reallocation	Reallocate increased flood control storage and water supply storage to flood control storage

Source: Author.

3) Storage Reallocation Case #3

- Reassessment Results: Increased Flood Control Capacity + Increased Water Supply Capacity

⟨Table 4-3⟩ Storage Reallocation Case 3

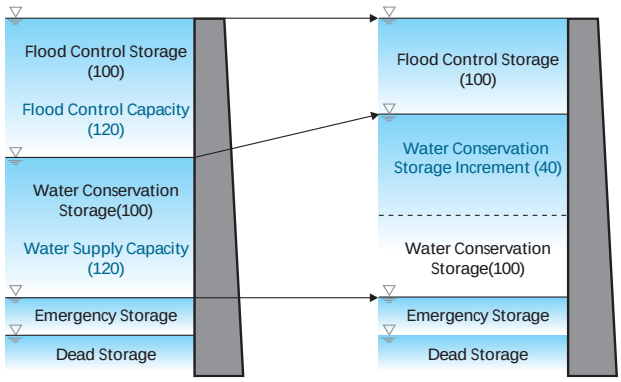
Reallocation Concept	
Reallocation	Reallocate flood control storage and water supply capacity surplus to flood control storage and water conservation storage, respectively

Source: Author.

4) Storage Reallocation Case #4

- Reassessment Results: Increased Flood Control Capacity + Increased Water Supply Capacity

⟨Table 4-4⟩ Storage Reallocation Case 4

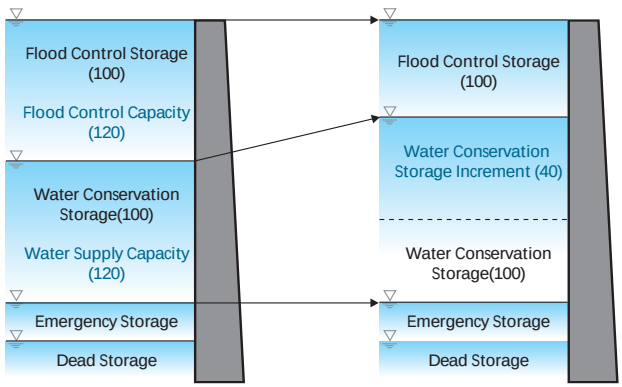
Reallocation Concept	
Reallocation	Reallocate flood control storage and water supply storage surplus to water conservation storage

Source: Author.

5) Storage Reallocation Case #5

- **Reassessment Results: Increased Flood Control Capacity + Decreased Water Supply Capacity**

〈Table 4-5〉 Storage Reallocation Case 5

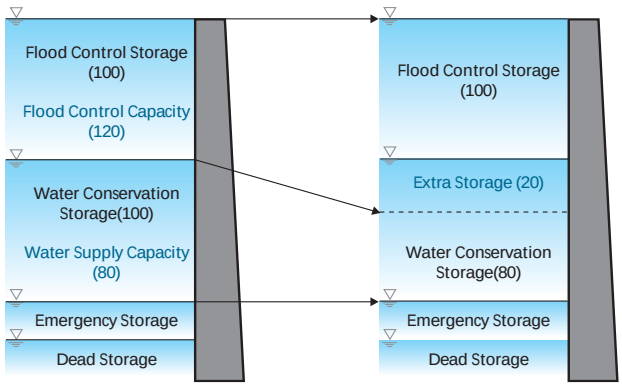
Reallocation Concept		
Reallocation	Reallocate flood control storage surplus to water conservation storage	

Source: Author.

6) Storage Reallocation Case #6

- **Reassessment Results: Increased Flood Control Capacity + Decreased Water Supply Capacity**

〈Table 4-6〉 Storage Reallocation Case 6

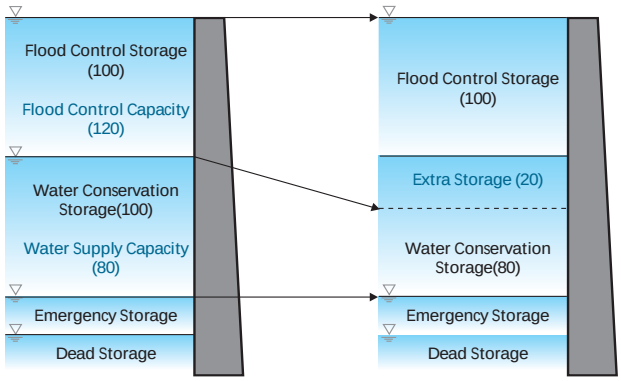
Reallocation Concept		
Reallocation	No reallocation (secure increased flood control storage as flood control surplus)	

Source: Author.

7) Storage Reallocation Case #7

- Reassessment Results: Decreased Flood Control Capacity + Increased Water Supply Capacity

〈Table 4-7〉 Storage Reallocation Case 6

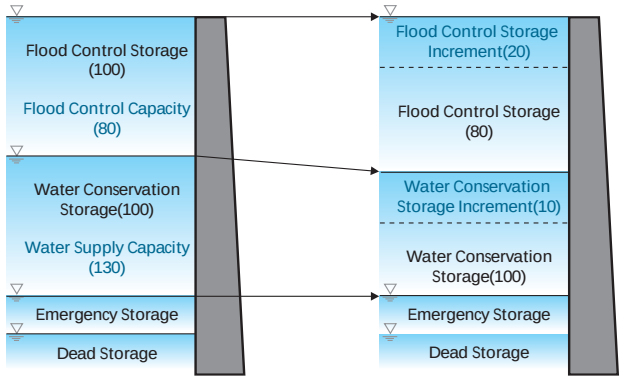
Reallocation Concept	
Reallocation	Reallocate water conservation storage surplus to flood control storage

Source: Author.

8) Storage Reallocation Case #8

- Reassessment Results: Decreased Flood Control Capacity + Increased Water Supply Capacity

〈Table 4-8〉 Storage Reallocation Case 8

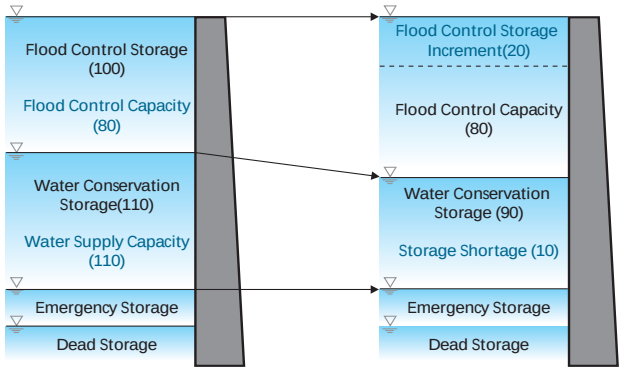
Reallocation Concept	
Reallocation	Reallocate water conservation storage surplus to flood control storage (surplus occurs from water conservation storage)

Source: Author.

9) Storage Reallocation Case #9

- **Reassessment Results: Decreased Flood Control Capacity + Increased Water Supply Capacity**

〈Table 4-9〉 Storage Reallocation Case 9

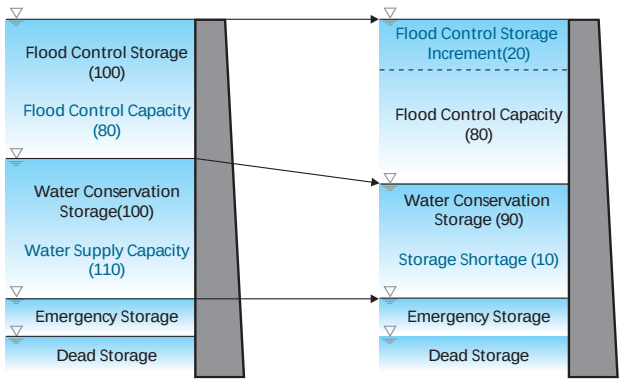
Reallocation Concept	
Reallocation	Reallocate water conservation storage surplus to flood control storage (shortage occurs from water conservation storage)

Source: Author.

10) Storage Reallocation Case #10

- **Reassessment Results: Decreased Flood Control Capacity + Decreased Water Supply Capacity**

〈Table 4-10〉 Storage Reallocation Case 10

Reallocation Concept	
Reallocation	Reallocate water conservation storage to flood control storage (severe lack of water supply capacity)

Source: Author.

〈Table 4-11〉 Storage Reallocation Options for each Case

Case	Reassessment Results		Storage Reallocation Options
	Flood Control Capacity	Water Supply Capacity	
1	Increased	Increased	No reallocation
2	Increased	Increased	Reallocate increased storage to flood control storage
3	Increased	Increased	Reallocate increased capacity to flood control storage and water conservation storage, respectively
4	Increased	Increased	Reallocate increased storage to water supply storage
5	Increased	Decreased	Reallocate flood control storage surplus to water conservation storage
6	Increased	Decreased	No reallocation (Secure increased flood control storage as flood control surplus)
7	Decreased	Increased	Reallocate water conservation storage surplus to flood control storage
8	Decreased	Increased	Reallocate water conservation storage surplus to flood control storage (surplus occurs from water conservation storage)
9	Decreased	Increased	Reallocate water conservation storage surplus to flood control storage (shortage occurs from water conservation storage)
10	Decreased	Decreased	Reallocate water conservation storage to flood control storage (severe lack of water supply capacity occur)

Source: Author.

1.4. Case Studies for Dam Reassessment and Storage Reallocation

1.4.1. Korean Geum River Basin Case Study

The Geum River Basin is the third largest basin in Korea. It has two multi-purpose dams (Dae-Chung Dam and Yong-Dam Dam) in the basin for flood control and water supply. The specifications of the Dae-Chung Dam and Yong-Dam Dam are as follows.

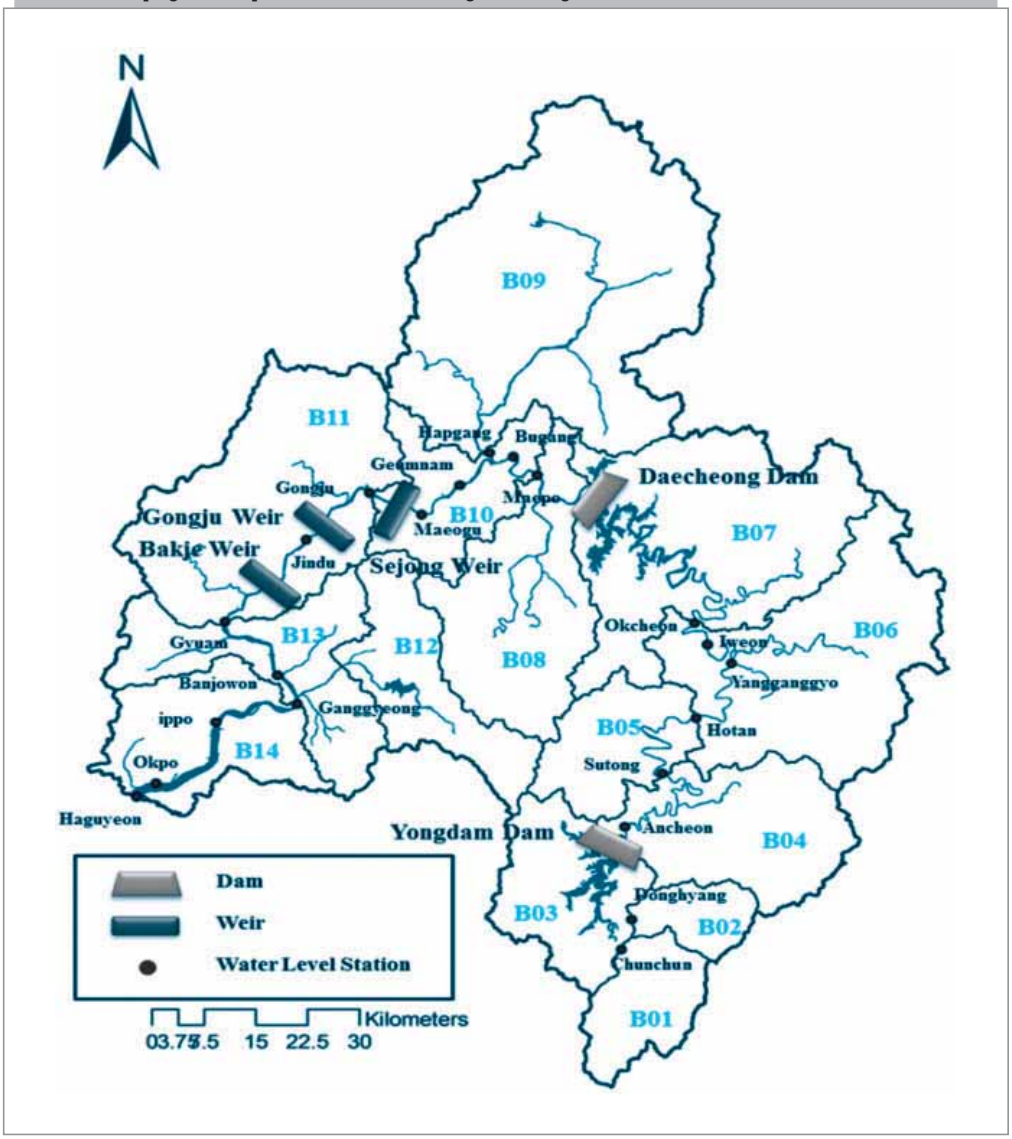
〈Table 4-12〉 Basic Information of Multi-purpose Dams in Geum River Basin

Dam	Height (m)	Length (m)	Dam Type	Basin Area (km^2)	Effective Storage (Million m^3)	COD
Dae-Chung	72.0	495.0	CGD	4,134	790	1981
Yong-Dam	70.0	498.0	CFRD	930	672	2006

Source: K-Water (2017).

In 2016, a reassessment was performed on two multi-purpose dams located in the Geum River Basin in order to use the basin's water resources more efficiently. It has been 36 years since the Daechung Dam was built and 10 years since the Yongdam Dam finished construction.

[Figure 4-8] Location of Daechung and Yongdam Dam in Geum River Basin



Source: Jung *et al*. (2018).

Upon analyzing changes in precipitation and dam inflow at the Dae-Chung Dam and Yong-Dam Dam after completion of their construction, both of the multi-purpose dams showed a decrease in annual inflow at the point of reassessment compared to when they were first built, and the design flood discharge had also decreased by 2% and 19%, respectively. These results are believed to have resulted from changes in key factors, such as parameters and unit hydrographs that are applied when flood discharge is calculated alongside changes in the natural environment, such as precipitation and land use.

〈Table 4-13〉 Change in Hydrologic Environment since Dam Construction

Dam	Annual Precipitation Change			Dam Inflow Change			Peak Discharge Change
	Average	Flooding Season	Non Flooding Season	Average	Flooding Season	Non Flooding Season	
Dae-Chung	4% ↓	3% ↓	8% ↓	20% ↓	15% ↓	30% ↓	2% ↓
Yong-Dam	8% ↑	15% ↑	3% ↓	4% ↓	9% ↑	26% ↓	19% ↓

Source: K-water (2017).

In the results of the water supply capacity reassessment, the Dae-Chung Dam's non-flood season precipitation had decreased by 20% compared to when it was first designed, which resulted in decreased water supply reliability. Furthermore, because the Yong-Dam Dam was newly constructed in the upstream of the Dae-Chung Dam in addition to decreased average annual precipitation, the Dae-Chung Dam is believed to have suffered a rapid decrease in inflow. For these reasons, the Dae-Chung Dam's potential water supply storage was about 556.9 million m^3/year, which is about a 30% decrease from when it was first built.

Average annual precipitation had increased at the Yong-Dam Dam. However, while the flood season inflow increased by 9%, non-flood season inflow had decreased by about 26%. As a result, overall inflow since construction had decreased by about 4%, showing that potential water supply storage had decreased by 83.9 million m^3/year.

〈Table 4-13〉 Change in Hydrologic Environment since Dam Construction

Dam	Annual Precipitation Change			Dam Inflow Change			Peak Discharge Change
	Average	Flooding Season	Non Flooding Season	Average	Flooding Season	Non Flooding Season	
Dae-Chung	4% ↓	3% ↓	8% ↓	20% ↓	15% ↓	30% ↓	2% ↓
Yong-Dam	8% ↑	15% ↑	3% ↓	4% ↓	9% ↑	26% ↓	19% ↓

Source: K-water (2017).

〈Table 4-14〉 Changes in Water Supply Capacity through the Dam Reassessment

Dam	Reassessment Items	Reassessment Result		
		Design	Current	Change
Dae-Chung	Water Supply Capability (Million m^3/year)	1,766.3	1,209.4	-556.9 (32% ↓)
Yong-Dam		665.9	582.0	-83.9 (13% ↓)

Source: K-water (2017).

In the reassessment results regarding flood control capacity, the designed flood discharge decreased by 2% at the Dae-Chung Dam, and the dam's peak flood water level decreased by 1.11m, which showed that there is a margin in flood control compared to the design.

For the Yong-Dam Dam, designed flood discharge decreased by 10% with a 1.01m decrease in peak flood water level compared to the original design. In the reassessment results on the flood control capacity of the Dae-Chung Dam and Yong-Dam Dam, based on the decrease in the peak discharge from both multi-purpose dams, there seems to have been no issues in the flood control capacity when the dams were first designed.

〈Table 4-15〉 Changes in Flood Control Capacity through the Dam Reassessment

Dam	Reassessment Items	Reassessment Result		
		Design	Current	Change
Dae-Chung	Design Precipitation (mm)	341	303	-38
	Design Flood Discharge (cms)	9,500	9,275	-225 (2% ↓)
	Peak Flood Level (EL.m)	80.0	78.99	-1.11
Yong-Dam	Design Precipitation (mm)	377	369	-8
	Design Flood Discharge (cms)	5,500	4,445	-1055 (19% ↓)
	Peak Flood Level (EL.m)	265.5	264.59	-1.01

Source: K-water (2017).

The results of reevaluation of Dae-Chung Dam and Yong-Dam Dam show that the flood control capacity increased (Scenario 1) and water supply capacity decreased (Scenario 4) in both dams.

Storage reallocation reflecting the revaluation results of the two dams has not yet been conducted. There is no major problem in flood control capacity, which is why the reallocation of flood control capacity has not been studied. In order to solve the problem of water supply capacity reduction, K-water is considering alternative

measures to secure additional water resources of 20.5 Million m^3/year by applying a joint operation between Dae-Chung Dam and Yong-Dam Dam, rather than alternatives to review capacity reallocation.

Based on the above dam reassessment results, the Dae-Chung Dam and Yong-Dam Dam were found to have reduced water supply capacities compared to their design, hence their stability will be further secured through developing new joint operation plans for the two dams and storage reallocation procedures.

1.4.2. USACE (US Army Corps of Engineers) Dam Storage Reallocation Case

There are two main organizations from the US federal government for dam (water resource) management: the US Army Corps of Engineers (USACE) and US Bureau of Reclamation (USBR). The USACE and USBR can perform diverse water resource-related projects under the approval of the United States Congress. The USACE takes charge of constructing and managing multi-purpose dams, including flood control, while the USBR takes charge of dam construction and management in relation to water supply. Therefore, the dams and reservoirs that were built through the USACE and USBR under approval from Congress are regulated under federal law (Rivers and Harbors Acts, Flood Control Acts, Water Resources Development Acts) so that they can achieve the construction purpose that was originally approved.

The US Congress enacted the Water Supply Act (WSA) in 1958 as a law that can support the development and supply of municipal and industrial water for the state government and local governments. The WSA provides regulations so that municipal and industrial water storage that is necessary in the region can be secured from existing flood control dams and newly constructed dams that are managed by the USACE.

1) Water Supply Act (WSA, 1958)

The US Congress granted the USACE with extended authority in order to secure water conservation storage for municipal and industrial water supply, but Congress also placed restrictions on the USACE's ability to reallocate the reservoir storage from existing projects and existing dams to secure the necessary storage space.

The following two matters were regulated regarding detailed circumstances for which storage reallocation was restricted:

1 If the project has a major impact on the approval, survey, plan, or construction purpose;

2 If it contains important or operational changes

Storage reallocations for dams that are subject to the above two scenarios required approval from US Congress. However, Congress did not clearly define what "major impact" or "important structural or operational changes" referred to in the WSA. As a result of this legal ambiguity, the USACE was able to reallocate reservoir storage according to general discretion.

2) USACE Engineering Manual EM 1165-2-105 (1961)

Since the enactment of the WSA, the USACE drafted their own manual for performing and exercising their duties and authority related to the supply of municipal and industrial water (U.S. Army Corps of Engineers, Water Supply Storage in Corps of Engineers' Projects, EM 1165-2-105). In 1977, the USACE adopted the following clause regulating that reallocations that do not involve a serious storage reallocation situation do not require approval from Congress:

〈Box 4-1〉 Addition to U.S. Army Corps of Engineers EM 1165-2-105 (Page 8a)

Modifications of reservoir projects to allocate all or part of the storage serving any authorized purpose from such purpose to storage serving domestic, municipal, or industrial water supply purposes are considered insignificant if the total reallocation of storage that may be made for such water supply uses in the modified project is not greater than 15 per centum of total storage capacity allocated to all authorized purposes or 50,000-acre feet, whichever is less
Storage reallocation of a dam is only possible within a range that does not exceed 15% of the total reservoir storage of 50,000-acre feet of the reservoir storage.

3) Storage Reallocation of Dams from the USACE in accordance with the WSA

Of the 134 dams that are managed by the USACE, about 11 million acre-feet (AF) are reservoir storage for municipal and industrial water. <Table 4-16> below shows cases of storage reallocation that was performed by the USACE for municipal and industrial water supply and shows that most of the reallocation took place within 15% of the reservoir storage. Storage reallocation was attempted for 640,000 acre-feet for a total of 44 dams in accordance with the WSA. However, 30% of storage was reallocated for only Cowanesque Lake. The Cowanesque Lake case was an exceptional case where the USACE's discretionary power regarding storage reallocation and the storage reallocation policies of Congress for each project happened to fuse.

〈Table 4-16〉 Corps Reservoirs with M&I Water Supply Reallocated Using WSA Authority

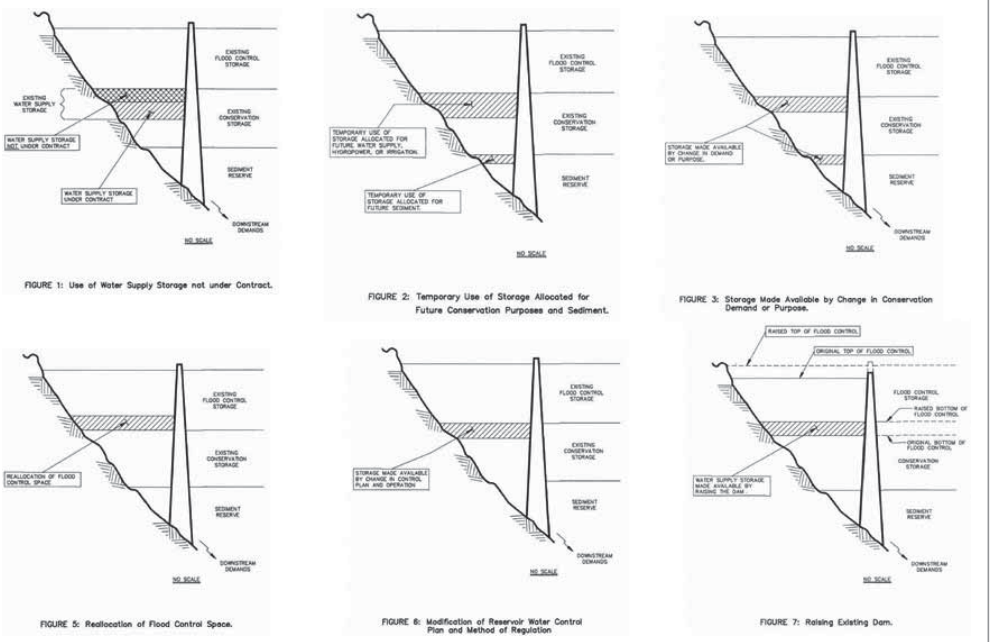
Reservoir Name and State	Usable Reservoir Storage (AF)	Supply Reallocated Under WSA(AF)	% of Storage Reallocated Under WSA
Denison Dam, L. Texoma, OK & TX	4,012,113	103,308	2.57
Melvern Lake, KS	337,000	50,000	14.84
Stockton Lake, MO	1,649,000	50,000	3.03
Tuttle Creek Lake, KS	2,001,000	50,000	2.5
Waco Lake, TX	733,536	47,526	6.48
Pomona Lake, KS	240,331	32,500	13.52
Hartwell, GA & SC	599,400	26,574	2.95
Cowanesque, PA	86,650	25,600	29.54
Tenkiller Ferry Lake, OK	1,458,000	25,472	1.75
John H. Kerr, VA	2,308,400	21,115	0.91
Beaver Lake, AR	1,224,700	20,995	1.71
Allatoona, GA	230,593	19,511	8.46
J. Percy Priset Dam & Reservoir, TN	124,000	17,311	13.96
Wister Lake, OK	417,600	13,819	3.31
Kanopolis Lake, KS	418,752	12,500	2.99
Marion, OK	141,114	12,500	8.86
Greers Ferry Lake, AR	1,650,500	11,556	0.7
Mosquito Creek Lake, OH	76,300	11,000	14.42
Youghiogherny River Lake, PA	151,000	10,000	6.62
Elk City. OK	248,398	10,000	4.03
John Redmond, OK	574,918	10,000	1.74
Council Grove Lake, OK	112,882	8,000	7.09
Center Hill Lake, TN	492,000	7,212	1.47
RathbunLake, IA	528,000	6,680	1.27
Curwensville, PA	111,998	5,360	4.79
Enid, MS	602,400	4,500	0.75
Green River Lake, KY	53,825	3,460	6.43
John W. Flannagan, VA	85,000	3,360	3.95

〈Table 4-16〉 Continued

Reservoir Name and State	Usable Reservoir Storage (AF)	Supply Reallocated Under WSA(AF)	% of Storage Reallocated Under WSA
J Strom Thurmond, GA	1,045,000	3,327	0.32
Grayson Lake, KY	119,000	2,508	2.11
Dale Hollow Lake, TN & KY	496,000	2,211	0.45
Carr Creek Lake, KY	34,981	2,052	5.87
Blakey Mt. Dam, Lake Ouachita, AR	617,400	1,575	0.26
Blue Mountain Lake, AR	233,260	1,550	0.66
Norfork Lake, AR	1,438,000	900	0.06
Bull Shoals Lake, AR	3,363,000	880	0.03
Richard B. Russell, GA & SC	266,806	872	0.33
Carters, GA	230,593	818	0.35
Cave Run Lake, KY	47,000	802	1.71
Laurel River Lake, KY	185,000	519	0.28
Summersville Lake, WV	57,900	468	0.81
Rough River Lake, KY	90,210	402	0.45
Harry S Truman Dam & Res., MO	4,959,000	283	0.01
Nimrod Lake, AR	307,000	143	0.05
Lake Lanier, GA	NA	NA	NA

Source: Congressional Research Service (2012).

[Figure 4-9] General Cases Derived from Existing Dam Reassessment



Source: USACE (1988).

2. Integrated Hydropower Dam Management Case Study in Han River Basin

2.1. Overview and Major Issues

2.1.1. Han River Basin

The Han River Basin is the most important basin in Korea and is located in Seoul, the capital city of Korea. The Han River Basin holds three multi-purpose dams (Chungju Dam, Hoengseong Dam, and Soyang River Dam, which has the largest reservoir storage in Korea (2.9 billion m^3)), three flood control dams (PyungHwaui Dam, Gunnam Dam, Hantangang Dam), and three multi-purpose weirs that were built through the Four Major Rivers Project.

Moreover, five hydropower generation dams (Hwacheon Dam, Chuncheon Dam, Euiam Dam, Cheongpyeong Dam, Paldang Dam) are located in the northern part of the Han River, while the Goesan Dam is located at the southern part as the hydropower generation dam.

[Figure 4-10] Han River Basin and Dam Location Map



Source: http://hrfco.go.kr

Of these, three multi-purpose dams, three flood control dams, and three multi-purpose weirs being operated by K-water. Six hydropower generation dams are owned by the KHNP (Korea Hydro & Nuclear Power Co.) and are being exclusively operated and managed for hydropower generation purposes.

2.1.2. Dams in the Han River Basin

Dams in the Han River Basin include multi-purpose dams and flood control dams that are managed by K-water, and hydropower generation dams that are managed by KHNP. These dams have been operating in compliance with their original purpose for many years, but there are now arguments that all dams in the Han River Basin should be co-managed in order to effectively counteract the more frequent floods and droughts that have been occurring as a result of recent climate change.

Sensitive suggestions are being made in response, such as performing an assessment on dam operation and unifying managing entities, but the following key issues have been raised:

[Figure 4-11] Major Issues of Responsible Multi Stakeholders of Dams



Issues	Basic Good Practice	Best Practice
Assessment	Adequate and effective assessment of dams in Han river basin	• Social aspect • Technical aspect (Single/Joint operation)
Management	Adequate and effective management plans and processes	• Transfer ownership • Consignment management
Stakeholders Engagement	Adequate and effective stakeholder engagement	• Communication & consultation for best governance
Expected Outcomes	Impacts are avoided, minimized, and mitigated, with no significant gaps	• Increased flood control capability • Increased water supply capability • Increased hydropower generation

Source: Author.

There are opposing arguments from the two institutions on the results of the quantitative analysis on the effects that may result from integrated dam management and the method of resolving potential issues that may occur during the process of unifying dam management. There are also different opinions on the effects of integrated dam management. Therefore, joint management between multi-purpose dams and hydropower generation dams in the Han River Basin will require a difficult discussion process between these two government-sponsored corporations.

Further, the integrated management and operation of multi-purpose dams and hydropower generation dams, which completely differ in the dam's legal ownership, dam management rights, and the dam's operational methods, involve even more problems from legal and institutional aspects than technical aspects.

2.2. Assessment

2.2.1. Water Resources in Han River Basin

The Paldang Dam's annual average inflow over the last 10 years in the Han River water system is 16.51 billion m^3, and the minimum inflow was 6.06 billion m^3 as of 2015, which was the year of severe drought at the Han River Basin.

The overall basin inflow for the three multi-purpose dams and three multi-

purpose weirs is 10.95 billion m^3, and the basin inflow of hydropower dams in the Han River water system is 6.03 billion m^3.

Recently, the multi-purpose dam water usage amount is 4.01 billion m^3 (municipal, agricultural, river instream flow), river water usage amounts to 710 million m^3 (municipal, industrial, agricultural water), and the multi-purpose dam water usage is about 81% of the basic design supply (4.97 billion m^3/year). The amount of water that is used for hydropower generation by multi-purpose dams is 6.27 billion m^3, and the amount of water for generation by hydropower dams is 5.6 billion m^3.

The average discharge by multi-purpose dams is 7.26 billion m^3, and the amount of water for power generation including water usage (3.95 billion m^3) is 6.27 billion m^3 (86%), and the amount of water other than power generation, such as gate discharge, is 930 million m^3 (14%).

〈Table 4-17〉 Water Resources at the Han River Basin (2006-2015)

(Unit: 100 million m^3/year)

	Total	Multi-purpose Dams	Multi-purpose Weirs	Hydropower Dams
Annual Average Inflow	165.1	72.6	32.4	60.1
Design Supply	49.7	49.7	-	-
Water Use (Municipal, Agricultural, Instream Flow)	47.2	40.1	-	7.1
Hydro Power Generation	118.7	62.7	-	56.0
Gate Discharge	9.3	9.3	-	-

Source: K-water (2017).

From the annual average inflow of 16.51 billion m^3, the Han River water system utilizes 4.72 billion m^3 (28%) as municipal, industrial, agricultural, and river instream flow, and power generation water, including water usage, amounts to 11.87 billion m^3 (70%). The Han River water system suffered extreme water shortages due to a severe, extensive drought from 2014-2015; inflow in 2015 was just 6.06 billion m^3, which is only about 37% of the average annual inflow over the past 10 years, which led to limitations in regular water supply, such as river instream flow supply.

Since the Han River water system requires 4.79 billion m^3/year every year, which is the basic design supply for multi-purpose dams, and the Paldang Dam requires 3.92 billion m^3/year every year, which is the required downstream discharge, there was a considerable lack of water in 2015.

In spite of this, since the multi-purpose dams and hydropower generation dams in the Han River water system are operated independently through twodifferent institutions, there are endless discussions on increasing operational efficiency by unifying dam management. Regarding efficient utilization of water resources in preparation for severe droughts and securing flood control space as a countermeasure for abnormal floods, there are also suggestions for acquiring national water security by making water management-oriented improvements in the management system of hydropower generation dams by focusing on hydropower generation. Therefore, there is an increased need for integrated dam management with the outstanding ability to respond in times of urgency by incorporating joint dam operations between multi-purpose dams and hydropower generation dams through a dual dam operation and management system.

2.2.2. Process of Negotiation for Integrated Dam Management

Multi-purpose dams and hydropower generation dams are not only managed by two separate corporations, but also have different operation methods because of their contrasting construction purposes.

〈Table 4-18〉 Reservoir Operating Conditions for Each Dam's Purpose

Multi-purpose Dam	Hydropower Generation Dam
• Discharges by setting a monthly allocation according to water use purposes (municipal, industrial, agricultural, power generation water) • Maximum utilization of dam storage (water conservation and flood control space) according to downstream flood condition and precipitation • Establish systematic water use plan in consideration of extreme droughts	• Complying with the dam's downstream water demand and water rights is the greatest concern • Majority of water is used for hydropower generation • Maintain a certain level that does not exceed the restricted water level in preparation against floods

Source: Author.

All three multi-purpose dams in the Han River water system are located in the uppermost stream of the basin. There is one in the northern end of the Han River and two at the southern end, and all three are operated by K-water. Most of the hydropower generation dams are located at the northern end of the Han River, and the most important Paldang Dam was built right at the point where the northern and southern Han River intersects.

Various alternatives have been reviewed in an effort to unify dam management, and the methods of changing hydropower generation dams into multi-purpose dams

have been reviewed several times in particular so that multi-purpose dams, multi-purpose weirs, and hydropower generation dams, which have been built and are in operation in the Han River water system, can be operated more efficiently.

An agreement has not been reached regarding dam management unification due to extremely complex and sensitive issues, such as the matter of dam ownership between K-water and KHNP and the managing entities of dams. As the next best alternative plan, the Dam Joint Operation Association in Han River Basin was established in 1999 as a consultative group between institutions that operate dams.

However, discussions are still in session due to unresolved limitations in dam management unification as a separate systematic tool. As a simple consultative group that proposes a guide for dam operation plans every month (target water level, discharge), there are still limitations in efficient water resources management because the group lacks authority and obligatory power regarding dam operations during a flood or drought.

Considering that issues pertaining to dam operation must go beyond mere problem resolution and must take a more preemptive risk counteraction approach, there are arguments that the multi-purpose dams and hydropower generation dams in the Han River basin must be unified and joint operated in real-time.

To resolve these issues, the Korean government entrusted the KHNP's hydropower generation dams to K-water in June 2016 as part of an adjustment in the function of public institutions, so that water can be managed with a focus on hydropower generation. This is evaluated as a way to utilize existing water resources more efficiently from the perspective of national water security, including countermeasures for climate change and disaster prevention for the 2.5 million people living in Seoul.

Policy mediation proposals related to unifying dam management in the Han River Basin are consistent with the direction of the Korean government's integrated water management policies for integrated management of water quality, water quantity, and disaster prevention. Regarding the adjustment in functions between K-water and KHNP for the Han River Basin's integrated dam management, the hydropower generation dams that were managed by KHNP were entrusted to K-water so that they can manage dams in terms of water supply, setting water quantity for flood control, and hydrological controls, while KHNP takes charge of managing power generators for the water quantity that was determined by K-water.

〈Table 4-19〉 Adjustment in Functions between Dam Management Institutions

K-water		KHNP
Water Resources Management (joint operation planning, determining discharge, etc.)	Dam Operation (hydrological controls, repairs and maintenance, etc.)	Operation of Hydro Power generation(power generator controls and maintenance)

Source: Author.

2.3. Expected Outcomes

Many studies have been conducted to analyze the effects of dam management unification for the Han River Basin. The specifications and water conservation effects according to dam operations may differ according to the analysis model and conditions, which may lead to differing analysis results regarding the effects of dam management unification between K-water and KHNP.

K-water has conducted several effect analyses (2001, 2016, 2017) for dam management unification in the Han River water system. Their review on the effects of joint operations between dams by using the HEC-ResSim analysis model on three multi-purpose dams (Soyang River, Chungju, Hoengseong) and six hydropower dams (Hwacheon, Chuncheon, Euiam, Cheongpyeong, Paldang) in the Han River Basin showed that the basin's flood control capacity would increase by 236 million m^3, which would reduce flooding at the Hangang Bridge point in Seoul to 2,835m^3/sec if this results in design flood discharge for a 0.39m reduction in water level.

The operating water level of hydropower generation dams and multi-purpose dams would change, and the water supply capacity would increase to 884 million m^3/year through joint and integrated operations of dams.

However, KHNP proposed another theory that differs from K-water's analysis results; they argued that about 10 billion tons of water were being supplied through hydropower generation free of cost per year to the Han River water system for the last 70 years since the construction of the Cheongpyeong Dam in 1943 and the Hoecheon Dam in 1944.

Furthermore, since a restricted water level was established at five hydropower generation dams since 1974, and this contributed to disaster prevention in the capital area through hydropower generation dams and flood control under the control and approval of the Han River Flood Control Office of the Ministry of Land, Infrastructure and Transport during every flood season, it was argued that hydropower generation dams at the Han River Basin are already being operated multi-purpose dams. In other words, KHNP's argument is that they are already performing three different

functions of water supply, flood control, and power generation, just like the multi-purpose dams that are managed by K-water.

As such, the effects of integrated dam operation in the Han River Basin are considerably different according to the dam's managing entity. However, integrated operation through joining several dams that are located in the same water system is expected to bring many more effects compared to when they are managed independently.

3. Future Direction of Hydropower Development in the Mekong River Basin

3.1. History of Sustainable Hydropower Development

This section presents the status of hydropower dams (existing, under construction) by country in the Lower Mekong Basin and surveys the development plans of hydroelectric dams of each country.

Energy security at the scale of both national and regional energy demands will continue to grow and the need for national energy security will remain eminent for Member Countries. The contribution from various types of energy sources including hydropower dams is expected to remain high because of its cost effective source of renewable energy.

Since previous decades, in their national policies the MRC member countries have emphasized the need to extend the access to electricity as a significant means to implement poverty reduction strategies, enhance national and regional energy security, reduce vulnerability to international energy price shocks, and generate export earnings in countries such as Cambodia and Laos. Such determination has led to the accelerated development of hydropower and large investment in electrical infrastructure in the Lower Mekong Basin. Hydropower development is expanding on the Mekong mainstream and in tributaries, and it is likely to intensify in the near future.

The first hydropower plant Ubol Ratana in Thailand conducted the start-up of turbine no. 1 on in 1966. By late 2015, 38 hydropower plants with installed power larger than 15 MW were completed and since then were in operation. Laos has the highest number of hydropower projects with 18, followed by Vietnam, while there are five in Thailand. The total installed capacity of the hydropower projects is 7,150 MW, while the calculated annual energy production is close to 29,450 GWh.

In the table below the hydropower projects in the LMB tributary schemes that had been commissioned up until the end of 2015 are listed. Only hydropower projects with an installed capacity of 15 MW or above have been included. Energy density for the projects have been calculated where figures for reservoir area at full supply level have been available. Energy density is a measure of the footprint of project in terms of installed effect per area of land inundated (megawatt divided by reservoir area). High energy density values indicate that the project has a good yield in relation to the area footprint of the reservoir. Run-of river (ROR) projects, which normally have limited intake ponds and not storage reservoirs, have the highest energy densities and thereby the lowest impacts in terms of land loss in relation to energy production

〈Table 4-20〉 List of Hydropower Dams Commissioned by End of 2015

	Project Name	COD	MW	Annual Energy GWh	Reservoir km^2	Energy Density MW/km^2
			Thailand			
1	Chulabhorn	1972	40	59	31	1.29
2	Pak Mun	1994	136	280	117	1.16
3	Sirindhorn	1971	36	90	288	0.13
4	Ubol Ratana	1966	25,2	56	410	0.06
5	Lam Ta Khong P.S.	2001	500	400	1430	0.35
			Laos			
6	Nam Ngum 1	1971	155	1,002	370	0.42
7	Se Xet 1	1990	45	133.9	ROR	-
8	Theun- Hinboun	1998/2012	500	1,251	105	4.76
9	Houay Ho	1999	152	450	37	4.11
10	Nam Leuk	2000	60	218	12.8	4.69
11	Nam Mang 3	2005	40	150	ROR	-
12	Se Xet 2	2009	76	309	20	3.8
13	Nam Lik 1-2	2010	100	435	24.4	4,10
14	Nam Theun 2	2010	1,075	6,000	450	2.39
15	Nam Ngum 2	2012	615	2,300	122.2	5.32
16	Nam Ngum 5	2012	120	507	15	8.00
17	Xekaman 3	2013	250	1,000.3	5.25	47.61
18	Nam Ngiep 3A	2014	44	152,3	ROR	-
19	Nam Ngiep 2	2015	180	732	-	-

〈Table 4-20〉 Continued

	Project Name	COD	MW	Annual Energy GWh	Reservoir km^2	Energy Density MW/km^2
20	Nam Khan 2	2015	130	558	-	
21	Houay Lamphan Gnai	2015	88	500	6.8	12.9
22	Nam Sun 3A	2015	69	278,4	-	-
23	Nam Sun 3B	2015	45	173,5	-	-
			Vietnam			
24	Dray Hlinh 1	1990	45	100		
25	Yali	2002	720	3,868	64.5	11.16
26	Se San 3	2006	260	1,325	-	
27	Se San 3A	2007	96	479	-	
28	Dray Hlinh 2	2007	16	94	-	
29	Buon Tua Srah	2009	86	358	-	
30	Buon Kuop	2009	280	1,459	37	7.57
31	Plei Krong	2009	100	501	80	1.25
32	Se San 4	2010	360	1,649	54	6.67
33	Sre Pok 3	2010	220	1,002	-	
34	Sre Pok 4	2010	80	360	-	
35	Se San 4A	2011	63	297	-	
36	Sre Pok 4A	2013	64	302	-	
37	Upper Kontum	2014	250	1,056	-	
38	Hoa Phu	2014	29	113	-	
Total	7,150	29,491				

Source: MRC hydropower database (2015).

While about 14 dams with a total capacity around 3,000 MW are planned for commissioning during the period 2016-2020, another series of 30 dams with a total capacity around 6,653 MW are under planning status, with the majority finalising Feasibility Studies.

Three mainstream dams have been submitted to the MRC under the PNPCA. The construction of the 1,285MW Xayaburi Project is 80% complete and is expected to be commissioned in 2019, while the Don Sahong (260MW) will be commissioned in 2019. The Pak Beng project (912 MW) has recently completed the PNPCA review

and, while there are substantial issues to be dealt with in a Joint Action Plan, the expectation is that this project will be commissioned by 2023 (TBC).

There are significant major hydropower investments planned in the LMB:

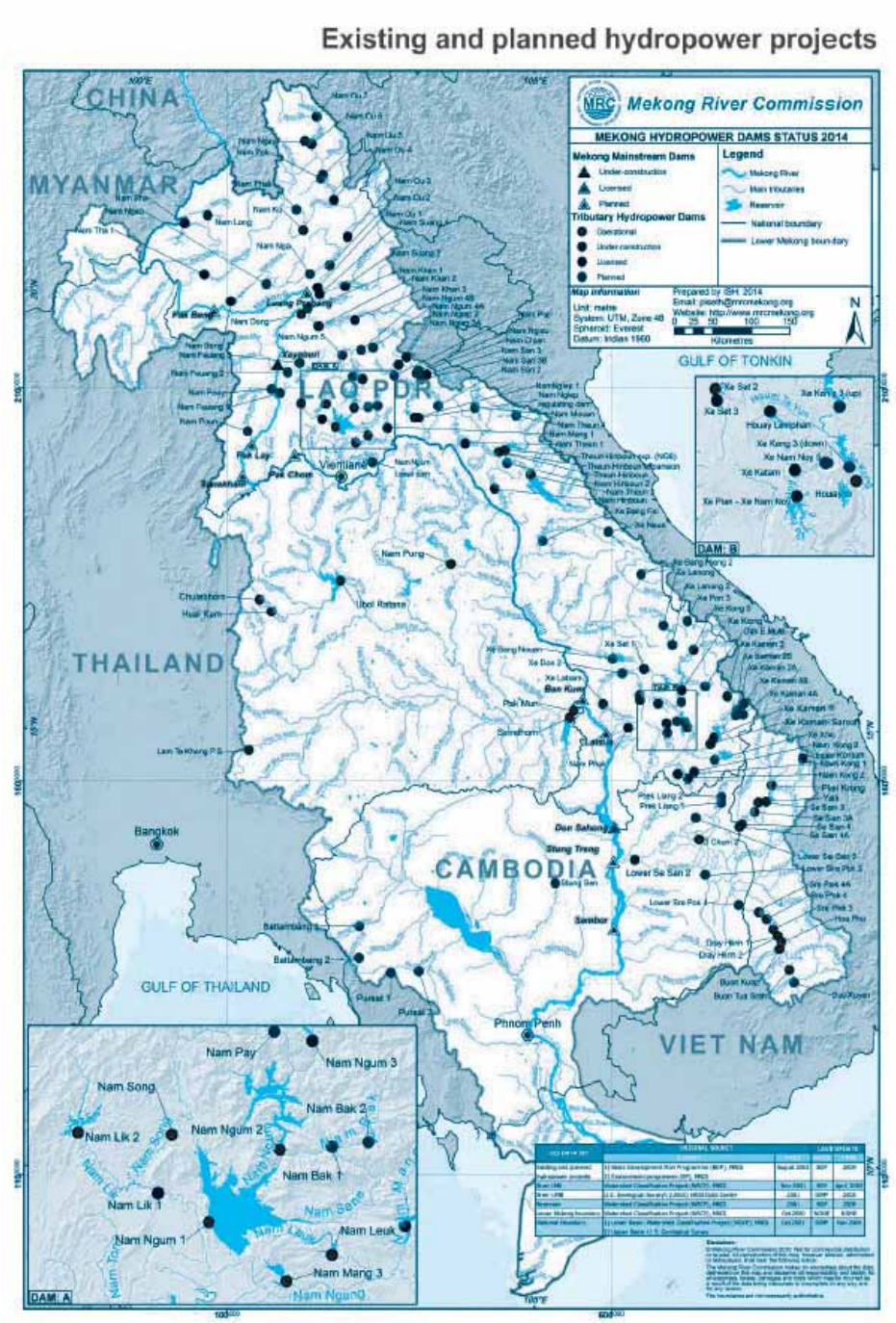
- Lao PDR has signed agreements with its neighbours to supply power, as follows:
  - 9,000 MW to Thailand by 2025
  - 5,000 MW to Vietnam by 2030
  - 1,500 MW to Cambodia by 2025
  - 100 MW to Malaysia and
  - 300 MW to Myanmar (under discussion).
- Cambodia is progressing with feasibility studies on the major mainstream developments in the Mekong floodplain (e.g. Sambor 2,000 to 3,000MW).

The lower Mekong Basin downstream of the Chinese border comprises the majority of the land area of Lao PDR and Cambodia, the northern and northeast regions of Thailand, and the Mekong Delta and Central Highland regions of Vietnam.

The map below identifies the majority of locations of existing and planned hydropower projects on the mainstream of the lower Mekong Basin and its tributaries.

Development of hydropower cascades in the Upper Mekong in China has largely completed, bringing both benefits and risks to the Lower Mekong. While hydropower development in Thailand and Vietnam is nearly complete, it is central to the economic and poverty reduction strategy of Lao PDR and is also planned in Cambodia. Further anticipated development of hydropower has the potential to bring about large and transformative benefits, especially for the poorer countries in the region, but may also lead to significant costs and risks especially to capture fisheries and sediment if not managed properly.

[Figure 4-12] Existing and Planned Hydropower Projects



Source: MRC (2015).

〈Table 4-21〉 List of Hydropower Projects per MRC Country with Estimated Commercial Operation Year

1) Lao PDR

Project ID Code	Project Name	Rated Head (m)	Plant Design Discharge (m^3/s)	Installed Capacity (MW)	Annual Energy (GWh)	COD (year)
L017	Xekaman 1	101.2	344.0	290.0	1,096.6	2017
L018	Xekaman-Sanxay	12.2	378.0	32.0	121.0	2017
L021	Nam Ngum 3	301.0	103.0	480.0	2,146.0	2019
L022	Nam Theun1	130.0	519.9	600.0	2,371.0	2020
L023	Nam Ngiep 1	127.0	230.0	272.0	1,507.0	2019
L024	Nam Ngiep-regulating dam	10.0	160.0	18.0	108.0	2019
L025	Nam Tha 1	65.5	289.5	168.0	756.0	2019
L027	Xepian-Xenamnoy	630.0	80.0	410.0	1,788.0	2019
L028	Xekatam	455.0	16.0	68.0	381.0	2020
L030	Nam Kong 1	186.0	44.5	150.0	469.0	2019
L031	Xe Kong 3up	33.7	460.0	105.0	410.6	2022
L032	Xe Kong 3d	17.2	568.0	100.0	375.7	2022
L033	Xe Kong 5	180.0	210.0	330.0	1,613.5	2019
L034	Mekong at Don sahong	17.0	2,400.0	260.0	2,044.0	2019
L035	Nam Ou 1	16.0	1,308.0	180.0	710.0	2019
L036	Nam Ou 2	15.0	994.0	120.0	546.0	2016
L037	Nam Ou 3	26.5	948.0	210.0	826.0	2019
L038	Nam Ou 4	23.0	710.0	132.0	519.0	2019
L039	Nam Ou 5	49.0	547.0	240.0	1,049.0	2017
L040	Nam Ou 6	60.0	349.0	180.0	739.0	2017
L041	Nam Ou 7	104.0	235.0	210.0	838.0	2018
L042	Nam Lik 1	19.5	300.0	64.0	256.0	2018
L043	Nam San 3A	676.0	12.0	69.0	278.4	2016
L044	Nam Pha	126.0	182.1	180.0	730.0	2016
L045	Nam Seuang 1	35.7	130.1	42.0	167.0	2022
L046	Nam Seuang 2	122.7	119.6	134.0	621.0	2022
L047	Nam Nga 1	97.3	107.9	100.0	434.3	2022

〈Table 4-21〉 Continued

Project ID Code	Project Name	Rated Head (m)	Plant Design Discharge (m^3/s)	Installed Capacity (MW)	Annual Energy (GWh)	COD (year)
L048	Nam Beng	70.0	43.2	36.0	145.0	2018
L049	Nam Feuang 1	57.0	57.1	28.0	113.2	2022
L050	Nam Feuang 2	130.0	22.9	25.0	110.5	2022
L051	Nam Feuang 3	211.0	11.3	20.0	88.5	2022
L052	Mekong at Pakbeng	16.0	7,250.0	912.0	4,846.0	2022
L053	Mekong at Luangprabang	33.0	4,976.0	00.0	8,258.0	2025
L054	Mekong at Xayabuly	29.0	5,000.0	1,260.0	5,990.0	2019
B057	Mekong at Sangthong-Pakchom	2.0	5,720.0	1,079.0	5,318.0	2025
B058	Mekong at Ban Kum	18.6	11,700.0	1,872.0	8,434.0	2025
L059	Mekong at Latsua (Phou Ngoy)	10.8	10,000.0	651.0	3,278.0	2025
L060	Xe Pon 3	210.0	25.0	47.6	164.2	2020
L061	Xe Kaman 2A	48.6	155.0	64.0	241.6	2018
L062	Xe Kaman 2B	78.8	90.0	100.0	380.5	2018
L063	Xe Kaman 4	459.0	39.7	54.0	267.7	2020
L065	Dak E Mule	433.8	27.4	130.0	506.0	2022
L068	Nam Khan 3 (Down)	39.0	176.8	60.0	240.9	2016
L069	Nam Ngum 4	235.0	105.5	220.0	267.7	2022
L071	Nam Ngum, (down) Lower dam	13.6	776.7	110.0	526.0	2022
L074	Nam Pouy 1	60.0	60.0	60.0	294.0	2020
L075	Nam Poun	70.0	148.8	50.0	245.8	2017
L076	Nam Ngao	347.6	6.6	20.0	155.0	2019
L080	Nam San 3B	298.0	17.1	45.0	173.5	2017
L087	Xe Neua	94.0	40.8	53.0	230.0	2020
L088	Nam Theun 4	157.0	20.5	80.0	130.0	2022
L089	Nam Mouan	103.2	105.7	100.0	439.3	2022
L090	Xe Bang Hieng 2	44.6	42.6	90.0	73.0	2022
L092	Xe Set 3	148.0	314.0	23.0	82.0	2016

〈Table 4-21〉 Continued

Project ID Code	Project Name	Rated Head (m)	Plant Design Discharge (m^3/s)	Installed Capacity (MW)	Annual Energy (GWh)	COD (year)
L093	Xe Bang Nouan	118.8	19.0	35.0	79.1	2021
L094	Xe Lanong 1	219.5	99.0	70.0	256.8	2021
L095	Xe Lanong 2	168.0	24.5	35.0	142.7	2018
L096	Nam Phak (Houykatam)	674.0	13.0	150.0	498.0	2019
L098	Houay Lamphan Gnai	536.4	11.4	84.8	452.0	2017
L099	Nam Kong 2	97.9	76.2	66.0	264.4	2018
L100	Xesu	29.0	120.0	30.0	125.6	2022
L103	Nam Ngiep 2	445.0	47.6	180.0	723.0	2017
L106	Nam Hinboun	17.1	448.7	30.0	155.2	2016
L108	Nam Bak	395.4	44.4	160.0	744.0	2020
L112	Nam Phouan	146.2	42.5	52.0	205.0	2020
L113	Sekong Downstream	8.3	1,105.0	76.0	387.8	2020
L115	Nam Ang Tha Beng	14.2	14.5	41.0	183.3	2022
L116	Xepian-Houaysoy	94.9	140.0	115.0	292.5	2020
L118	Nam Kong 3	84.5	60.6	45.0	170.0	2017

2) Cambodia

Project ID Code	Project Name	Rated Head (m)	Plant Design Discharge (m^3/s)	Installed Capacity (MW)	Annual Energy (GWh)	COD (year)
C002	Lower Se San 2	28.5	2,118.0	400.0	1,953.9	2017
C003	Battambang 1	34.0	27.0	24.0	120.0	TBD
C004	Battambang 2	450.0	5.8	36.0	187.0	TBD
C005	Sambor	16.5	17,668.0	2,600.0	11,740.2	TBD
C006	Stung Treng	11.6	9,834.0	900.0	5,096.5	TBD
C007	Stung Pursat 1	122.0	38.8	40.0	335.0	TBD
C008	Stung Pursat 2	23.0	57.0	10.0	42.1	TBD
C009	Lower Se San 3	40.5	760.0	260.0	1,310.2	TBD
C010	Prek Liang 1	132.5	66.8	72.0	324.3	TBD

〈Table 4-21〉 Continued

Project ID Code	Project Name	Rated Head (m)	Plant Design Discharge (m^3/s)	Installed Capacity (MW)	Annual Energy (GWh)	COD (year)
C011	Prek Liang 2	173.0	40.1	56.0	259.6	TBD
C012	Lower Sre Pok 3 (3A)	20.0	1,699.2	300.0	1,201.4	TBD
C013	Lower Sre Pok 4	7.5	736.8	48.0	220.7	TBD
C014	Stung Sen	19.0	145.0	23.0	124.2	TBD
C015	Sekong	7.5	2,910.7	190.0	557.5	TBD
C016	Lower Se San 1	17.3	682.0	96.0	485.0	TBD
C017	Lower Sre Pok 3B	9.5	817.2	68.0	306.8	TBD
C018	Prek Chhlong 2	22.5	86.0	16.0	89.6	TBD

3) Vietnam

Project ID Code	Project Name	Rated Head (m)	Plant Design Discharge (m^3/s)	Installed Capacity (MW)	Annual Energy (GWh)	COD (year)
V008	Duc Xuyen	71	93.0	58.0	181.0	TBD

4) Thailand

- No more planned dams since the last one built in 2001.

Source: MRC (2015).

3.2. Reviews on Previous Works and Studies on the Issue

This section analyzes and presents the results collected from many previous works and studies on hydropower dam development in the Mekong River basin.

The volume "Regional Sector Overviews" of the "MRC Basin Development Plan (BDP)" produced in November 2002 (revised in September 2005) is a document which analyzes issues and opportunities described in many previous works and studies on hydropower dam development in the Mekong River basin. The document describes that: "The total potential for feasible hydropower projects in the four Lower Mekong Basin countries is approximately 30,000 megawatts (MW). Of this, 13,000 MW are on the Mekong's mainstream. The remainder is on the tributaries (13,000 MW in Lao PDR, 2,200 MW in Cambodia and 2,000 MW in Viet Nam). In 2002 there were only some 6 percent (some 1,800 MW) of the Lower Mekong's hydro potential developed and they all were on the tributaries only".

By changing the flow, sediment, nutrients, energy and biota, dams interrupt and alter important ecological and physical processes of a river. Thus, dams have local upstream, downstream, and cumulative impact on fisheries.

In 2002 it was already observed that more than 30 major dams have been constructed on Mekong tributaries in the last 35 years.

The document added also that the above number of hydropower projects is spread among the 20,000 small dams/weirs in Thailand and hundreds of small irrigation projects in Lao PDR. These could eventually increase the impact on fisheries. Small scheme irrigation is typically planned and implemented with little consideration for the impacts they may have on aquatic ecosystem for fisheries. It is possible that the cumulative effect of many small dams could be larger than that of a few large dams.

The effects of dam/reservoir projects on fisheries can be categorized in four groups:

- effects on water fluctuation (reduction in duration/extent of flooding downstream;
- in-stream flow changes that impact mainstream ecology;
- blocking fish migration; and,
- water quality alteration.

Compared to other global regions in the world in terms of actual renewable water resources per capita, the Mekong basin is not water stressed. However a number of locations currently face a series of critical water issues, such as (MRC, 2010; Pech, 2013):

- Water shortages in Thailand coupled with increasing irrigation water demands
- Increasing salinity intrusion in the Mekong delta in Vietnam
- Threats and declines in basin fisheries and the degradation of natural habitats in many parts of the basin
- Recurring un-seasonal floods and droughts
- Reduced water quality, land-subsistence and morphological changes in the floodplains and delta areas; and
- Intensification of sectoral competition within and amongst the Mekong countries.

Concurrently, hydropower dam development is happening on the mainstream of the Mekong and tributaries, and it will intensify in the near future. From the map below it is therefore anticipated that there will be more dams built in Lao PDR

and Cambodia, while Vietnam will complete the ones that are under construction. Thailand does not have any more dams to build in the Mekong Basin.

3.2.1. Lower Mekong Basin – Mainstream hydropower dams

Proposed dams on the lower mainstream Mekong are listed in <Table 4-22>. Of these, ten would involve construction of dams across the entire river channel, eight within Lao PDR and two in Cambodia. The Don Sahong project within Lao PDR will involve commanding only the Hou Sahong Channel, leaving the other channels of the Mekong at Kone Falls uninterrupted. The Sambor project included in the table is a smaller, alternative dam that will include a natural sediment and bypass channel.

〈Table 4-22〉 Mainstream Hydropower Schemes

Name of Project	Country	Status	Installed Capacity (MW)
Pak Beng	Lao PDR	Planned	912
Luang Prabang	Lao PDR	Planned	1,410
Xayaburi	Lao PDR	Under construction	1,285
Pak Lay	Lao PDR	Planned	1,320
Sanakham	Lao PDR	Planned	660
Pak Chom	Lao PDR	Planned	1,079
Ban Khoum	Lao PDR	Planned	2,000
Pou Ngoy (Lat Sua)	Lao PDR	Planned	651
Don Sahong	Lao PDR	Under construction	260
Stung Treng	Cambodia	Planned	980
Sambor[1)]	Cambodia	Planned	1,703
		Total	12,260

Note: Alternative to the original Sambor that was 2600 MW (Wild and Loucks, 2015).
Source: Department of Energy Business, Ministry of Energy and Mines, Lao PDR, 2017.

Tributary hydropower schemes have been classified as either operational, under construction, or licensed/planned.

3.2.2. Hydropower dams and Key Risks, Impacts, and Vulnerabilities in LMB.

The study named Hydropower Risk and Impact Mitigation Guidelines and Recommendations (ISH0306) is a MRC study which summarizes the "Key LMB Hydropower Risks, Impacts, and Vulnerabilities" related to hydropower development, with recommendations and guidelines for mitigation measures. This study has organized a series of national and regional workshops to discuss and identify key risks, impacts, and vulnerabilities with its associated mitigation options. Consequently, a set of five key common potential overarching changes related to hydropower development has been identified as follows:

- Annual / inter-annual changes to flow
- Daily / short-time scale changes to flow and water level
- Loss of river connectivity
- Impoundments
- Diversion intra basin transfers

Within these major changes a set of sub-changes (left column) for each thematic area has also been identified. The associated risks, impacts and vulnerabilities are associated with these changes.

〈Table 4-23〉 A Hydrology and Downstream Flows – Key Risks, Impacts, and Vulnerabilities

Change	Key Risks, Impacts, and Vulnerabilities
Annual / inter-annual changes to flow	
Changes in seasonality and continuous uniform release	Change of timing and duration of floods and low flows, changes in flows Tonle Sap, and changes in salt intrusion in the delta
Modification of flood intervals: Reduction in occurrence of minor floods and no change in large events	Peaks in flood and low flow change, smoother hydrograph
Daily / short-time period changes in flow	
Hydro-peaking	Safety and navigation related changes caused by sudden rise or drop of water levels

Source: MRC, Guidelines for Hydropower Environmental Impact Mitigation and Risk Management in the Lower Mekong Mainstream and Tributaries, 2018.

〈Table 4-24〉 Geomorphology & Sediments – Key Risks, Impacts, and Vulnerabilities

Change	Key Risks, Impacts, and Vulnerabilities
Annual / inter-annual changes to flow	
Changes in seasonality and continuous uniform release	Winnowing of smaller sediment leading to bed armouring and reduction in downstream sediment supply Bank scour focused over limited range leading to increased bank erosion
	Winnowing of smaller sediment leading to bed armouring and reduction in downstream sediment supply
	Bank scour focused over limited range leading to increased bank erosion
Modification of flood intervals: Reduction in occurrence of minor floods and no change in large events	Channel narrowing through encroachment of vegetation Increased risk in upstream of flooding and floodplain stripping during large (>1:10 ARI) flood events
Change in relationship of flow and sediment transport	Decoupling of tributary and mainstream flows Erosion and / or deposition at tributary junctions due to tributary rejuvenation
Daily / short-time period changes in flow	
Hydro-peaking	Rapid water level fluctuations and wetting and drying of banks increases susceptibility to bank erosion and seepage erosion (piping) processes
	Increase in shear stress during flow changes increases erosion and bed incision
Loss of river connectivity	
Disconnect between flow and sediment delivery	Sediment availability not timed with periods of recession, leading to decreased deposition and increased erosion
	Loss of seasonal sedimentpulse
Creation of impoundments	
Trapping of sediments	Reduction in sediment availability downstream of dam leading to increased erosion
Changes to the grain-size distribution of sediment downstream	Changes to the grain-size distribution of sediment downstream contributing to channel armouring and alteration of habitat distribution and quality
Water level changes within impoundment	Lake bank erosion, increased risk of landslides
Diversions or intra basin transfers	
Decreased flow in donor basin	Channel narrowing due to vegetation encroachment
	Armouring of beds and bars due to reduced sediment transport
	Decrease in frequency of high flow events increases impacts of extreme events (upstream flooding, floodplain stripping)
Increased flow in receiving basin	Increased bank erosion and bed incision to accommodate increased flow

Source: MRC, Guidelines for Hydropower Environmental Impact Mitigation and Risk Management in the Lower Mekong Mainstream and Tributaries, 2018.

〈Table 4-25〉 Continued

Change	Key Risks, Impacts, and Vulnerabilities
Annual / inter-annual changes to flow	
Changes in seasonality and continuous uniform release	Changes / loss of seasonal temperature patterns downstream
Change in relationship between flow and sediment delivery	Increased water clarity increasing risk of algal growth Increased water clarity increasing water temperature Changes to magnitude and timing of nutrient delivery downstream
Daily / short-time period changes in flow	
Hydro-peaking or fluctuating discharge	Fluctuating water quality including increase in variability of temperature and nutrients
	Altered concentrations of downstream discharges
Loss of river connectivity	
Changes to nutrient transfer	Trapping of nutrients within impoundment leading to change in downstream delivery
Creation of impoundments	
Conversion of river to lake	Lake stratification leading to low dissolved oxygen bearing water and release of nutrients, metals or pollutants from sediments
	Increased water clarity in lake increases risk of algal blooms
	Temperature change in lake (warmer or cooler)
	DO and temperature of discharge affected by impoundment – Low DO or high gas supersaturation
Diversions or intra basin transfers	
Diversion of water from one catchment to another	Change in nutrient and other water quality parameters in both donor and receiving catchments

Source: MRC, Guidelines for Hydropower Environmental Impact Mitigation and Risk Management in the Lower Mekong Mainstream and Tributaries, 2018.

〈Table 4-26〉 Aquatic Ecology and Fisheries – Key Risks, Impacts, and Vulnerabilities

Change	Key Risks, Impacts, and Vulnerabilities
Annual / inter-annual changes to flow	
Changes in seasonality (e.g. delayed floods, increase of dry and decrease of wet season flows)	Habitat alteration/ loss related to increased erosion (river bed incision, bed armoring, bank erosion etc.)
	Habitat alteration/ loss related to water quality changes (e.g. temperature, water clarity, salinity (relevant for the Delta), nutrient transport)
	Loss of ecological functions (e.g. migration/spawning triggers)
	Loss of productivity due to reduced flood pulse (increase in permanently flooded areas and decrease in seasonally flooded areas)
Daily / short-time period changes in flow	
Fast increase of flow	High drifting rate of fish and macroinvertebrates, loss of food sources, offset of migration triggers, stress for aquatic organisms
Fast decrease of flow	Stranding/ loss of fish and macroinvertebrates, stress for aquatic organisms
Morphological alterations	Increased erosion and river bed incision causes habitat degradation
Thermo peaking	Unnatural (fast changing) temperature regime, stress for aquatic organisms, offset of migration triggers
Barriers / loss of river connectivity	
Disconnect between flow, sediment and nutrient delivery	Habitat loss related to morphological alterations, offset of migration triggers, reduced productivity with regard to nutrient trapping and limited delivery downstream
Habitat fragmentation	Blocked/ reduced spawning and feeding migrations, potential isolation of sub-populations
Turbine passage	Stress, fish damage and kills
Spill flow passage	Stress, fish damage and kills

〈Table 4-26〉 Continued

Change	Key Risks, Impacts, and Vulnerabilities
Creation of impoundments	
Trapping of sediments	Morphological alteration and habitat loss. Upstream: sedimentation, possibly filling up of deep pools, reduced vertical connectivity, change of choriotopes (fish, benthic invertebrates), degradation of shoreline habitats; Downstream: loss of habitat structures (e.g. sand bars), reduced habitat quality (e.g. change of choriotopes, river bed armouring), reduced connectivity to tributaries and floodplains (related to river bed incision)
Loss of free flowing river sections	Delay/deposition of drifting eggs and larvae
	Loss/ reduction of fish species adapted to free flowing rivers
	Loss of orientation for upstream migrating fish
Increased visibility	Algae growth and changes in temperature, oxygen
Stratification & temperature changes	Stress due to water quality changes (temperature, oxygen)
Water level changes within impoundment	Stranding of fish and macroinvertebrates, degradation of shoreline habitats
Reservoir flushing	Flushing of benthic organisms and fish, potentially high losses related to high turbidity, destruction of habitats
Diversions or intra basin transfers	
Reduction of river dimension	Reduced productivity, species alteration (e.g. loss or large species), reduced depth may impact connectivity, water quality changes
Homogenisation of flows	Armouring of beds and bars due to reduced sediment transport, habitat loss
Increased flow in receiving basin	Increased bank erosion and bed incision to accommodate increased flow
Water quality changes	Stress
Combined effects	Reduction of biomass and diversity of fish and other aquatic organisms

Source: MRC (2015).

〈Table 4-27〉 Biodiversity, Natural Resources, and Ecosystem Services- Key Risks, Impacts and Vulnerabilities

Change	Key Risks, Impacts, and Vulnerabilities
Annual / inter-annual changes to flow	
Changes in seasonality to flow	Changes in timing of flow to wetlands and floodplain riparian habitats
Modification of flood recurrence intervals	Dispersal of species to and between floodplain habitats
Change in relationship between flow and sediment/nutrient delivery	Changes in wetlands functions, dynamics and ecosystem services due to timing of sediment and nutrient delivery
Change inundation/exposure of downstream floodplains and wetlands	Loss of wetland/floodplain habitats
Daily / short-time period changes in flow	
Fast increase and decrease of flow velocity	Degradation of function, dynamics, and ecosystem services of wetland and riparian habitats
Loss of river connectivity	
Change to sediment and nutrient transfer (amount)	Changes in wetland functions, dynamics, and ecosystem services due to a decrease in the transfer of sediments and nutrients
Impoundments	
Change to/loss of riparian areas	Loss of riparian ecosystems, habitats, and biodiversity
Diversion scheme / inter basin transfers	
Alternation of flow regime of contributing and receiving (sub) catchments	Flow changes to wetland and floodplain areas (decrease or increase), leading to changes in ecosystem functions, dynamics, and services, as well as biodiversity

Source: MRC, Guidelines for Hydropower Environmental Impact Mitigation and Risk Management in the Lower Mekong Mainstream and Tributaries, 2018.

While study ISH0306 provides Guidelines and the Manual in detail describing risks, impacts, and vulnerabilities, it also suggests mitigation options thatare based on a wide array of examples of international good industrial practice mitigation options suitable to the Greater Mekong Sub-Region (GMS) and the Lower Mekong Basin (LMB) regions.

Finally, the Guidelines and the Manual are supported by a Case Study Report (Volume 4), where promising mitigation options have been modelled and analysed for five mainstream cascade hydropower dams north of Vientiane, Lao PDR, during the 2nd Interim Phase and all mainstream dams during the Final Phase. Additional to the latter, there are also some alternative conceptual schemes that layout assessments both for mainstream dams and those of the Mekong tributaries.

3.3. Major Issues on Hydropower Development in each Mekong Country

The main issues related to the construction and management of hydropower dams in the Mekong Basin are analyzed, and the major issues from each country level, as well as from the Mekong River Basin level, are presented separately.

1) Cambodia

Cambodia's power sector was seriously damaged by the war, but since January 1979 the Royal Government of Cambodia (RGC) has made tremendous efforts to restore the national economy and to build more infrastructure for improving the socio-economic conditions of the Khmer people. Since then, a series of hydropower dams have been built to meet the increasing dam and of electricity.

In 2003, according to the annual "Report on power sector of the Kingdom of Cambodia for the year 2003, Electricity Authority of Cambodia", there was only one hydropower dam at that time (Kirirom Hydropower Dam).

From the Annual "Report on power sector of the Kingdom of Cambodia for the year 2013, Electricity Authority of Cambodia", electricity generation in 2013 became more diversified and is constituted of fourtypes: (1) Hydropower Plants, (2) Diesel Power Plants, (3) Thermal Power Plants using coal and (4) Plants using wood and other biomass. During 2013, there were at least seven hydropower dams in operation with a power production of 1,015.54 million kWh.

〈Table 4-28〉 Summary Information about Generation Facilities and Energy Sent Out by Generation Type

	Type of Generation	Installed capacity, kW		Proportion of installed capacity in % for 2016	Energy sent out, Million kWh		Proportion of Energy sent out in % for 2016
		End of year 2015	End of year 2016		Year 2015	Year 2016	
1	Hydropower	926,700	930,000	55.32	2,159.64	2,567.96	46.84
2	Diesel/HFO	304,629	304,215	18.10	163.66	478.33	8.72
3	Bio mass	19,945	17,570	1.05	38.15	42.44	0.77
4	Coal	403,000	429,200	25.53	2,127.82	2,394.22	43.67
	Total	1,657,274	1,680,985	100.00	4,489.27	5,482.96	100.00

Source: Ministry of Mines and Energy, Electricity Authority of Cambodia, Report on power sector of the Kingdom of Cambodia for the year 2016.

From the Annual "Report on power sector of the Kingdom of Cambodia for the year 2016, Electricity Authority of Cambodia", electricity generation in 2016 was 5,483 GWh.

Already in 2008 the RGC prepared a list with 29 hydropower projects with installed capacity larger than 10 MW as potential hydropower dams for implementation. The technical potential was estimated to be 6,695 MW for hydropower dams:

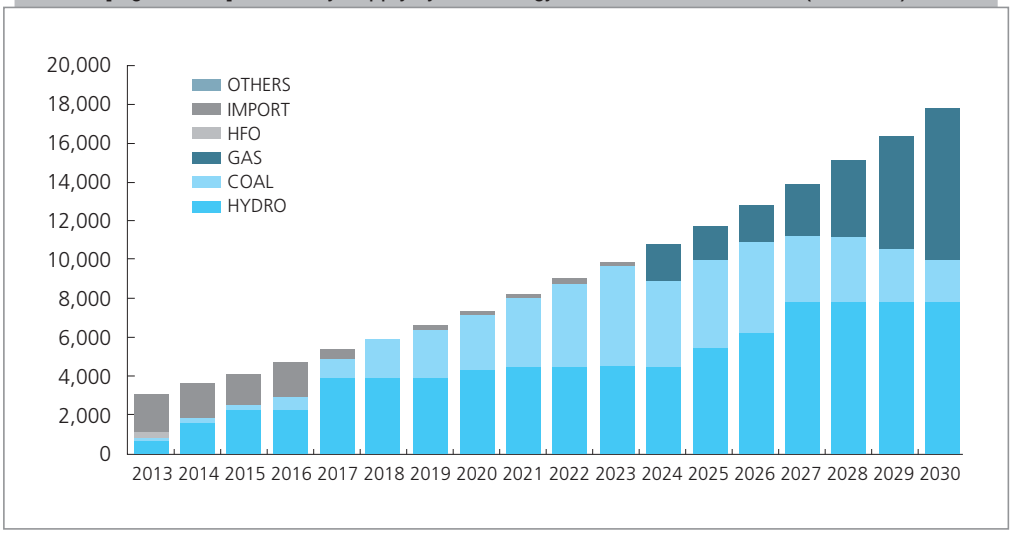
- On the Mekong mainstream: 3,580 MW (53.50%)
- On Mekong Tributaries: 1,771 MW (26.50%)
- Outside the Mekong Basin: 1,344 MW (20%)

Eradicating poverty can become more difficult, when at the same time mitigating environmental impacts is asking for development founded on sustainability outcomes. The fact that social-economic development is tied up with the environment, the energy sector has an important role in sustainable development. Therefore, the RGC is committed to "balancing hydropower development with environment conservation" through higher aggregated value and policies that give incentive to minimizing the impacts from hydropower projects on social and environmental factors.

Each hydropower dam is well studied, surveyed, consulted, designed, constructed, and monitored by highly competent experts and contractors from qualified hydropower development countries, mainly from China, Vietnam, and Korea. Nevertheless, implemented hydropower projects still have to provide efficient measures to mitigate the most common negative impacts or solve trade-offs from hydropower dams, among which include fish migration, preservation of fish species, water quality conservation, resettlement and compensation issues, sediment trapping, and management.

The RGC has anticipated the needs for more hydropower dams constructed to meet the demand by 2030. As it is already seen in the Power Development Plan 2005-24 (PDP) of the RGC, Cambodian PDP is promoting the generation capacity with particular interest on large hydropower and coal-fired plans.

[Figure 4-13] Electricity Supply by Technology Source Forecast to 2030 (in GWhrs)



Source: Ministry of Mines and Energy, Royal Government of Cambodia, 2015.

There are big challenges that Cambodia needs to resolve, such as the high electricity prices, especially while the demand is still on the rise but shortages are persisting. The power generation is still dependent on imported fossil fuels, with many generations of equipment that are old and inefficient. The market structure needs to be more competitive in order to give people better access to energy, which can help move them away from the use of traditional biomass for cooking. The Renewable Energy (RE) needs better marketing with better RE technologies business models to promote RE usage in the energy mix. On the other hand, there is a need for institutional and educational capacities in strengthening the public awareness for energy efficiency and renewable energies and stimulating policies and incentives for energy efficiency and renewable energy investment.

2) Lao PDR

The Government of Lao PDR policies in the power sector include:

- Earn foreign exchange through electricity export to finance GOL's economic and social programs;
- Increase access to electricity by grid extensions and off-grid rural electrification;
- Satisfy growth in domestic demand;
- Maintain an affordable tariff to promote economic and social development;
- Operate the State electricity utility (EdL) on sound commercial principles;
- Replace dependence on imported fuels for energy generation.

With the Greater Mekong Subregion (GMS), the power interconnection and power trade among the GMS countries, the market for Lao hydropower electricity is huge. In Manila, Philippines, during the ASEAN Energy Business Forum 2017 (PowerTrends 2017) from September 27-29, 2017, the Department of Energy Business, Ministry of Energy and Mines (Lao PDR) reported that consuming 1,200MW, Laos currently operates approximately 6,700MW supplying the grids inside the country and neighbors. In meeting commitments to achieving full electrification and exporting electricity to its neighbors, the country is now constructing around 5,800MW. In addition, several projects with a combined installed capacity of 5-6,000MW are planned. Laos also attempted to offer private investors participation in developing infrastructure projects, such as high voltage transmission facilities, which are difficult to be a cost recovery project taking into account the volume of transmitted electricity.

Large or medium hydropower dams are well studied, surveyed, consulted, designed, constructed, and monitored by highly competent experts and contractors from qualified hydropower development countries.

Nevertheless, implemented hydropower projects still have to overcome common negative impacts or solve trade-offs from hydropower dams, among which include fish migration, preservation of fish species, water quality conservation, resettlement and compensation issues, sediment trapping, and management.

Therefore, in order to help Lao achieve its socio-economic objectives, it would be wise to help improve the institutional capacity of environmental and social management in order to strengthen the implementation of rules, regulations, and legal frameworks. Likewise, more training in public consultations and participation will be useful to involve the wide range of stakeholders to help plan the new hydropower project sustainably. Mitigation of impacts can be accurately estimated if the database and information database are properly designed, operated, and maintained. Such an approach would also help developers from various dams in a cascade system to improve their coordination.

3) Thailand

Most hydropower dams were constructed decades ago. Thailand does not build or plan to build any dam in their country, as they have been facing serious opposition from the public for negative environmental and social impacts. The last one was built in 2001: Lam Ta Khong dam with pump storage features.

4) Vietnam

In Vietnam, large hydropower dams are often carefully surveyed, consulted, designed, constructed, and monitored by highly competent experts and contractors from qualified hydropower development countries, such as Sweden, United States, Japan, China, Switzerland, and Russia. To date, failures of large dams have been effectively avoided (Pham Hong Giang, 2013).

Nevertheless, already in 2005, medium scale and small scale hydropower projects have encountered several problems since the day the provincial authority has received the right to grant investment licenses directly to hydropower project developers, so that they can build small and medium-scale hydropower dams in their respective province.

There are about 2005 small hydropower plants under operation with a capacity of 1,664MW, and 179 projects are being constructed with a total capacity of 2,360 MW. They should be operational by 2020.

According to MOIT (2013) there are around 249 projects under the approval process for investment licenses, and some 155 potential locations were identified and included as part of hydropower development plans in several provinces.

Most small hydropower projects did not strictly comply with dam safety measures regulated by the provision of laws, leading to unpredictable risks and failures. The report of the Committee on Science, Technology and Environment of the National Assembly revealed that nearly 30% of small hydropower dams were not technically verified. Therefore, many small dams have failed, causing substantial damages to property, affecting people's lives in downstream regions. These failures were mainly caused by poor preparation and construction by investors and poor management by local authorities (Le Anh Tuan & Lam Thi Thu Suu, 2013; Pham Hong Giang, 2013). In addition, for small and medium dams, approximately 66% lacked safety plans and 55% lacked flood prevention plans (Hoang Linh, 2014). Most of the medium and small hydropower plants were considered as multi-purpose dams in the planning stages, serving not only for electricity generation, but also as irrigation sources and flood control. Most investors follow through on these plans (Pham Hong Giang, 2013).

To efficiently resolve compensation matters and resettlement schemes, additional effort will be required to improve resettlement policies with specific guidelines for land acquisition, along with the emphasis on the involvement of affected people in the decision making process.

3.4. Recommendations

To achieve the outcomes set out in the agreed MRC Strategy Plan 2016-2020, there are strategic issues to be addressed by a proposed update for the SHDS2018, which can lead to potential measures/solutions to overcome Basin concerns, needs, and challenges:

- Support the economic development objectives of member countries (including navigation)
- Protect and enhance food and livelihood security
- Increase resilience against climate change including drought and flood management
- Ensure continued energy security for all member countries
- Protection of valued ecosystems and ecosystem services
- Further enhance transboundary cooperation.

Therefore, there are Key Strategic Issues to be addressed as to help sustainable hydropower development as described in the SHDS2018

For example:

- The findings from the Basin Development Strategy 2011-2015 and the related Scenarios Assessment (MRCS, 2011) indicated that there are national development plans that are sub-optimal. There are several areas for improved benefits beyond national boundaries and opportunities to minimize transboundary impacts. Many of the opportunities to enhance benefits beyond national boundaries that arise from cross sector integrated planning and operation.
- The draft findings of the Council Study (currently nearing completion in 2017) have further confirmed that there are significant and important opportunities to reduce transboundary impacts through the reconsideration of hydropower development plans.
- The MRC's study on Guidelines on Mitigation of Hydropower Impacts on Mekong Mainstream and Tributaries (MRCS, 2017 in press) has drawn attention to several siting, design and operational alternatives that can reduce these transboundary impacts.

Therefore, it is recommended that the MRC should emphasize with particular consideration on Transboundary Cooperation and joint activities for sustainable hydropower planning and management where:

- For joint activities to be successful, the sharing of information and learning

experiences, in a structured and timely manner, should be established. Therefore, joint planning and data/information sharing through increased transboundary cooperation can help to produce optimal and high economic benefits with minimal environmental impacts to the LMB.

For monitoring and coordination of HP developments in a transboundary MRC context:

- Owing to the fact that the proposed mainstream dams will be built in cascade and owned by different owners, the communication exchanges between each dam can become complicated. Therefore, it is necessary that efficient coordination must be assured between different parties (MRC, the host country/government, dams owners, dam operators, local communities, aid agencies, relief organizations). Common rules and regulations covering all important coordination aspects of dam operation will be necessary. These additional rules and regulation for all dams in the cascade may cover the common Operating rules and Emergency procedures.

4. Implications and Recommendations

Changes in conditions from when the dam was first designed to climate change and water use in the present day can be largely categorized into changes in water demand or changes in water supply. Aside from these, there are also varying changes in the water environment, such as water rights and an increase in related water disputes, changes in the concept of environmental flow, increased need of river instream flows for ecosystems, and changes in the river environment. Moreover, since there are many changes that were unforeseen or omitted from consideration during the construction and design stage with respect to multi-purpose dam operations, a reassessment is necessary based on present standards.

When examining the demand for water, it is also necessary to review changes in demographics, which becomes the most basic standard of demand. Such demographic changes must involve various analyses on the total population, regional changes due to urbanization from agricultural land, and population changes by industry.

Flow regime changes due to climate change and urbanization are worth mentioning from the perspective of water supply. Some rivers are quickly drying up, and there are decreased underground water reserves due to reduced underwater water levels, decreased base flow, and decreased dam inflow. As seasonal changes can be observed at dam inflow areas, dam operation methods must also be reviewed

once more in consideration of these changes.

In order to secure lacking water resources and power, building new water resource infrastructures such as dams might seem like an obvious solution. However, what is more important than building new water resource infrastructures is to utilize existing infrastructure with more efficiency. Since the hydro-meteorological environment, social and economic conditions change from when dams are first designed, the same effects from building new dams can be obtained through a process of reassessment.

Hence, there is an urgent need for a systematic standard and technical method for performing reassessments on dams over a certain age, as well as a legal and systematic standard for reallocating the dam's storage (flood control storage, water supply storage, power generation storage, etc.) by reflecting the reassessment results.

Countless dams are currently in planning or being built at the Mekong River. However, if new storage can be secured through the reassessment of existing dams, this method may be able to minimize conflicts between countries at the Mekong River stemming from dam construction. Since the Mekong River is a transboundary river, there are disputes constantly being presented between multiple stakeholders regarding dam construction and operation. Therefore, standards and procedures that can properly address these conflicts must be established as quickly as possible.

In spite of the infinite profit that can be gained by integrating several dams existing in the Mekong river basin, there are many cases in which it is practically impossible to carry out the integrated joint operation of several dams because the dam ownerships are different.

Further, the legal ownership and operating rights for dams at the Mekong River are highly diverse. Since there are many dams with different operating rights in the same basin, if there is a flood or water shortages resulting from a drought, it will be necessary to minimize damage from floods or droughts for joint operation and integrated management between dams. Despite this, integrated dam operation for achieving the original purpose of dam construction remains a difficult task, hence there is need for a new organization that can mediate conflicts for each basin in the Mekong River. If an integrated dam management method can be utilized through a conflict resolution process, even greater effects can be achieved than from independent management of existing dams.

The capacity reallocation scenarios that reflect the dam revaluation process and the revaluation results presented in this report are based on the experiences and case

of Korea. In particular, since the Mekong River is involved in several Southeast Asian countries, it is not possible to directly apply the dam evaluation method and capacity reallocation method introduced here because the national policies, design standards, and operating standards related to the dam are very different.

Therefore, in order to promote such dam revaluation and capacity reallocation without conflict with stakeholders, it is considered that the legal and institutional review and supplementation related to the operation and design of the dam should be given priority.

After the legal and institutional supplementation is completed, the technical assessment presented in this report and the application of the new dam operation rules will be sufficiently possible.

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94320
9 791159 323041
ISBN 979-11-5932-304-1
ISBN 979-11-5932-302-7(set)

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