AN ABSTRACT OF THE DISSERTATION OF

Sarintip Phadungsontikul for the degree of Doctor of Philosophy in Environmental Sciences presented on November 1, 2022.

Title: Developing Sustainable Water Resource Management: A Case Study of the Prasae Reservoir in Rayong Province, Eastern Thailand.

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Aaron T. Wolf

Water is an essential natural resource for human survival and plays an important role in food, manufacturing, and energy systems, as well as in ecosystem maintenance. The rapid increase in global water demand is due to economic and social development competition. At the same time, water availability and access to clean and safe water sources remain limited. In addition, climate change affects the variability of rainfall and water resources. This has resulted in water conflicts and water shortages which are becoming the most pressing issues that must be addressed. The purpose of this study is to examine an in-depth study of water resource management drawing on the case of the Prasae Reservoir in Rayong Province. This study will collect data from in-depth interviews on the question of what is the optimal, just, and sustainable method for managing available and excess water of the Prasae Reservoir, considering balancing the needs to allocate water efficiently, maximize the benefits to society, and, thereby, create fairness between water users. The existing water resources management practices and guidelines will be analyzed and assessed the possibilities of implementing new strategies in water resource management.

Appropriate technology will be considered in water management to increase the capacity and efficiency of water management. The participation of interested persons relevant to water resource consumption is emphasized to create sustainable water management.

The results revealed that there are several challenges to the Prasae Reservoir water management policies and plans. Water management cannot be considered only for the Prasae River Sub-basin due to the linkage of the diversion pipe system and water diversion system between the Prasae and its vicinity sub-basins. The remaining water in the Prasae Reservoir can be diverted to the other water resources or received water from vicinity Sub-basins based on rules, regulations, and conditions that are acceptable to all parties to alleviate water shortages. Demand- and supply-side management along with appropriate technology are analyzed to meet growing water demand and improve water management efficiency with the aim of achieving sustainability and fairness for all sectors. Public participation and a negotiating process between management and water users are the keys to reducing the water conflict efficiently and effectively, better than regulation or the law. It is concluded that the findings provide insights into the development of strategic policies to address the current and future water challenges of the Prasae Reservoir.

Keywords: sustainable water management, fairness, excess water, water diversion, the Prasae Reservoir, water shortage

Developing Sustainable Water Resource Management:
A Case Study of the Prasae Reservoir in Rayong Province, Eastern Thailand

by
Sarintip Phadungsontikul

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APPROVED:

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Director of the Environmental Sciences Graduate Program

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Sarintip Phadungsontikul, Author

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LIST OF ABBREVIATIONS

BGR 9	Bureau of Groundwater Resources Office Region 9, The Department of Groundwater Resources
CSR	Corporate Social Responsibility
DGR	The Department of Groundwater Resources
DNP 2	Protected Areas Regional Office 2 (Sriracha), The Department of National Park Wildlife and Plant Conservation
DWR	The Development of Water Resources
DWR 6	Water Resources Region 6, The Department of Water Resources
East Water	Eastern Water Resources Development and Management Public Company Limited
EEC	Eastern Economic Corridor
EECO	Eastern Economic Corridor Office of Thailand
FP	Farmer Group
FTI	The Federation of Thai Industries
GIS	Geographic Information Systems
GRR	World Economic Global Risk Report
IRB	Institutional Review Board
IDA	International Desalination Association
IEAT	Industrial Estate Authority of Thailand
IWRM	Integrated Water Resources Management
IWUG	Integrated Water Users Group

LIST OF ABBREVIATIONS (Continued)

IWUO	Irrigation Water Users Organization
JMC	Joint Management Committee
LMRC	Lower Middle Rule Curve
LRC	Lower Rule Curve
LSL	Lower Storage Level
MDGs	Millennium Development Goals
MRC	Mekong River Commission
MRC (Chapter 4)	Middle Rule Curve
NGOs	Non-Governmental Organizations
NSL	Normal Storage Level
NWRC	The National Water Resources Committee
ONWR	The Office of National Water Resources
PM	Participatory Irrigation Management
PWA	The Provincial Waterworks Authority
RBCs	River Basin Committees
RID	The Royal Irrigation Department
RID 9	Regional Irrigation Office 9, The Royal Irrigation Department
SDGs	Sustainable Development Goals
TAI	The Access Initiative
UN	United Nations
URC	Upper Rule Curve

LIST OF ABBREVIATIONS (Continued)

UMRC	Upper Middle Rule Curve
WUA	Water Users Association
WUC	Water User Cooperative
WUG	Water Users Group
WUGO	Water Use Group Organization
YEC Rayong	Rayong Chamber of Commerce

1. Introduction

1.1 Introductory Statement

Freshwater is an important resource for life that can be used to eradicate poverty, and enhance gender equality, food security, and ecological preservation (UNESCO, 2016). Two-thirds of the Earth's surface is water. Of all water on earth, 97% is saltwater from the ocean. The remaining 3% is freshwater, most of which are not accessible in ice caps and glaciers (NASA, 2021). “Less than 1% of the world's freshwater is readily accessible for direct human uses” (SIWI, 2015). Wolf (2007) states that the economically available water for human use is estimated at 0.0007% and it tends to decline significantly.

The relationship between changes in hydrological cycles and changes in climate affects water resource management and other use of water (Lu, Takle, & Manoj, 2010). Climate change may increase the frequency and severity of droughts and floods in different regions at different times. This is caused by changes in rainfall patterns, soil moisture, humidity, glacial mass balance, river flow as well as underground water sources (UNESCO, 2016). These factors create pressure on the water source and affect the important economic elements of GDP such as food productivity, land value, and an area's habitability (Climate Institute, 2007). Other than climate change, population growth, economic development, and technological advancements, as well as water pollution, are driving the rapid increase in demand for freshwater. This is in contrast to the amount of freshwater available in the future, which becomes more uncertain (Okello et al., 2015).

Access to clean water and sanitation is a fundamental human right. Without clean water and easy access, it will affect people's health, safety, and quality of life. For example, women and children are often attacked by men and wild animals on long journeys to collect water (UN-Water, n.d.). The amount of freshwater available is closely linked to water quality. Lack of sanitation and waste treatment facilities contributes to the degradation of water quality that is a major cause of water shortages. It can reduce the amount of freshwater available for human use (Peters, 2000). The degradation of water resources not only affects the natural environment but also affects public health (UNESCO, 2016). Environmental changes that threaten the quantity and quality of the world's freshwater resources are becoming the most pressing issue that should be addressed more (Wolf et al., 2010). At the same time, water is becoming increasingly scarce and expensive as the constraints of increasing water withdrawal for domestic, industrial, and agricultural use are determined by high economic costs and opportunities to increase withdrawals from rivers or streams without negatively affecting the use of water in streams. The main approach, which has become balancing limited water supplies with rapidly growing demands, is to improve water use efficiency. However, as more people become reliant on a single source of water, the risk of drought increases (Frederick & Gleick, 1999).

Water scarcity is one of the challenges of sustainable development, which increases the pressure as the world's population grows, the standard of living increases, diets shift, and the impacts of climate change worsen (FAO, 2019). Controlling other aspects that are not directly related to water but are equally important can also help to reduce water demand. Controlling demographic growth, improving the efficiency of the use of goods that consume water (in particular food products) in their production processes and supply chains, promoting appropriate land use planning, and attenuating the effects of climate change on water through adequate mitigation and adaptation measures are all examples of how this can be accomplished (Cosgrove & Loucks, 2015). Proper water resource management necessitates taking into account both supply and demand. The mismatch between supply and demand over time and space has prompted the development of much of the water resources infrastructure that exists today (Loucks et al., 2005). Water resource management using existing policies and regulations is one approach to addressing many water-related issues, such as water reuse and water rights. It considers the effects of natural events and human intervention on natural water resources, such as damming or dredging, as well as the long-term, cumulative effects of water policy decisions on the economy, institutions, and the environment. This could be accomplished through the development of policies governing domestic water supplies, groundwater pollution and overdraft, wetlands restoration, and issues such as water imports and exports (Fluence News Team, 2017).

Improving infrastructure systems will take less time if the necessary funding is obtained, as opposed to improving government policies and procedures, which require a longer period. Implementing integrated water resource management (IWRM) is one method to achieve better water management (Cosgrove & Loucks, 2015). It is "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (UN, 2014). IWRM aims to improve catchment basin conditions and create sustainable water security within current constraints (IWA, n.d.). Sustainable water management not only promotes the use of water in a manner that meets the needs of current and future societies but also recognizes the protection and conservation of water resources necessary for future generations (Loucks et al., 2005). Accordingly, the purpose of my thesis is to examine the transformative conditions to practice that can be achieved at multiple levels to achieve sustainable water management, with a particular focus on Thailand's developing country context.

In this chapter (chapter 1), I will discuss the global water scarcity situation and the water scarcity tensions that are expected to worsen shortly. Water demand has risen dramatically as a result of an economic and social development competition. Meanwhile, water availability and access to clean and safe water sources are deteriorating, leading to internal and international water conflicts. These issues have prompted the search for measures and guidelines for sustainable water management in order to achieve the most cost-effective use of resources, the greatest benefit to society, and create equity for all sectors, including recognition of environmental importance. Thus, my research has four objectives:

1. To study and analyze existing water management policies and plans to provide recommendations for the improvement and development of sustainable water management systems in the Prasae Reservoir, Rayong Province.

2. To analyze and assess the possibilities of implementing new strategies in water resources management to reduce conflicts between water users.

3. To provide appropriate technology that can be applied in water management to increase the capacity and efficiency of water management in the Rayong area to meet the increasing water demand in agriculture, industry, and community.

4. To study the participation of local people and government agencies in water management in the Prasae Reservoir, Rayong Province.

To achieve these objectives, three main research questions were developed:

1. What is the optimal, just, and sustainable method for managing available and excess water of the Prasae Reservoir, considering balancing the needs to allocate water efficiently, maximize the benefits to society, and, thereby, create fairness between water users?

2. How can appropriate technologies increase the capacity and efficiency of water management in the Rayong area?

3. How does public participation affect the sustainable water management of the Prasae Reservoir? Are most stakeholders able to accept that excess water will be diverted to other areas, depending on the situation and season?

To explore these questions, the study will review water management policies and plans, analyze documents related to Prasae Reservoir water management, and conduct in-depth interviews with stakeholders at both policy and practice levels. The Prasae Reservoir's rules and new strategies for water allocation and management will be improved and audited through a process of public participation for transparency and fairness, thereby ensuring stability and sustainability in water resource management.

The research problems and theoretical approaches of the study are set out in Chapter 2, which describes policies, strategies, and an overview of water management problems in Thailand. This will lead to a description of research problems in Prasae Reservoir, Rayong Province, which is a case study area supported by research questions and hypotheses while at the same time delimitating the scope of the study. This chapter also includes basic information and management of the Prasae River Sub-basin, such as topography, climate, land use, and agencies and organizations involved in water management at Prasae Reservoir.

Chapter 3 provides an outline of the methodology and rationale for using qualitative techniques to collect and analyze preliminary data. An in-depth interview was conducted using a variety of questionnaires based on the roles and positions of the actors involved in the water management of Prasae Reservoir. The situation map will be used in discussions with all stakeholders to analyze the connections and relationships within the system. These will be accurate representations of the system. In addition, SWOT (strengths, weaknesses, opportunities, and threats) and TOWS (Threats, Opportunities, Weaknesses, and Strengths) analysis will be used in the discussion of the results of the study, which will be presented in Chapter 4.

Chapter 4 categorizes all of the Prasae Reservoir water management analysis results into three categories: stakeholder interview results, situation maps (accurate representations of the system), and secondary data from relevant agencies that assist in the analysis of the Prasae Reservoir water management policies and plans. The results of the analysis are presented to answer research questions divided into interesting topics: water management plan for Prasae Reservoir, water management technology, public participation, and conflict between water user groups. Prasae Reservoir's water management efficiency is improved by analyzing its strengths, weaknesses, opportunities, and threats, with the aim of balancing the needs for efficient water allocation, for maximum societal benefit, and thereby creating fairness among water users.

Chapter 5 will provide an overview of the key findings of the in-depth interview and what the results of the analysis reveal. Factors and elements that can paradigm shift towards sustainable water management of the Prasae Reservoir will be considered to determine the most appropriate approach to improve the Prasae Reservoir's water management efficiency and to create water security in Rayong and the Eastern Region.

Chapter 6 provides a summary of the main topics derived from the results and discussion chapters. What I have learned from the research will be presented, especially the problems, obstacles, limitations, and future research suggestions.

1.2 The Global Water Crisis

1.2.1 The Definition of Water Stress, Water Scarcity, and Water Risk

Water stress, water scarcity, and water risk are three terms we hear a lot as we move forward in the twenty-first century. They are related, but they have different meanings (Waterless, 2019). Water stress is a more comprehensive concept compared to water scarcity, the former refers to the ability or lack of it to meet human and ecosystem needs for freshwater. It is determined by several elements such as water-related physical characteristics, water availability, water quality, and water accessibility (Schulte, 2017). When water demand exceeds supply that exists for a certain period of the year or can continue for several years, it results in water stress. This can be triggered by severe and protracted droughts, critical water constraints, overexploitation in aquifers, and contamination of water resources (Waterless, 2019).

Water scarcity or water crisis or water shortage refers to the lack of sufficient water resources to meet the water needs of a particular region, including the ability to access clean drinking water and sanitation. It can also refer to the difficulty of obtaining freshwater resources and the deterioration and depletion of existing water resources (Madaan, n.d.). "This is typically calculated as a ratio of human water consumption to available water supply in a given area" (Pacific Institute, 2014). Water scarcity can occur when demand exceeds supply or when the distribution is hampered by inadequate infrastructure (Karlsson, n.d.). Water scarcity is not only about the human and environmental demands of a given area but is also linked to human rights and access to adequate safe drinking water, which is essential for development. It is being exacerbated by population growth, wasteful consumption, rising pollution, and changes in weather patterns caused by global warming (Petruzzello, 2021). Water scarcity can be classified into two types: physical and economic. Physical water scarcity occurs when there is insufficient water to meet all demands, often found in arid regions. Economic water scarcity, on the other hand, is caused by a lack of investment in infrastructure and poor water management (Oki & Quiocho, 2020).

The probability of an entity experiencing a negative water-related event is referred to as "water risk". Water risk is perceived differently by each sector of society and the organizations that comprise it. Water scarcity, pollution, poor governance, insufficient infrastructure, climate change, and other factors are all factors that contribute to water risks (Pacific Institute, 2014). The relationship between water risk and water security is inverse. This implies that if the risk of water increases, it will result in a decrease in water security. Water risk includes natural disasters (such as floods and droughts) and can have an impact on food security due to a lack of irrigation water required for a reliable food system (Garrick & Hall, 2014). According to the United Nations Global Compact, water risk can be divided into three categories. First, physical risks arise from insufficient water (scarcity), too much water (flooding), or water that is unsuitable for use (pollution). Second, regulatory risks happen as a result of water policies that are changing, ineffective, poorly implemented, or inconsistent. Water scarcity, conflicts between different users, or excessive pollution often led to stricter regulatory requirements. Last, reputational risks arise from stakeholders' perceptions that the company does not conduct business with responsibility or sustainability for water resources, including the health and well-being of workers, aquatic ecosystems, and communities (Woodward, 2018).

1.2.2 Global Water Demand and Water Stress

Water is a critical natural resource for human livelihood and plays an important role in food, manufacturing, and energy systems, as well as in the maintenance of ecosystems (United Nations Global Compact, n.d.). Freshwater challenges are as diverse as they are pervasive around the world. More than 2 billion people currently live in water-stressed areas, with a projected 5 billion by 2050. Between 2000 and 2050, global water demand is expected to increase by 55%. Water issues include not only scarcity, pollution, and flooding, but also access to clean and safe drinking water. Climate change is exacerbating all of these issues and will continue to do so (United Nations Global Compact, n.d.). Freshwater resource availability varies by region, with some areas having too much water while others have too little (Pikovsky, 2019). Currently, the majority of North America, Europe, Brazil, and even parts of Africa have more than enough renewable freshwater. In contrast, North Africa, the Middle East, India, Mexico, large parts of South America, and many islands are among the regions that are severely under-served (Figure 1). There are large areas that are looking for solutions to get potable water to where it is needed (Rainmaker, 2020).

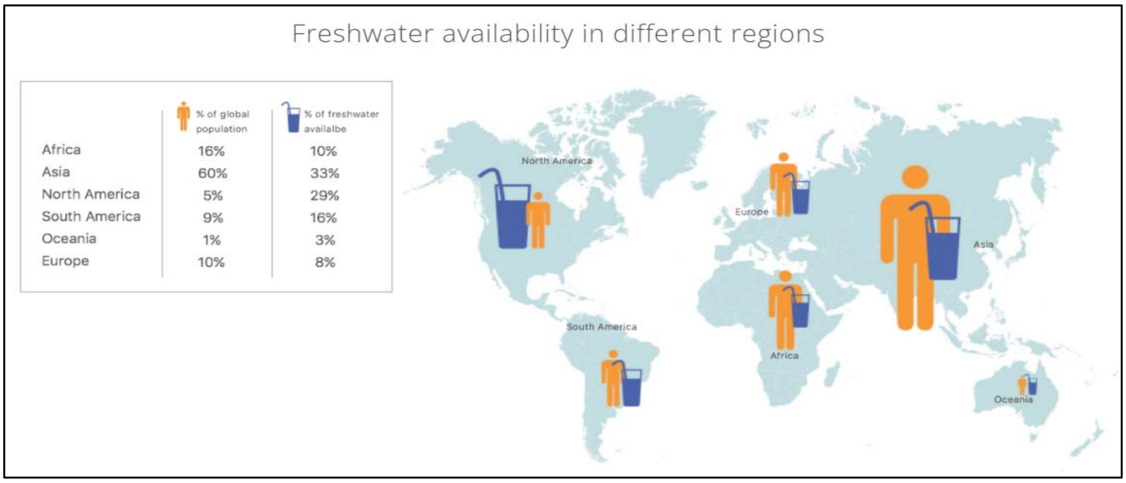

Figure 1. The Relationship between Available World Water Resources and World Population

Source: Rainmaker (2020)

The inequality of distribution and availability of freshwater resources, the importance of per capita water availability in each country, coupled with increasing misuse, has resulted in continued increases in water demand. These have led to a global situation with an increased risk of pollution and severe water stress (Bonamente et al., 2015).

Adequate water supplies are critical to the quality of human life because they meet food, energy, industrial, and household needs while also supporting ecosystem functions that benefit the global economy. The World Economic Forum identified water scarcity as a serious global threat in its list of the most pressing global risks. Population growth, dietary changes, and climate change not only have an impact on water resources and the increasing demand for water but also raise concerns about future water resources (Brauman et al., 2016).

A quarter of the world's population, or nearly 1.8 billion people spread across 17 countries (Figure 2), are facing a water crisis and the trend of water scarcity is becoming more and more severe (Dormido, 2019). Irrigated agriculture, industry, and municipalities withdraw more than 80% of the available supply on average each year, exposing these countries to extremely high levels of water stress. Countries are vulnerable to fluctuations such as droughts or increased water withdrawals because the supply-demand gap is so narrow. This is the driving force behind the growth of various communities in the face of “Day Zeros” and other crises (Willem Hofste, Reig, & Schleifer, 2019). According to the World Resources Institute's Aqueduct Water Risk Atlas, 12 of the 17 countries are in the Middle East and North Africa. Asia is home to two countries: India and Pakistan. San Marino in Europe, Botswana in Africa, and Turkmenistan in Central Asia are the only remaining hotspots (Dormido, 2019).

The Middle East and North Africa are the most water-stressed countries because the region is hot and dry, so water supply is limited, to begin with. Climate change and rising water demands are putting countries under greater strain. According to the World

Bank, this region is expected to suffer the greatest economic losses as a result of climate-related water scarcity, with losses ranging from 6 to 14% of GDP by 2050 (Willem Hofste, Reig, &Schleifer, 2019). Qatar, which is the most vulnerable to water scarcity, is heavily reliant on seawater desalination systems to supply drinking water to its people and industries (Dormido, 2019). India is experiencing the worst water crisis in its history, putting its people in danger, raising concerns about the negative effects of water stress. While the United States is in better shape than the rest of the world, it depends on where you live. The midwestern states historically experienced more rainfall than usual during the summer. The World Resources Institute reports that New Mexico and other parts of the Southwest are under extreme stress (Waterless, 2019).

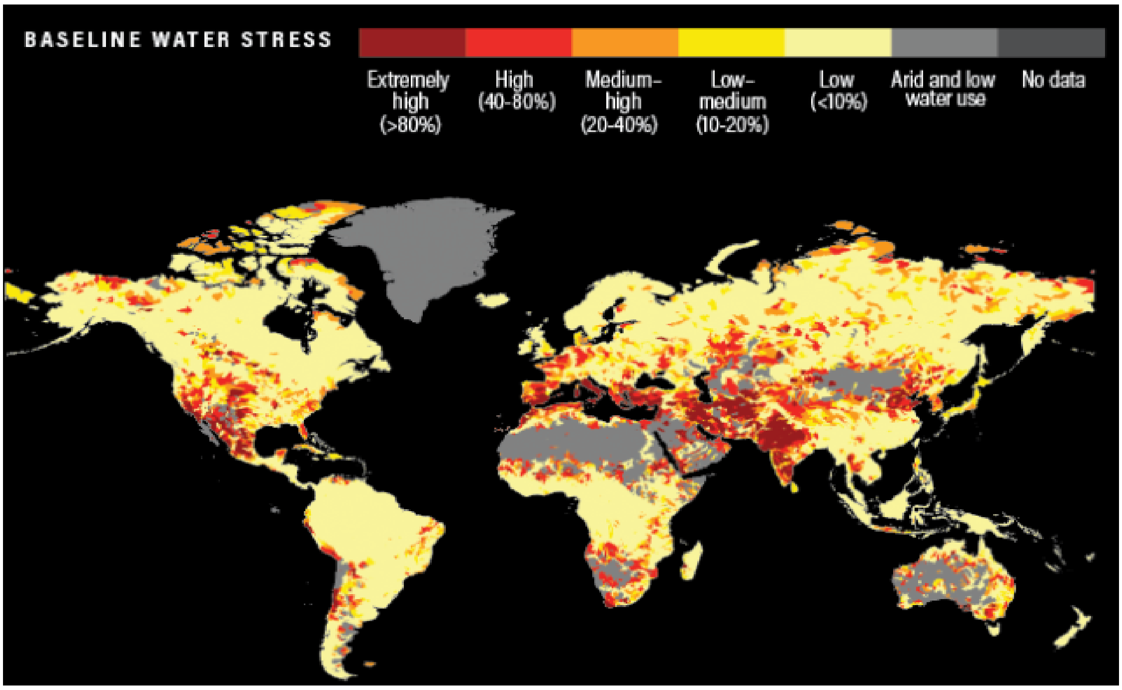

Figure 2. 17 Countries Face Extremely High – Water Stress

Source: Willem Hofste, Reig, &Schleifer (2019)

Changes in water supply and demand are unavoidable. According to the World Resources Institute, 33 of 167 countries will face extremely high-water stress in 2040 (Figure 3), based on an analysis of climate models and socioeconomic situations, along with rankings of future water stress as a competitive measure and surface water loss. The Middle East is home to 14 of the 33 likely most water-stressed countries in 2040, including nine that are considered extremely highly stressed with a score of 5.0 out of 5.0: Bahrain, Kuwait, Palestine, Qatar, United Arab Emirates, Israel, Saudi Arabia, Oman, and Lebanon. The region, which is already arguably the world's least water-secure, relies heavily on groundwater and desalinated seawater and faces significant water-related challenges shortly (Maddocks, Samuel Young, & Reig, 2015).

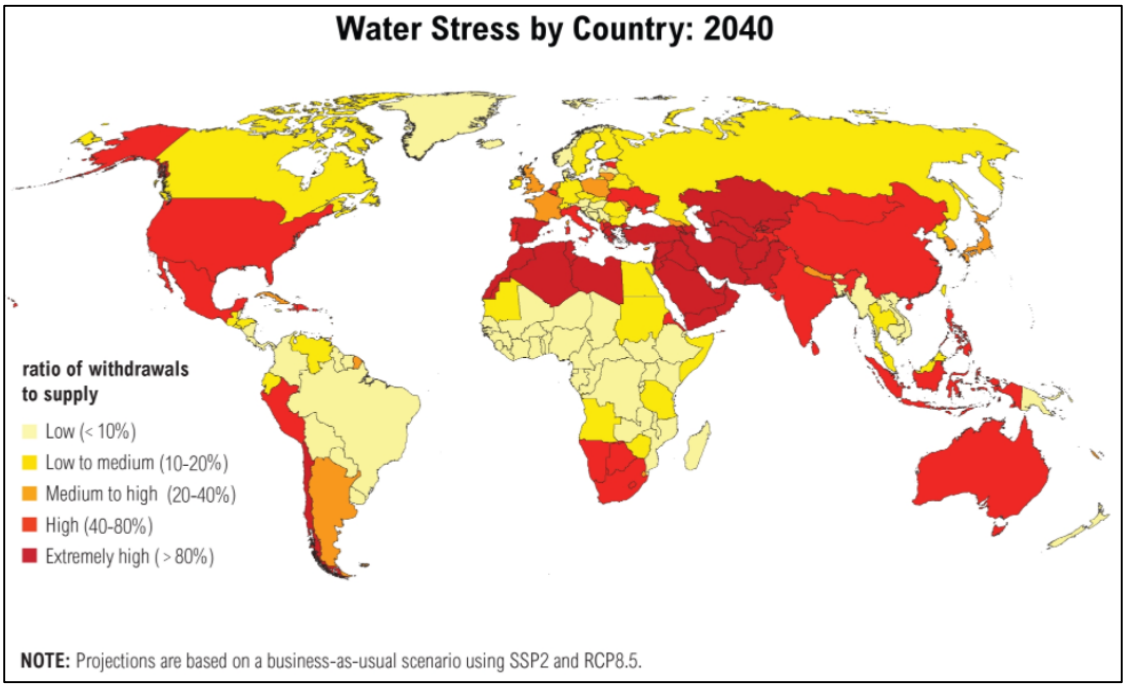

Figure 3. Water Stress by Country: 2040

Source: Maddocks, Samuel Young, & Reig (2015)

Because of the scarcity of water resources, tensions between different users may rise both nationally and internationally. Changes within a shared basin between two or more countries could lead to cross-border tensions in the absence of strong institutions and agreements. This becomes a conflict that causes regional instability (World Water Council, n.d.). Over the next two decades, global water demand will rise dramatically in all three components: industry, domestic, and agriculture. Although industrial and domestic demand will grow faster than agricultural demand, agriculture demand will remain the highest (Boretti & Rosa, 2019). By 2050, more than 40% of the world's population will live in areas with water stress and degraded water quality will affect the stability of water availability in the future (OECD, 2013). While the population is expected to increase to 9 billion by 2050, demand for food and energy will increase (The World Bank, 2017).

Agriculture is important because of its high-water consumption (Figure 4). Current agricultural demand growth rates on the world's freshwater resources are considered unsustainable, and forecasts show a significant increase. Using water inefficiently for crop production depletes aquifers, reduces river flows, degrades wildlife habitats, and has resulted in the salinization of 20% of the world's irrigated land area (Bonamente et al., 2015). Water use for agriculture currently accounts for 70% of total global water use. The majority are used for irrigation. Global estimates and projections are subject to uncertainty. Food demand will rise by 60% by 2050, necessitating the expansion of arable land and the intensification of production. This will result in increased water consumption (Boretti & Rosa, 2019). Over the past several decades, irrigation has not only been a key importer in increasing crop yields in many countries but has also been a major driver in the amount of water used for agriculture. South & East Asia and the Middle East, including Pakistan, Bangladesh, and South Korea, have extensive irrigation systems that cover more than half of the agricultural land. 35% of India's agricultural land is irrigated (Ritchie & Roser, 2018).

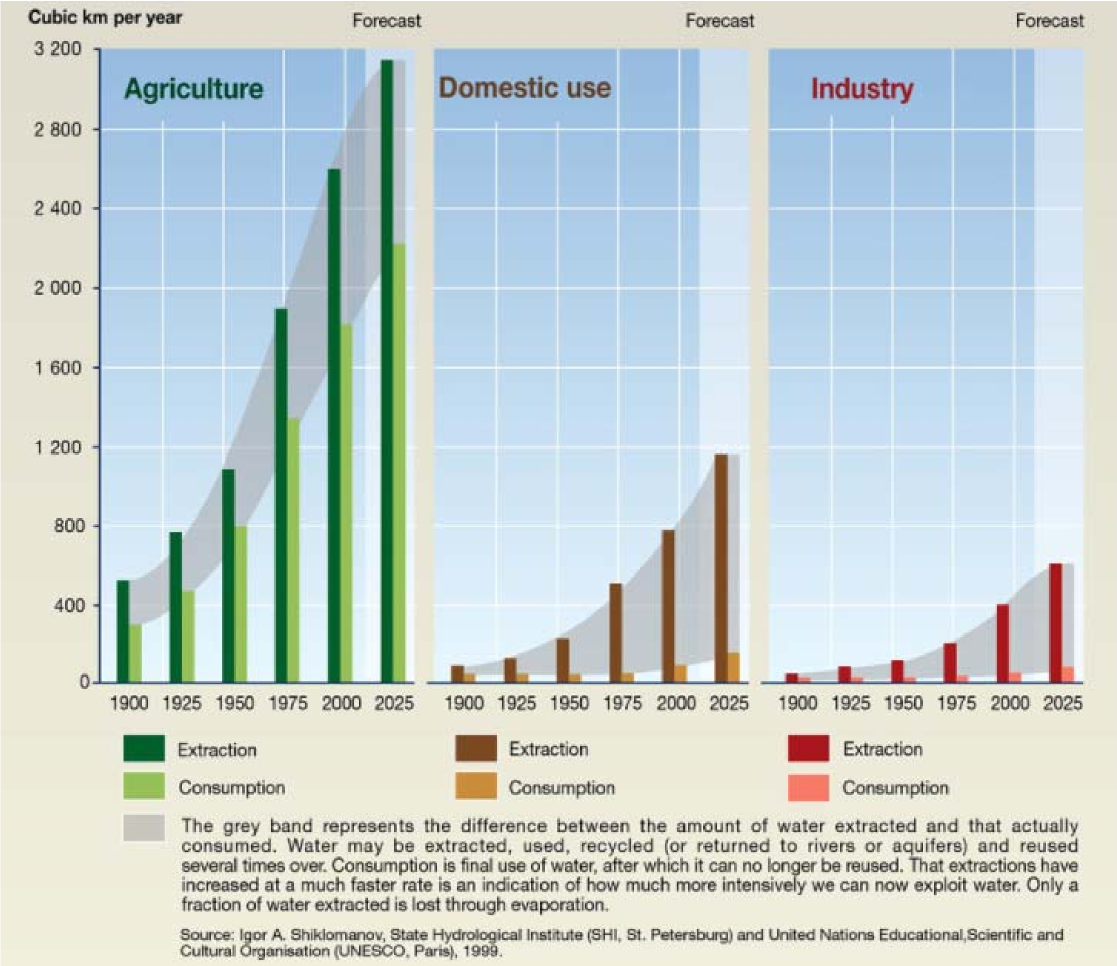

Figure 4. Trends in Global Water Use by Sector

Source: GRID-Arendal (2009)

Global industrial sectors currently use 20% of total water, accounting for 75% of total industrial energy production and the remaining 25% manufacturing. Except for

North America and Western Europe, global industrial water demand will rise by 2050. Africa currently has little industrial water use, but demand for industrial water will increase by 800% in Africa and by 250% in Asia. Global manufacturing water demand will increase by 400% (Boretti & Rosa, 2019). Although household water use is the most visible, most countries' domestic demand is small in comparison to agricultural and industrial uses. In most countries, less than 30% of withdrawals are used for domestic purposes (Ritchie & Roser, 2018). The shortage of freshwater resources affects food security and the quality of life for humans in many countries around the world. The exploitation of excessive freshwater resources regardless of their potential is rapidly increasing. The rapid growth of population, climate change, and changing water usage behaviors increase water demand and put pressure on freshwater resources. This becomes a challenge for sustainable water management to meet future needs (Kummu et al., 2016).

1.3 The Connection between Water and Conflict

The United Nations (UN) recognizes the importance of water resources and declares it a human right because water is a critical component of human livelihood, community culture, and ecosystems (Conca, 2012). The issue is that freshwater is not always available and is not distributed evenly. Only about 1% of all freshwater on Earth is easily accessible to humans, with the rest trapped in ice caps, glaciers, and permanent snow, as well as unrecoverable underground sources (KB Godschalk, 2007). There are 310 international river basins globally, which cover 47.1% of the world's land surface (McCracken & Wolf, 2019) and cross the boundaries of two or more nations where 40% of the world's population lives. This, in and of itself, suggests the possibility of water-related conflict (KB Godschalk, 2007). The water cycle limits the availability of freshwater. Humans currently trap and use less than one-fifth of global runoff (the portion of the water cycle between rainfall and the sea), implying significant future growth potential. Groundwater extraction provides a temporary supplement, but many aquifers are being depleted at unsustainable rates. Desalination of seawater is becoming more popular in some areas, but it will most likely remain a niche solution for the foreseeable future. None of this takes into account the significant portion of runoff that should be left alone in order to sustain vital freshwater ecosystems. Within a few decades, one-third of the world's population will live in river basins with significant water deficits (Conca, 2012).

According to the World Economic Forum's Global Risk Report (GRR), water crises have been ranked among the top five risks in terms of impact for the past eight years. It is still tucked away among a slew of other risks that are rated as having a high likelihood and a very high impact. Extreme weather events, natural disasters, the failure of climate change adaptation and mitigation, and biodiversity loss are examples of these (Van Der Heijden & Stinson, 2019). Politicians and the media alike have expressed concern over the last decade that "water wars between countries could be just around the corner" and that "the world will soon be at war over water" (Schmeier, 2019).

Water battles are conflicts of interest over different powers of control or access to shared water bodies that can occur across international or international borders, states, and territories. Freshwater access has become an economic, social, and human rights issue. as well as human rights in many countries (Bland, n.d.). The three spheres that cause water conflicts are hydrosphere, economic and political, where problems in one can lead to conflict in another. Large basins of water can be used for a variety of purposes, including power generation, food production, industrial development, municipal water supply, recreation, or some combination of these. Different user groups' objectives create conflict over the general schedule of quantity and time of water distribution. Water conflict can be divided into three categories within the hydrosphere: water quality problems, water quantity problems, and ecosystem problems. Human consumption, industry, and agricultural use, for example, compete for water while simultaneously releasing waste into water sources that negatively impact ecosystems (Hanasz, 2013).

Water-related violence can be categorized into three forms. The first form, water is a trigger of violence, which is a dispute over access and control of water. The second form is that water or water systems are used as weapons of this conflict, including suppressing water or flooding downstream communities by using dams. Water infrastructure, such as water resources, treatment plants, or pipelines, is the final form of being in the position of casualties or targets of conflict (Milne, 2021). Freshwater can be a competitive trigger because it is not only a fundamental measure of human survival but can also be controlled through man-made developments such as hydroelectric dams and large-scale irrigation schemes. Similarly, pre-existing tensions can be exacerbated when water resources become scarce, as in the case of transboundary waters, and when a state has an advantage over the unequal use and development of water. It can become linked to the countries' domestic securities and political priorities (Schmeier, 2019).

Conflicts over water can occur at the local, national, regional, and global levels. Tensions over the use of a water well, or between pastoralists and modern irrigated agriculture, are examples of local conflicts. Local water-related conflicts can become violent in subsistence agriculture, where traditional conflict management systems have been eroded and new ones have not been firmly established. At the national level, conflicts over land use and water rights, as well as infrastructure development, can arise; however, these are usually resolved peacefully. Rather than violent conflict, unsustainable development that leads to local conflicts is a greater challenge. Regional conflicts frequently arise over shared river basins or transboundary aquifers. Tensions at this level are typically diplomatic and economic rather than violent. Water in the form of food, also known as virtual water, connects the availability of world water to the global food trade on a global scale. Physically water-scarce countries that withdraw more than 75% of river water are more vulnerable to regional and global water tensions (Mason & Siegfried, 2020).

Tensions and disputes between countries are on the rise as a result of growing issues such as water scarcity, rapid population growth, deterioration in water quality, and uneven economic growth. “If current trends continue, we could be faced with a very grave situation,” said former Soviet Union President Mikhail Gorbachev (The New Humanitarian, 2006). Given the current state of water availability and future projections, the UN has confirmed that there are approximately 300 areas around the world where a water conflict is expected by 2025 (Zarza, 2019). Two-thirds of the world's population will live in areas characterized by acute water stress or scarcity (The New Humanitarian, 2006). The UN also identified four hotspot regions where conflict risks are expected to rise over the next 15 to 30 years: the Middle East, Central Asia, the Ganges-Brahmaputra-Meghna basin, and the Orange and Limpopo basins in southern Africa (Hydrofinity, 2018).

Conflicts occur in various parts of the world: the Israeli-Palestinian conflict over the occupation of the West Bank and Gaza Strip, in which Israel not only claims ownership of all water resources but has also begun to use water to harm its opponents. It, for example, destroyed a pipe that supplied drinking water to Palestinian families in the Jordan River Valley. Furthermore, before carrying out any activity or developing any infrastructure related to water resources, Palestine must obtain a license from the Israeli army (Zarza, 2019). In Cochabamba, Bolivia, the processing of drinking water sparked violent protests in 2000, culminating in the so-called 'Water War of Cochabamba,' which killed at least nine people. Even though the city's water was renationalized and access to water was given new legal protection, Cochabamba is still suffering from dwindling water supplies due to global climate change, excessive consumption, and technological shortcomings (Detges, Pohl, & Schaller, 2017). The construction of hydropower dams in the Mekong River Basin in China and Laos has caused diplomatic tensions. This has been attributed to the fact that the countries downstream of the dam, including Cambodia, Laos, Thailand, and Vietnam, are aware of the effects on water supply, flow changes, sediment trapping, and the destruction of important agricultural areas and aquatic ecosystems. Although the Mekong River Commission (MRC) is the primary mechanism for promoting regional cooperation in the development and management of Mekong River water, its ability to resolve tensions is limited due to a lack of enforcement powers and China's and Myanmar’s non-membership. To encourage cooperation with downstream residents, China has proposed an alternative institutional mechanism and offered assistance for downstream dam construction in the Lower Mekong basin rather than joining the MRC. Downstream countries, on the other hand, lack confidence that their upstream neighbor will respect their interests in the absence of a written water-sharing agreement (Climate Diplomacy, n.d.).

Yemen is one of the most water-scarcest countries in the world due to its relatively low rainfall, which has continued to decline by 9% per decade on average since the 1990s. The rapid increase in population, altered consumption habits, and serious mismanagement, especially the promotion of wrong farming, have resulted in a dramatic decrease in Yemen's water availability. Corruption and inequality in the distribution of water resources are increasingly frustrating for the disadvantaged. This was the cause of the intensifying protests. Water scarcity exacerbated the political and security crisis that led to the collapse of Yemen's state (Climate Diplomacy, n.d.). Promoting water-saving agriculture is one of the keys to solving water scarcity because it absorbs more than two-thirds of the water people use each year. Farmers in some drought-stricken areas are more likely to switch to more efficient sprinkler or drip irrigation systems, including using remote monitoring tools to monitor proper humidity use. In addition, the conservation of watersheds, forests, and surrounding cities not only absorbs rainfall but also prevents crop losses from floods and droughts (Moloney, 2020).

Water conflicts also lack effective methods of prevention or management and violence continues to be widespread in today’s world. The greatest risk comes not from countries waging war for or control of shared water resources, but rather in inefficient water management, the marginalization of water-related livelihoods, and the undercutting of critical services provided by freshwater ecosystems. All of these issues are exacerbated by many governments' inability to legally and effectively address such challenges. These problems are rarely related to increased water scarcity but rather are the result of obsolescence, injustice, or lack of good vision about water policy (Conca, 2012). Understanding the root cause of the problem to find ways to reduce the factors affecting water and conflict is necessary for reducing the risk of violence over freshwater. Water scarcity and disputes over access to water resources are the main factors in cases where water is a trigger. Water scarcity is typically not a problem. Water distribution or infrastructure flaws, on the other hand, create tensions in access to freshwater, as do uncertain or conflicting legal rights to water. Furthermore, the lack of effective institutions or governance mechanisms for managing and allocating water is likely to exacerbate water-related tensions (Gleick, 2018).

To develop monitoring mechanisms to identify future tensions and design resilient institutions, it is necessary to understand the indicators of conflict and cooperation, which are important prerequisites. Institutional capacity-building programs can help mitigate the potential impacts of rapid change in basins that are particularly vulnerable to tensions (Wolf, 2007). Promoting a framework for riparian cooperation by establishing the River Basin Commission has demonstrated a response to conflicts over shared water bodies, such as the Nile Basin Initiative, the Rhine Commission, and the MRC, as well as supporting the establishment of supranational institutions through capacity development programs to increase knowledge and skills and find ways to collaborate on shared water resources at various political levels. This was an initial political effort to introduce a pragmatist paradigm in international relations to integrate previously conflicting state actors in a supranational institutional setting. Effective water governance not only plays an important role in aiding political and economic cooperation across administrative borders but also helps alleviate conflict situations (WOCAT, 2014).

The most important policy reform is improving people's rights to water and the benefits of water, but it also supports strong participation mechanisms that give stakeholders the right to make decisions on water governance. The UN Watercourses Convention, which is based on the principles of information sharing and dispute resolution mechanisms, provides a useful framework for guiding negotiations between governments to minimize conflict over shared basins. Environmental provisions, on the other hand, which are focused on pollution control, do not address ecological flows and ecosystem management (Conca, 2012). Technological advancements have the potential to play a significant role in this new era of collaboration. Generating insights about the interplay of risk factors by using real-time data has enabled the development of sophisticated early warnings tools such as the Water, Peace and Security Partnership, which crunch vast amounts of data using machine learning and other technologies to identify patterns that indicate the high risk of a conflict situation developing. It can identify factors that need to be addressed to reduce potential conflict through capacity building and stakeholder engagement (Van Der Heijden & Stinson, 2019).

To resolve water conflicts, technical solutions must be complemented by a carefully structured and skillful dialogue process that results in water cooperation. To find effective solutions, negotiations must be held to collaborate with other disciplines to identify the root causes of conflict and the link between water and conflict (Schmeier et al., 2019). It seems that the future of water, conflict, and competition are inextricably linked. Water insecurity must be addressed through a multi-sectoral approach that includes aid organizations, international financial institutions, diplomatic engagement, private sector innovation, and the military. Water management is a peace guide that facilitates international negotiations despite growing tensions between countries. Water cooperation has resulted in people-to-people and expert-to-expert relationships, as evidenced by the governing agencies and institutions (Risi, 2019).

1.4 Technology and Solutions for Water Management

1.4.1 Water Management Technology

Water scarcity is caused by the convergence of two phenomena: rising water demand and the depletion of usable freshwater resources. Global water consumption has more than doubled in the last century as the world's population has grown. This has an impact on the limits that can provide a sustainable water supply, particularly in arid areas where severe water shortages are expected due to urbanization (Facilitator, 2020). Every continent and nearly 20% of the world's population are affected by water scarcity. The UN has estimated that nearly 1.8 billion people will live in water-scarce areas by 2025 and two-thirds of the world's population may live in water-stressed conditions. This has a knock-on effect on the economy and environment for people all over the world, necessitating the urgent need for effective water resource management (The Digital Watch, n.d.).

The goal of water resource management is to increase equitably economic and social welfare while not interfering with ecosystem function, which requires a multidisciplinary approach (Petruzzello, 2021). In the field of water management, technology plays several roles. It assists in infrastructure design, real-time operational system planning, and environmental water management, all of which can be considered in a matrix with water resource management, irrigation management, water supply (and treatment) and sanitation, and environmental water management (Rao Harshadeep & Young, 2020). Some examples of water management technologies are as follows:

1) Water reuse (Water recycling) and wastewater treatment technology

Water recycling is the practice of reusing water for useful purposes such as agriculture, municipal water supply, industrial processes, and environmental restoration (Figure 5) (Ha & Schleiger, 2021). Water reuse strategies can aid in the alleviation of water scarcity. The main strategies, in this case, are reuse and recycling, as well as the use of zero-liquid discharge systems. In the zero-liquid discharge system, water is continuously treated, used, and reused within the plant rather than being discharged into sewers or other external water systems (Madaan, n.d.). The goal of wastewater treatment is to remove harmful bacteria, chemicals, and virulent toxins from sewage by purifying the water through physical, chemical, and biological processes. Physical wastewater treatment uses gravity and electrical attraction to separate harmful substances from water, and the water is then disinfected using chlorine, ozone, and ultraviolet light, which is a chemical process. The final step is to convert organic matter in wastewater into energy through the oxidation and biosynthesis of bacteria, algae, and fungi (Norwich University Online, 2017). Because of advances in wastewater treatment and reuse, chemicals and minerals can be reclaimed and reintroduced into the treated water. Growing algae for biofuels is another potential wastewater use that could potentially solve a different problem, namely reducing reliance on fossil fuels (Markham, 2018).

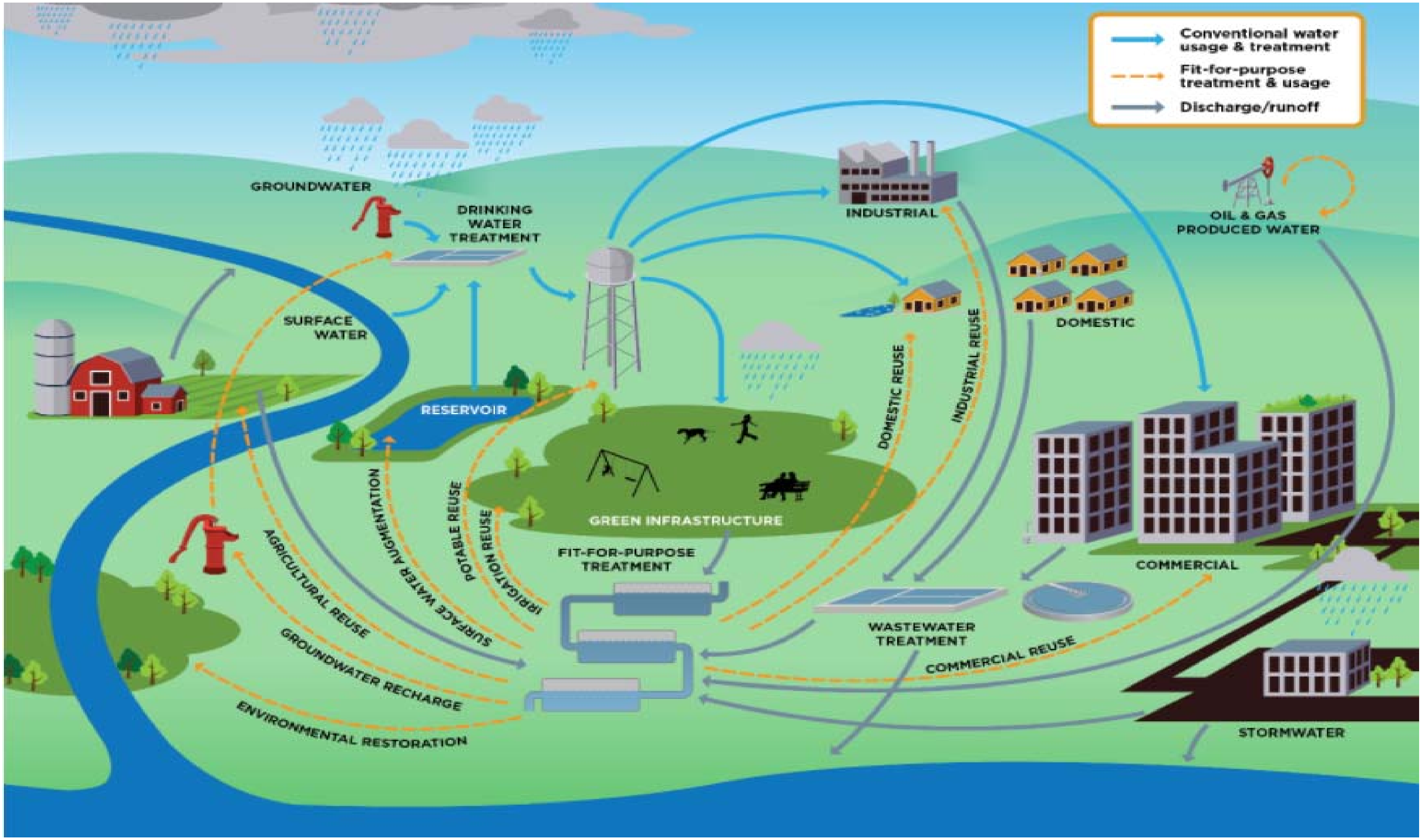

Figure 5. Flowchart of Water Reuse

Source: Ha & Schleiger (2021)

2) Hand-dug well and drilled well

When water is less than 100 feet deep below the land surface and roads are inaccessible or nonexistent, skilled technicians can dig a well that is lined, capped, and hand pump-equipped well (Figure 6). A drilling rig is required if the water level is deeper than 100 feet and roads are accessible, with drilling depths ranging from 100 to 400 feet depending on location (Lifewater, 2018).

Figure 6. Hand – D ug Well

Source: Lifewater (2018)

3) Rainwater harvesting

Rainwater harvesting is the practice of collecting and storing rainwater rather than letting it fall. Rainwater is collected from a roof-like surface and directed to water tanks, cisterns, deep pits (wells, shafts, or boreholes), aquifers, or permeable reservoirs (Figure 7). Using a net or other tools can collect dew and fog. The difference between rainwater and stormwater harvesting is that runoff from roofs is collected rather than from creeks, drains, roads, or other surfaces. Harvested water can be used not only for long-term storage but also to recharge groundwater (Facilitator, 2020).

Figure 7. Rainwater Harvesting

Source: Facilitator (2020)

This is one method for conserving groundwater and providing clean water. Rainwater harvesting systems can be as elaborate as a large umbrella or as simple as gutters and rain barrels on residential buildings (Markham, 2018). Portable rainwater harvesting units are made up of a foldable catchment made of washable fabric that is placed above a moveable barrel to collect precipitation water for non-potable purposes. It is popular at the household level due to its low cost, which includes rooftop catchments plumbed to a cistern where the water can be treated for potable uses (Bautista, 2015).

4) Groundwater recharge and artificial groundwater recharge

Water that collects in fissures and crevasses beneath the earth's surface and flows into aquifers is referred to as groundwater. An aquifer is a porous body of soil or rock that stores or transports groundwater. Aquifers are typically filled or recharged by rain or snowmelt as the water flows downward until it reaches less permeable rock (Fluence News Team, 2017). The use of man-made conveyances such as infiltration basins, trenches, dams, or injection wells to supplement natural groundwater supplies is known as groundwater recharge. Aquifer storage and recovery is a type of groundwater recharge that is used to supplement groundwater resources while recovering water for future use. Rain and snowmelt naturally recharge groundwater and surface water to a lesser extent (rivers and lakes) (Figure 8). Human activities such as paving, development, and logging may impede recharge. These activities can result in topsoil loss, which reduces water infiltration, increases surface runoff, and decreases recharge. The use of groundwater, particularly for irrigation, has the potential to lower water tables. Groundwater recharge is a critical process for long-term groundwater management (Facilitator, 2020).

Across the country, groundwater levels are dropping. The practice of increasing the amount of water that enters an aquifer through human-controlled means is known as artificial recharge (Figure 9). Groundwater can be artificially recharged in a variety of ways, including redirecting water across the land surface via canals, infiltration basins, or ponds; installing irrigation furrows or sprinkler systems; or simply injecting water directly into the subsurface via injection wells (Facilitator, 2020).

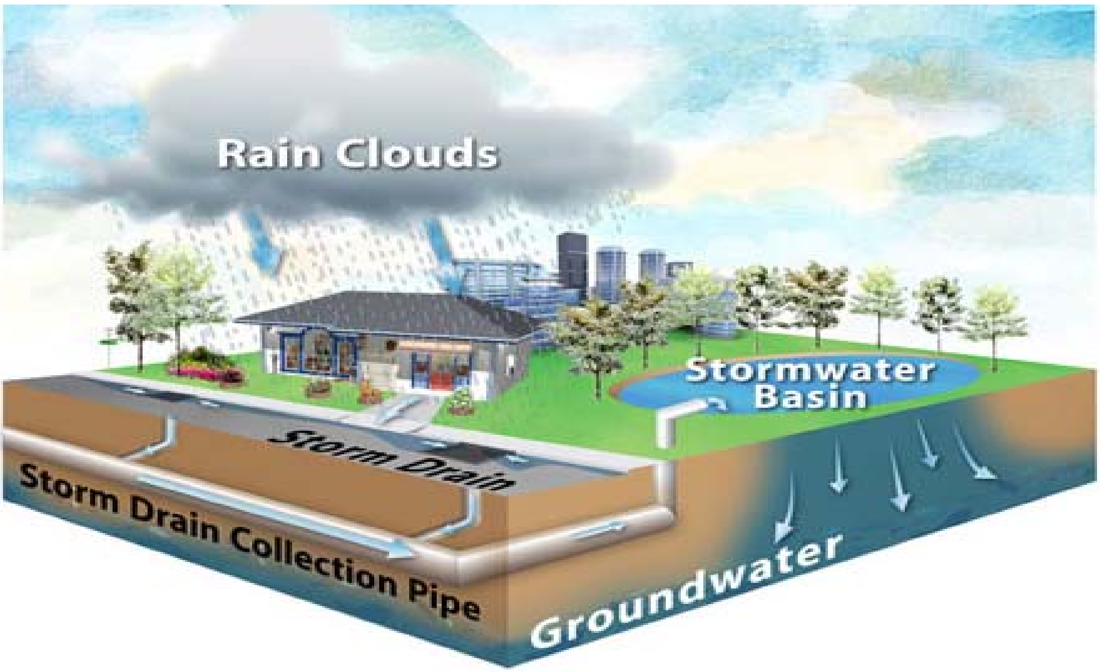

Figure 8. Groundwater Recharge

Source: Facilitator (2020)

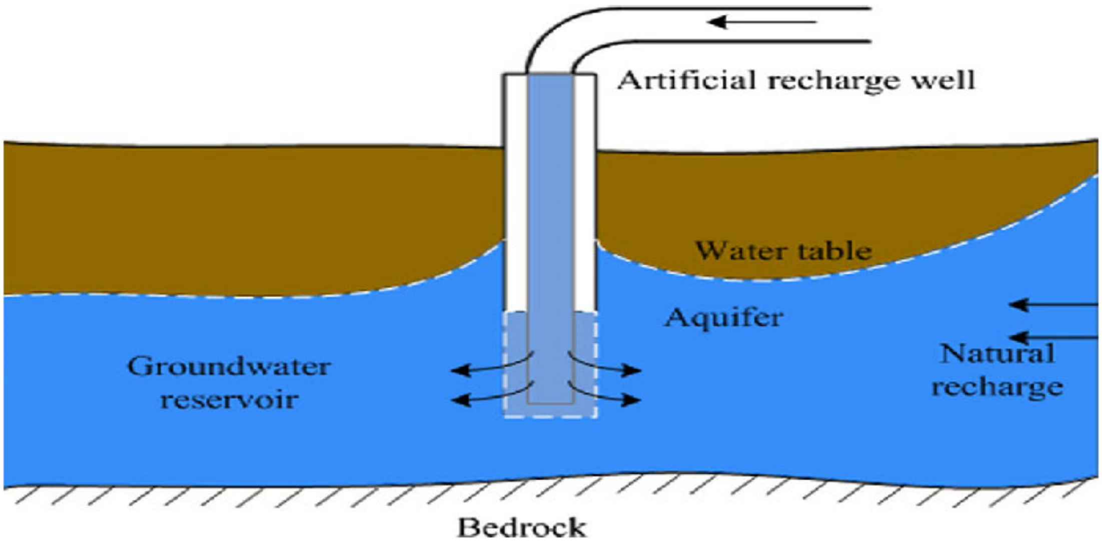

Figure 9. Artificial Groundwater Recharge

Source: Facilitator (2020)

Artificial groundwater recharge has not only been around for decades, but it is also widely regarded as the most effective method of addressing water scarcity in many areas. The process of recharge can be either natural as part of the hydrological cycle or induced by humans (Castelo, 2021).

5) Aquifer storage and recovery

Another water scarcity solution is aquifer recovery and storage. Surface infiltration into unconfined, shallow aquifers is used for recharge. In recent years, this process has evolved to allow for direct injection into deeper aquifer systems, allowing for freshwater storage in areas where none previously existed. The clogging of pores caused by particulates, chemical precipitation, and biofilm formation is a significant barrier to injection and infiltration recharging (Castelo, 2021). The direct injection of surface water supplies such as potable water, reclaimed water (i.e., rainwater), or river water into an aquifer for later recovery and use is known as aquifer storage and recovery (Figure 10). A well is frequently used for injection and extraction (Facilitator, 2020).

The goal of aquifer recovery is to replenish aquifer water. Preventing saltwater intrusion into freshwater aquifers and controlling soil subsidence can be achieved by injecting water into aquifer recovery wells. Aquifer storage wells can not only store water in the ground and recover it for drinking water, irrigation, industrial needs, or ecosystem restoration projects but they may also be recovered from the same injection well or from nearby injection or recovery wells (Facilitator, 2020)

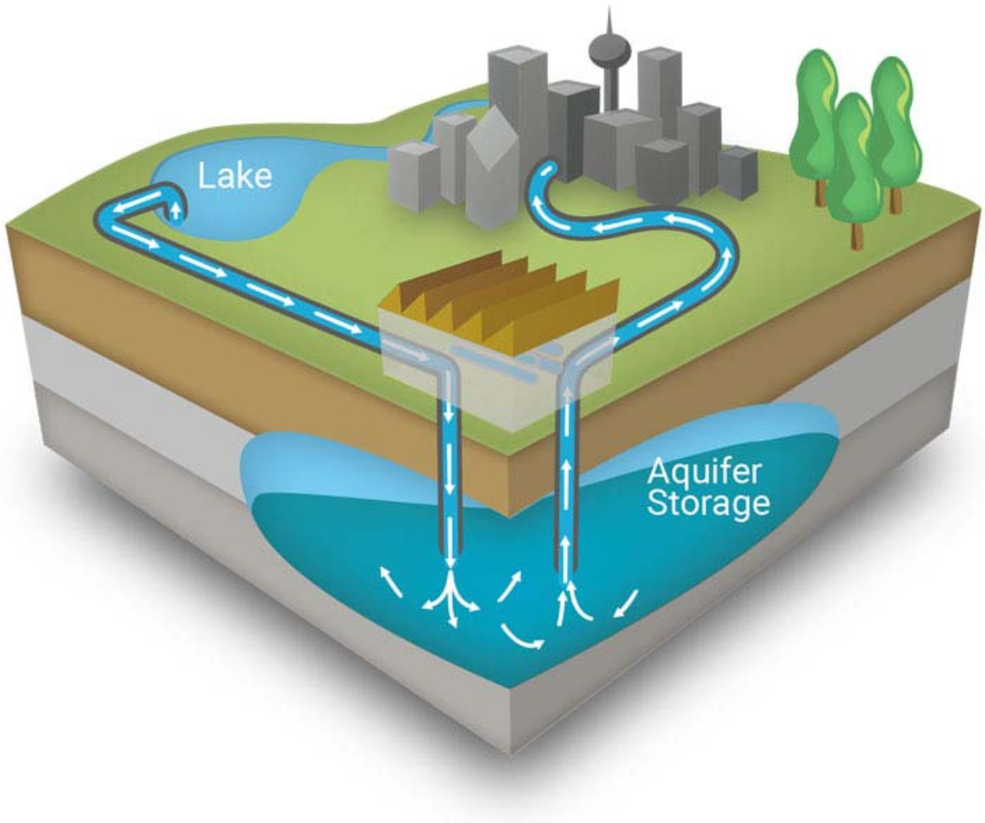

Figure 10. Aquifer Storage and Recovery

Source: Facilitator (2020)

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6) Desalination

Desalination is a technology that makes new water sources available, and it is primarily used in arid and semi-arid regions. It can be found on land or along the coast. According to the International Desalination Association, the Gulf accounted for 50% of global desalination volume in 2002, followed by North America (16%), Europe (13%), Asia (11%), Africa (5%), and the Caribbean (3%), with South America and Australia accounting for less than 1% of global desalination volume (Lopez-Gunn & Ramon Llamas, 2008). Advances in membrane technology and materials science, coupled with increasing costs of treating wastewater and meeting regulatory requirements, have resulted in the rapid growth of seawater desalination in recent decades. Desalination currently accounts for about 10% of the municipal water supply of urban coastal centers worldwide, with that figure expected to rise to 25% by 2030. The cost of desalination water production will be reduced in the future as a result of new technological advancements that focus on reducing energy consumption, improving process reliability and flexibility, and greatly reducing the volume of concentrate emissions (brine) discharge (Daigger, Voutchkov, Lall, & Sarni, 2019).

Desalination is the process of removing dissolved salts and minerals from seawater or saline groundwater (Figure 11). It can be accomplished through a variety of methods, including boiling, filtration, electrodialysis (using an electric current to remove the ions that comprise salts), and reverse osmosis (Figure 12). All of these procedures consume a lot of energy and are also expensive (Ha & Schleiger, 2021).

Figure 11. Desalination Plant

Source: Facilitator (2020)

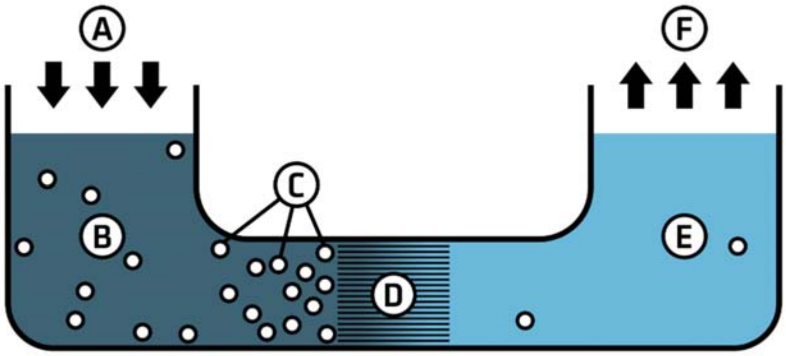

Figure 12. Reverse Osmosis

"In this process, pressure (A) is applied to salt water, which contains ions (charged atoms or molecules) and other contaminants (C). The water is forced through a semipermeable membrane (D), through which the contaminants cannot pass. Clean freshwater that is safe to drink (E) is then distributed (F)".

Source: Ha & Schleiger (2021)

The use of large amounts of energy in desalination not only emits greenhouse gases that contribute to climate change but also has a negative impact on marine life and ecosystems. Fish and other marine life are killed as they pass through desalination plants, and the effluents released by desalination plants are too salty for marine life. Some desalination plants generate sea salt as a source of revenue, obviating the need for any effluent. Another possibility is to dilute the brine with cooling water from a nearby power plant, or simply with seawater (Paster, 2018). The desalination process, which is popular in many parts of the world, particularly the Middle East, extracts salt from seawater and converts it to freshwater. According to the International Desalination Association (IDA), there are currently over 18,000 desalination plants in 150 countries around the world. These plants provide clean water to over 300 million people (OHIO University, 2021).

7) Offshore fresh groundwater

There are large volumes of offshore fresh groundwater around the world that could be used as a reserve water supply in the era of climate change-caused drought (Attias, Thomas, Sherman, Ismail, & Constable, 2020). Fresh groundwater can be found up to 100 km off the coastline. More than 450,000 km^3 of freshwater is buried beneath the seabed on the global continental shelves (Figure 13). The volume of this water source is greater than that extracted from continental aquifers around the world since 1900 (Post, Groen, Kooi, Person, Ge, & Edmunds, 2013). The volumes of offshore groundwater vary across coastal regions of the world depending on geological and other hydrological factors such as groundwater recharge and the influence of rivers. South and Southeast Asia have large volumes of offshore groundwater which should be further investigated and explored the potential of these volumes (Zamrsky, Oude Essink, Sutanudjaja, van Beek, & Bierkens, 2022).

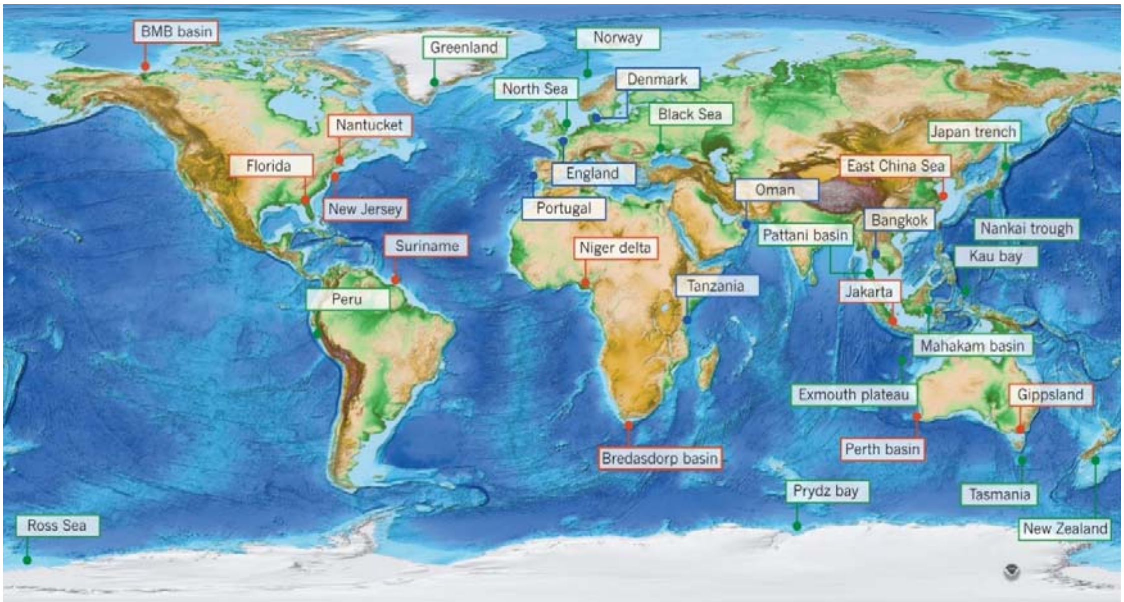

Figure 13. World Map of Topography and Bathymetry Showing Known Occurrences of Fresh and Brackish Offshore Groundwater

Source: Post, Groen, Kooi, Person, Ge, & Edmunds (2013)

The impetus for using offshore fresh groundwater as an alternative water source could be attributed to water scarcity, mitigating the effects of groundwater use in coastal areas, and preparing to meet growing demand during severe drought periods (Micallef et al., 2020). However, decisions about development and management will not be easy due to unclear technological requirements, economic feasibility, negative environmental impacts, and unclear legal implications of off-sea groundwater extraction. Offshore fresh groundwater utilization may occur when costs are comparable to or less than those of seawater desalination (Micallef et al., 2020).

8) Agricultural irrigation technology

Because crops require water to grow and thrive, the agriculture industry is one of the largest consumers of freshwater in the United States. Farmers are increasing efficiency and lowering costs by combining more precise technology, such as drones, sensor networks, and data analytics, with pressure irrigation systems (OHIO University, 2021). More than half of the water used in the United States is for agricultural purposes, resulting in severe constraints on the amount of water available for general consumption. Balancing agricultural needs with broader public needs is critical for water conservation during droughts. Smart farm technology, for example, not only monitors soil moisture levels but also determines the appropriate amount of water in the fields (Norwich University Online, 2017). The three main irrigation technologies—gravity, sprinkler, and micro—can all be improved to save water. In practice, however, farms may use water savings to boost yield, switch to thirstier crops, or irrigate more land. In the United States, farmers are implementing a variety of irrigation technologies to optimize their water use, including sprinkler systems, soil moisture sensors, computer or smartphone decision support tools, and remote control of irrigation equipment to help increase irrigation efficiency. Small farm size, large capital investments, and a lack of available information on the technologies are all barriers to the adoption of more efficient technology. Lack of connectivity, such as access to broadband, can be a barrier to precision agriculture technologies, particularly in rural areas (GAO, 2019).

Drip irrigation is a type of micro-irrigation system that allows water to drip slowly to plant roots, either above or below the soil surface (Figure 14). The goal is to direct water into the root zone while minimizing evaporation. Drip irrigation systems use a network of valves, pipes, tubing, and emitters to distribute water. A drip irrigation system may be more efficient than other types of irrigation systems, such as surface irrigation or sprinkler irrigation, depending on how well it is designed, installed, maintained, and operated (Facilitator, 2020).

Figure 14. Drip Irrigation to Conserve Water

Source: Facilitator (2020)

1.4.2 Other Solutions

1) Infrastructure monitoring and repairs

Water infrastructure is a critical component of water management and control because it includes all infrastructure used to build, pump, transport, divert, store, treat, and deliver safe drinking water, as well as the tools and equipment used to build it. Groundwater wells, dams, storage tanks, surface-water intakes, pipes, drinking-water facilities, and aqueducts are examples of these structures. Natural infrastructure, which uses landscape management techniques such as conservation, restoration, and sustainable management, is also included in infrastructure. Water scarcity is inextricably linked to poor water infrastructure. This is a key reason for improving the quality of water infrastructure, whether natural or artificial (Castelo, 2021). Infrastructure monitoring and repair are critical for conserving water and preventing water loss through the water supply system because these small amounts of water increase over time (Fluence News Team, 2017).

2) Environmental policy

In today's world, the main cause of water scarcity is water pollution, which is the release of hazardous wastes into the clean water system. This not only reduces the amount of water available for consumption but can also have an impact on health (Castelo, 2021). Water scarcity can be mitigated by protecting and restoring ecosystems that naturally collect, filter, store, and release water, such as wetlands and forests. An intact ecosystem will be able to support other ecological processes, especially economic and social value. Natural areas, on the other hand, are frequently destroyed or degraded for more immediate economic benefits without regard for their ecological importance (Fluence News Team, 2017).

3) Water conservation

Although there are concerns about the effectiveness of water conservation, it is one approach to reducing water demand in order to address water scarcity. Conservation efforts are typically publicized and encouraged during times of drought, but conservation is critical to maintaining supply-demand balance, particularly in areas facing population growth (Fluence News Team, 2017). Water conservation is the practice of using less water and doing so more efficiently. Water-saving technologies and behavioral choices can both be used to conserve water in the home. High-efficiency clothes washers and low-flow showers and toilets are two examples of water-saving technologies. Turning off the water while brushing your teeth, taking shorter showers and showers instead of baths, and repairing leaky faucets are all examples of water-saving behaviors. A dishwasher uses less water than hand-washing dishes because it is only turned on when they are full. Similarly, doing fewer, larger loads of laundry saves water over doing fewer, smaller loads more frequently. Choosing low-water-footprint foods (such as eggs) over high-water-footprint foods (such as beef) can also help to conserve water (Ha & Schleiger, 2021).

Whether it is the use of emerging water-saving technologies and the development of sponge cities, smart cities, low-carbon cities, and resilient cities, or the development of new theories and methods such as landscape sustainability science, watershed science, and geodesign, all play an important role in reducing water demand. Scientists, policymakers, and the general public must collaborate to put these measures in place, as well as provide adequate financial and material support. Furthermore, encouraging the development and dissemination of new technologies through international collaboration not only aids in the construction of water infrastructure but also raises public awareness of water conservation (He et al., 2021). Water conservation encompasses all policies, strategies, and activities aimed at managing the natural resource of freshwater in a sustainable manner, protecting the hydrosphere, and meeting current and future human demand (thus avoiding water scarcity).

4) Economic and social solutions

According to economic theory, demand for water should behave similarly to demand any other good: if all else is equal, water use should decrease as prices rise. Thus, water pricing has frequently been proposed as a means of providing incentives for water use reduction and/or efficiency through a price signal. Water pricing is also promoted in order to internalize the environmental and social costs of water use while also raising funds for public water supply infrastructure and operations. The reality, however, may not be so straightforward (PRI, 2001). Petruzzello (2021) stated that several studies have shown that higher water prices not only reduce water waste and pollution but can also be used to fund water infrastructure improvements. Setting water price policies, on the other hand, may necessitate greater caution in light of the potential impact on people, particularly the poor. Due to the water tax, heavy users in industry and agriculture may reduce their wasteful water consumption, whereas households are unaffected. While consumers would most likely see higher product prices as a result of increased production costs, such a tax would ideally help decouple economic growth from water use. In many places, replacing water-consuming appliances like toilets and showerheads can result in significant savings.

5) Water management

Water management through the use of regulations and policies can aid in the reduction of water scarcity. Water-related issues such as water reuse, water resource management, water rights, industrial water use, wetland restoration, domestic water supplies, water pollution, and others can be addressed by regulations and policies. Water management, in particular, is capable of addressing human interventions and various natural events on resources, as well as long-term water policy decisions on the environment and economy (Madaan, n.d.). Although water management is commonly thought to be the responsibility of national or regional governments, it is increasingly being practiced at the state, provincial, or local levels. Companies and industries are also implementing best practices in water management to help them thrive and become better resource stewards. Politics and bureaucracy are two of the most significant barriers to effective water management (Fluence News Team, 2017).

1.4.3 Conclusion

Water management is one of the most pressing issues of the 21st century. The rapid increase in the world's population, coupled with increased competition for water resources by agricultural, industrial, and domestic users, has resulted in significant stress to water resources and aquatic ecosystems in both quantity and quality. Water problems must be solved using technological advances. Three examples are advancements in rainwater harvesting, micro-irrigation technology, and wastewater reuse. It will also be critical to conduct research aimed at reducing conflicts between agricultural and environmental uses (Jury & Vaux, 2005). Water technology is recognized as a solution to the problem of water scarcity, but it cannot completely conceal the socially intertwined water world. Water issues touch on all social fabric threads, including a skewed distribution of wealth, human rights, and security. Water-related measures must include all residents while paying special attention to groups that are more vulnerable to water, such as the poor, women, the elderly, people with disabilities, and other underrepresented ethnic/indigenous groups. Technologies are critical in addressing water scarcity, but they must be used as a supplement, not as a panacea. However, technology alone cannot address the underlying social fabric that has resulted in water scarcity, such as a lack of rule of law and institutions within the country, a population shift to urban areas, and even global scale climate change (Namgung, n.d.).

1.5 Public Participation in Water Management

1.5.1 The Definition of Public Participation

Recognizing the importance of public participation, many countries around the world today have scheduled public meetings and made regular comments on government action in their laws and regulations. The importance of public participation in good governance and civil society has also been emphasized by the UN and other international organizations (EPA, 2021). The Inter-American Democratic Charter, adopted by the Organization of American States in 2001, recognized public participation as a fundamental right and obligation that underpins participatory democracy. The Earth Summit on Environment and Development, also known as the Rio Summit, addresses Rio Declaration Principle 10 on three key principles for policy-making and participation regulation: access to information, access to participation, and access to justice (Bastidas, 2004).

Public participation is a process where each contributor shares facts, experiences, and opinions with other participants in order to gain a better understanding of the issue (Conway, n.d.). Public participation is an important way to influence government decisions that affect you, your community, and your livelihood (Environmental Law Institute, 2013). The process of public participation involves each contributor gaining a better understanding of both the issue(s) at hand as well as how other participants perceive the issue (s). Participants can share their knowledge, experiences, ideas, preferences, hopes, fears, opinions, and values. It is a process in which everyone's energy is pooled to achieve a better result (Conway, n.d.).

The inclusion of diverse sectors of community members in an ongoing community development process is referred to as participation. Participation is a dynamic process shaped by community members' desire to be involved in matters that affect their lives. Participation is an important concept in development because it has the potential to influence, challenge, change, and modify the current state of affairs for the benefit of all community members. Participatory approaches can also be closely linked to sustainable and decentralized development (Waweru, 2015).

The goal of public participation is to promote transparency, openness in government, and ownership in project development decisions. It not only assists people in understanding how government works and decision-making processes, but it also bridges the gap between the government, civil society, the private sector, and the general public to create a shared understanding of the local situation, priorities, and projects. Public participation is at the heart of inclusive decision-making because it promotes openness, accountability, and transparency (Yvonne, 2010). While there are numerous benefits to involving the public in planning and decision-making processes, there are also drawbacks. Participation by the general public can be time-consuming and sometimes costly (Wouters, Hardie-Boys, & Wilson, 2011).

Participation that works for all parties and stimulates interest and investment in both administrators and citizens is what authentic public participation is. It requires rethinking the underlying roles of administrators and citizens, as well as the relationships between them. Meaningful participation, in theory, brings the public into the process from issue framing to decision making. It creates an environment in which all participants have an equal footing and no group is privileged over the other (Jo Hanneke, 2017). When engaging in meaningful public participation, an agency will solicit input from a diverse range of stakeholder interests. Agencies should not be concerned that soliciting public input will obligate them to do "what the public wants." The sponsor agency's job is then to strike a balance between these various points of view and concerns, and to reflect the decisions back to the public so that it understands how its diverse concerns were taken into account (EPA, 2021).

So far, public participation in policymaking has not only provided governments with new sources of ideas and information exchanged during the decision-making process, but it has also contributed to the creation of accountability and responsibilities for both government officials and citizens. Citizen participation is critical in local development because it provides governments with feedback and public consultations to improve performance quality, resulting in a higher quality of life for the people (Tobin, 2016). Effective public participation can be achieved when participants are able to clarify their position and interests and listen to the opinions of others. Good planning, punctuality, competent personnel, and adequate resources are all factors that contribute to the greatest success of public participation (Conway, n.d.). Public participation enables citizens to participate in policymaking, more transparent and creative decision-making, and increased public awareness of environmental issues. This, in turn, promotes long-term development

(Figure 15). A successful public participation process not only encourages the best possible cooperation among the parties involved but also has the potential to build consensus and avoid conflicts as stakeholders feel ownership of the process (Roniotes, Malotidi, Virtanen, & Vlachogianni, 2015).

Figure 15. The Link between Sustainable Development and Public Participation

Source: Roniotes, Malotidi, Virtanen, & Vlachogianni (2015)

1.5.2 Public Participation in Water Management

Public participation in water-related decision-making provides a valuable pathway for achieving more equitable and sustainable water delivery, now and in the future. Goal 6 of the Sustainable Development Goals (SDGs) recognizes public participation as an important means of ensuring water availability and sustainability for all, including supporting and strengthening local community participation in water governance. To support the International Decade of Action "Water for Life" 2005-2015, The UN General Assembly recognizes the importance of full participation of stakeholders, particularly women, in water management and supply, as well as related issues. According to the UN World Water Development Report, vibrant and robust participation in water governance is a critical component for propelling sustainable and inclusive development for all citizens (Odei Erdiaw-Kwasie, Abunyewah, Edusei, & Buernor Alimod, 2020). In the early 1990s, the Rio Declaration on Environment and Development was signed, sending a message that sparked international law on public participation. Agenda 21, a comprehensive action plan, recognizes the significance of allowing individuals, communities, and organizations to participate in decisions that may be environmentally detrimental to their life and work and determine the critical role of the public, women, adolescents, and indigenous peoples, as well as local communities to participate in the formulation of policies and decisions on water management of States (Tignino, 2015). Other international organizations, such as the World Commission on Dams, the Global Environment Facility, the UN Environment Program, and a number of international non-governmental organizations (NGOs) (e.g., the International Union for the Conservation of Nature or the Global Water Partnership), have created publicly accessible water management information (Razzaque, 2009).

Because of increased public awareness and concern about the link between environmental health and human well-being, public participation in water resource management has grown exponentially in recent years. People's expectations of participation in policy-making have grown in tandem with the expansion of human rights in legal and political systems. The international community's support for "good governance" and "civil society strengthening" has also contributed to an increase in interest in participatory mechanisms. Bottom-up public participation allows people to share information and accountability, which may aid decision-makers in understanding and responding to public concerns while developing environmental policies. Concerning water management plans at the local level, there is a strategic shift within the water sector from consultation to shared decision-making (Razzaque, 2009). There are 276 international river basins in 148 countries that are important in the global water system (Giordano et al., 2013). The transboundary nature of water basins complicates their management because actions taken by one riparian state can have a negative impact on the quality and availability of resources in neighboring states, with serious consequences for the populations living within their borders. As a result, riparians established transboundary institutions that prioritized the inclusion of basin stakeholders in decision-making and management processes. For example, the Danube River Basin Management Plan (2009) was created with the participation of observers and stakeholders in order to protect river ecosystems and contribute to the basin's economic development. The Okavango River Basin Commission and NGOs have collaborated to implement the 'Every River Has Its People' project (1999-2007), which aims to empower local stakeholders to effectively participate in decision-making and river resource management (Schulze, 2012). The Mekong River Basin Agreement (1995) makes no mention of public participation, but a separate policy document identifies activities in which people could be involved, such as information gathering, dissemination, consultation, and participation culminating in some level of decision-making. International and national protests over the decision on the river could be reflected in this separate document (Razzaque, 2009).

The roles of women in water resource management are also important for effective governance. As collectors, users, and managers of water in the household, women in Central Asia have amassed a wealth of knowledge about the quality and dependability of acceptable water storage methods. Nonetheless, despite their important role, women are frequently overlooked by family or local leaders. As a result, significant reserves of knowledge and expertise are not being utilized to optimize water management and economic development (Komagaeva, 2021). Effective public participation is critical to improving the efficiency of the river basin's water resource management and achieving comprehensive management success (Jinglinga et al., 2010). To promote water resource management in the community and achieve true public participation in sustainable water management, public participation in water resource management must place an emphasis on the people as the center, listen to people's opinions and decision-making processes, and consider the context of the area (Mongkonchoochoktawee & Chompunth, 2021).

Due to forecasts of water scarcity and an increase in conflict and human rights abuse over water by 2025, the water sector has been one of the utilities of significant social and economic importance over the last decade. Access to information about water quality emerged as a key area for improvement in most countries during the first round of national assessments conducted by The Access Initiative (TAI). The Millennium Development Goals (MDGs) of increasing access to water can have a significant impact on education, health, and economic livelihoods. It not only assists people in making decisions and protecting themselves from harm, but it also improves their access to other necessities such as food. A more open and transparent participatory water decision-making process will help to achieve the goals of effective water management and conservation (Krchnak, 2005).

Water governance and public participation in developing and implementing solutions to the world's critical water challenges are becoming increasingly important. Many organizations, including the UN, the World Bank, the Global Environment Facility, and others, have not only examined efforts to improve water governance in recent years but a significant amount of innovative work has been directed at learning from the practice of stakeholder engagement in order to address challenges and the importance of ongoing communication between participants and institutional support. Stakeholder participation in water management is frequently fraught with conflict when disparate interests lead to mistrust and noncooperation. Conflict resolution techniques may be an important component of stakeholder engagement (Megdal, Eden, & Shamir, 2017). Participants in the public participation process used system thinking and systems understanding to form new networks and work to resolve conflicts that arose as a result of the intense interactions that can occur during the participatory process. Understanding the system also helps decision-makers, planners, and community members make better decisions. As part of the principles of sustainable development, participatory decision-making is an important component of sustainable river basin management. Public participation in integrated river basin management can make decisions ranging from implementing actual measures to participating in environmental monitoring and research (Poppe, Weigelhofer, & Winkler, 2018).

1.6 Sustainable Water Management

Access to safe freshwater water is both the universal human right and the MDGs. The importance of sustainable management of freshwater resources is recognized at both the global and regional levels. This has evolved into a scientific paradigm that promotes the management of integrated water resources. Climate and freshwater systems are intricately linked. Any change in one of these systems affects the other. Climate change, which affects the availability of freshwater in both quantity and quality, is one of the factors putting pressure on freshwater systems. Climate change, population change, lifestyle, economy, and technology all have an impact on water use or hydrological cycles, which must be addressed to manage water resources (Figure 16).

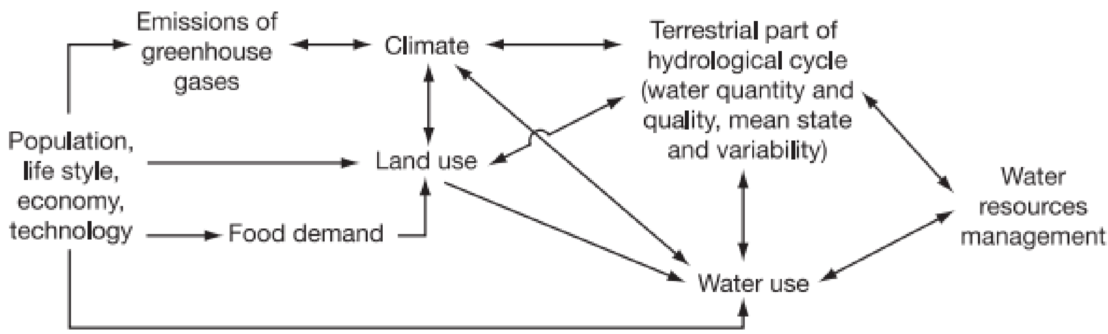

Figure 16. Impact of Human Activities on Freshwater Resources and their Management, with Climate Change being only One of Multiple Pressures

Source: Kundzewicz et al. (2007)

The majority of the MDGs are related to water management and climate change, either directly or indirectly (Kundzewicz et al., 2007). The world's largest water user is agriculture, which accounts for 72%of the average per capita water diversion. This was followed by industrial and domestic, which accounted for 19 and 9% of the total. These three sectors will face worsening water allocation problems in the coming years as the industry will continue to be vital to the country's economy. While agriculture, which relies on irrigation for two-thirds of its output, will continue to rely on water. More water is required in society for domestic use. As a result, there is an urgent need to develop policies to control, manage, and allocate water resources in an integrated and holistic manner, with the goal of maximizing societal benefit (ESCWA, 2003).

Water security is one of the goals of water resource management. As the world's population increases rapidly, urbanization and climatic and non-climate uncertainty make it impossible to predict and plan a single path to water security. In the context of the World Bank, achieving water security in terms of both quantity and quality necessitates a more integrated and long-term approach to water management. This can be said that water resource management is dependent on the collaboration of many organizations from various disciplines in order to plan for holistic water use in the future (Aquatech, 2019). IWRM strives to achieve sustainable water resource management. Although the precise meaning of the term varies greatly, all definitions cover the concept of environmental conservation and improvement, particularly concerning the water environment. This considers competing users, ecosystems in streams, and wetlands, as well as the environmental impact of water management policies. Water and land governance must be considered in water management to ensure sustainable water resources for the political, socioeconomic, and administrative systems (Kundzewicz et al., 2007). IWRM is an empirical concept derived from practitioners' on-the-ground experience. Following Agenda 21 and the World Summit on Sustainable Development in Rio de Janeiro in 1992, the concept became the subject of extensive debate as to what it means in practice. The definition of IWRM proposed by the Global Water Partnership is widely accepted. "IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (UN, 2014).

The Global Water Partnership technique describes the four stages of the iterative cycle towards integration and sustainability, which require an enabling environment (e.g., policy, goals, legal, financial, incentive structure), a distinct institutional role (e.g., organizational structure), and management tools (such as needs assessments, IWRM plans, water efficiency measures, conflict resolution strategies) (Figure 17).

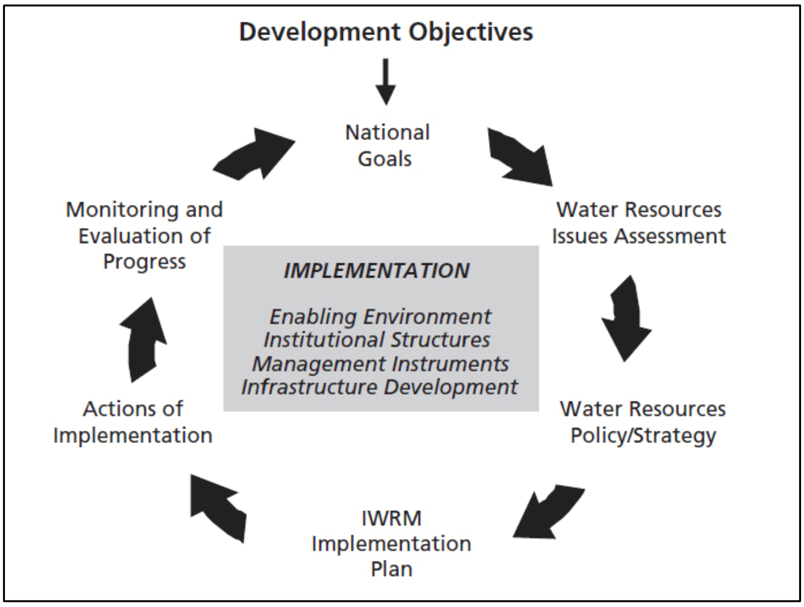

Figure 17. Stages in IWRM Planning and Implementation

Source: USACE (2014)

Phase 1 is an assessment of the current situation to identify problems, threats, opportunities, and needs. In the following phase, the problem will be assessed and potential solutions will be identified. The options are then evaluated in order to create a coordinated and detailed plan. Following IWRM implementation, the final phase is monitoring and evaluation in order to restart the cycle (plan) with forethought based on the evaluation feedback (USACE, 2014).

IWRM entails taking into account all of the various uses of water resources. Individual water consumption has a significant impact on water management and allocation for the SDGs. A lack of cooperation and connectivity between different sectors in water resource management has resulted in complexity, conflict, and resource depletion. Stakeholder negotiation is one of the processes that help in the integration (WWAP, 2012).

Data on the day-to-day levels and status of water bodies, such as flows, quality, abstraction, and discharge levels, are required at the operational level. Depending on the size of the area, management units may be divided into sub-basins or highlight areas of special importance. At the associative level, data that have been synthesized at the basin or regional scales, particularly where there may be water transfer between neighboring areas, are used. It consists of a demand pattern, indicators of economic development, an ecosystem, and human health. Those working outside of the water management area will directly benefit from the information. Decisions on the development and allocation of resources at the constitutional level require sufficient information to process based on detailed information on the state of the water system and projection simulations of future scenarios. Many different government agencies will make use of the information (Mcdonnell, 2008).

The main point of IWRM is a cross-sector integration of policy to better coordinate the development and management of water, land, and other resources. This can improve economic and social welfare, social equality, and environmental sustainability. IWRM by policy sector is more than just an attempt to connect each water purpose with its primary sector; it also necessitates integration between water subsectors, which are represented as water management objectives. These include water supply, water quality, environmental water control, irrigation, flood control, navigation, hydropower, and recreation (Figure 18). The other links are the result of sector interdependence (Grigg, 2008).

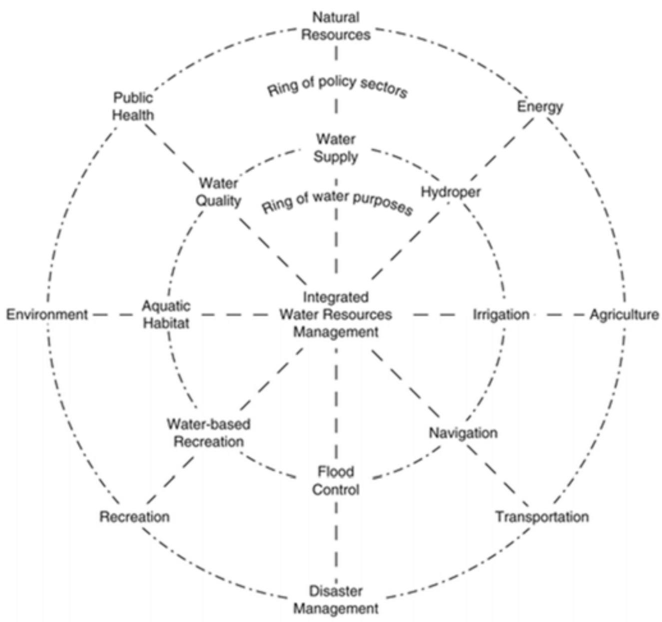

Figure 18. Integration of Water Management by Sectors

Source: Grigg (2008)

The concept of vertical integration between government units at the national, regional, and local levels requires cooperation with government agencies at the same level (horizontal dimension) (Figure 19). Coordination among government agencies can be accomplished through a variety of projects, international water treaties, interstate agreements, inter-local agreements, and so on (Grigg, 2008).

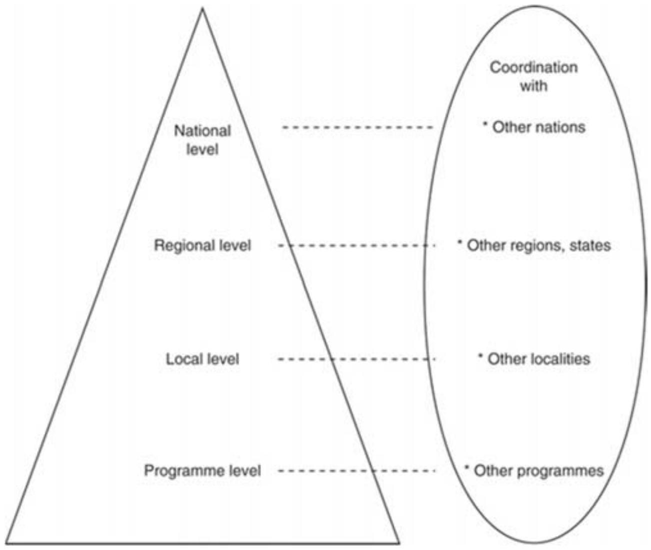

Figure 19. Integration Across Government Units.

Source: Grigg (2008)

In its natural state, water must be viewed holistically, as well as when balancing competing demands in agriculture, industry, and the environment. Collaboration within and across sectors is required for water resource management. If it can be integrated horizontally and vertically within the framework of water resource and service management, it will result in efficiency, equity, and sustainability (Figure 20). The primary goal of IWRM is to improve governance and promote balanced development in terms of social equity, economic growth, and environmental sustainability (Varis, Enckell, & Keskinen, 2014).

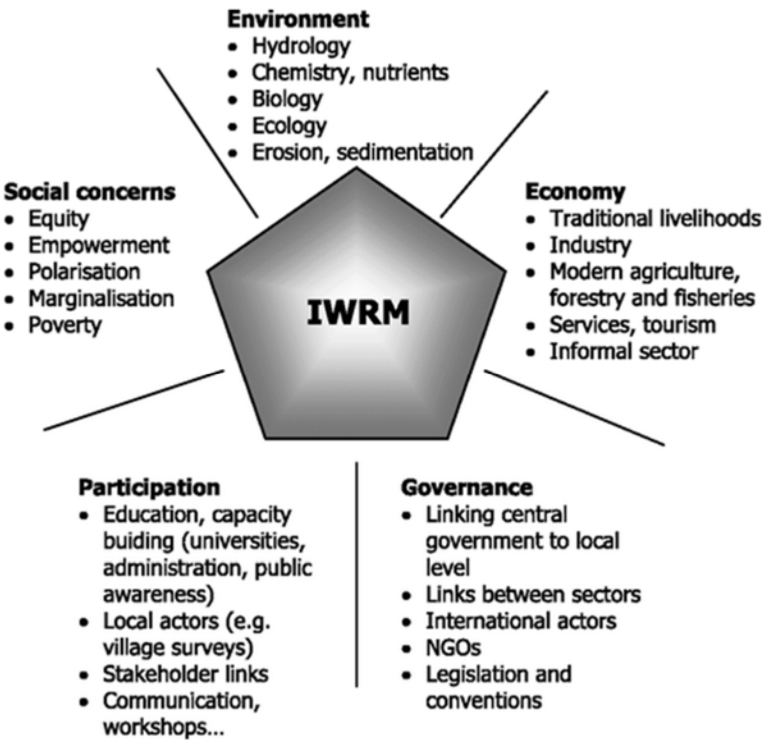

Figure 20. Integrated Water Resources Management Under the Promotion of Good Governance

Source: Varis, Enckell, & Keskinen (2014)

Water is not only important for economic and social development, healthy ecosystems, and human survival, but it is also the key to sustainable development. The Brundtland Commission has defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (UN, 2015). Economic, environmental, and ecosystem service delivery, as well as cultural goals such as identity and subjectively defined values, are examples of "needs." These are referred to collectively as the sustainability triple bottom line. The combination of preserving the natural environment, resources, and community, as well as the advancement of the economy and societal goals, is known as sustainable development. Sustainable water management is an essential component of sustainable development. It is similarly defined as meeting the current water needs for all water users without compromising future supply while taking social objectives into account and maintaining ecological, environmental, and hydrological integrity (Russo, Alfredo, & Fisher, 2014).

On a global scale, sustainable water means that everyone has affordable access to the water they need to sustain life, with a daily minimum of 20 to 50 liters. Whereas for water utilities, sustainability can mean designing efficient water and wastewater systems to manage operations and infrastructure while also ensuring the long-term viability of the communities they serve. Regional and national governments will develop sustainable water strategies, which will vary depending on many factors, including the maturity of water infrastructure, the impact and risks of climate change, the level of governmental ambition, regulation, and access to finance, among others (Aquatech, 2019). There are four areas of sustainable water management: water catchment and preparation, wastewater treatment, water distribution, and efficiency enhancement regarding water use. The various technological fields (instruments and measures) for sustainable water management are depicted in these areas (Figure 21). Sustainable water management necessitates technical, cost-effective, and efficiency-related solutions, as well as adequate anti-pollution measures, to meet the ever-increasing demand for water while also ensuring long-term sustainability in the water sector (CIO, 2020).

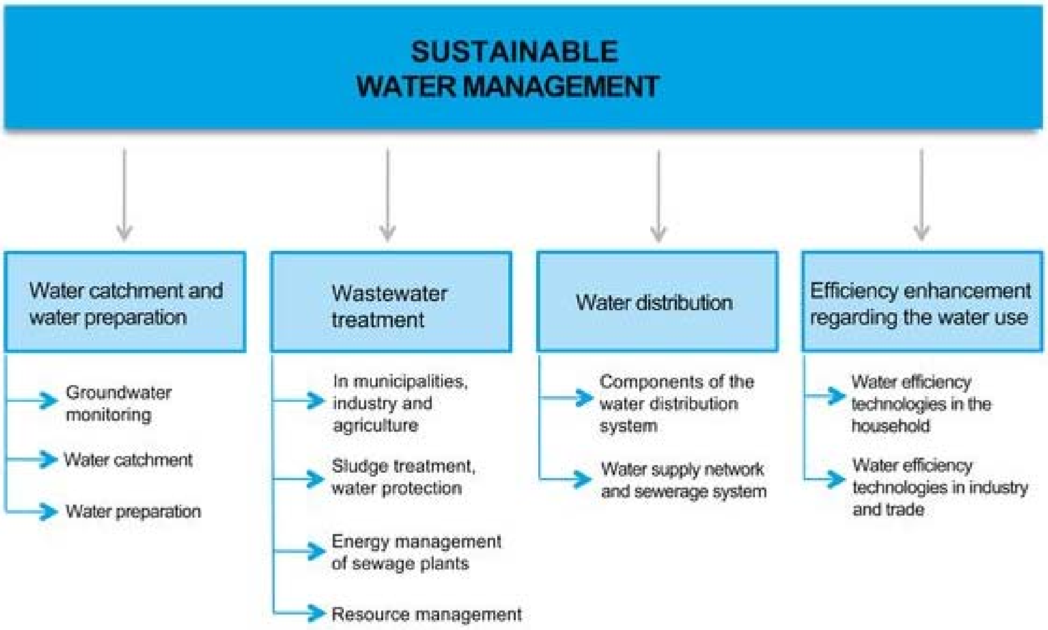

Figure 21. Sustainable Water Management

Source: CIO (2020)

Because water is required for development, sustainable development and sustainable water management are inextricably linked. Water is a fundamental requirement for human life and well-being; therefore, proper water management is a means of improving food production, reducing poverty, and preventing water-related diseases (Russo, Alfredo, & Fisher, 2014).

1.7 Chapter Conclusion

This chapter provides a research background focusing on increasing pressures on global water supply, distribution, and management as a result of rapid global population growth, urbanization, climate change, and human activities affecting water resources. Water demand rises as agricultural, industrial, and domestic sectors compete for it. Access to water resources and the availability of water, both in quantity and quality, on the other hand, has become a source of contention over international or domestic waters. Although technology has been developed to help in water storage and water conservation in order to alleviate water scarcity, there are cost constraints, particularly in developing countries with insufficient funding for water resources. Water resource management is all about managing water variability, and water adaptation are critical to protecting water for economic, social, and ecological growth, as well as for better quality of life.

Water scarcity has become the world's most pressing issue, with more water demand than supply in many regions. The effective governance of available water resources will be critical to achieving water security, fairwater resource allocation, and the resolution of related disputes (WGF, n.d.).

In Chapter 2, I will define the research problems, objectives, scope, and research questions. It also includes a literature review on Thailand's water management and basic information about the Prasae River Sub-basin, which is the focus of my research.

2. Literature Review and the Case Study of the Prasae Reservoir

This chapter describes related literature, research, and overview for a comprehensive understanding of Thailand's water resources management. Water resources management policies, strategies, and interconnection at various levels are described to provide a clear picture of how the plan will be implemented. Thailand has currently established plans on three levels: Level 1 is the National Strategy, which is the goal of the country's sustainable development based on good governance. This will serve as a framework for developing consistent and integrated plans. The National Strategy will be put into action through the systematic transfer of goals and development issues to Level 2 and 3 plans. Level 2 is a guideline for driving the country in various dimensions to achieve the Strategy's goals and transfer it to the Level 3 Plan's action guidelines. It consists of the Master Plan under the National Strategy, the National Reform Plan, the National Economic and Social Development Plan, and Security Plan. Level 3 is a clear, practical plan based on the mission of the government agencies that is consistent and supports the implementation of the Level 1 and Level 2 plans or is prepared as required by law or prepared according to obligations or international conventions (NESDC, 2021). However, this chapter describes only the plans relevant to this research, including the 20-Year National Strategy (2018 - 2037) (Level 1), the Master Plan under the National Strategy with an emphasis on water management issues throughout the system (Level 2), and the 20-Year Master Plan on Water Resource Management (2018-2037) (Level 3).

The case study approach to water resources management of the Prasae Reservoir in Rayong Province was selected to examine the policy-making of effective, sustainable, and equitable water management for all sectors. The background of the research problem, research scope, and research questions are presented in order to achieve the research objectives. It is also necessary to describe the general information of the Prasae River Sub-Basin and the Prasae Reservoir to comprehend the study area's characteristics such as topography, climate, land use, and water management. This information will be used in the analysis and comprehension of the findings from the in-depth stakeholder interviews presented in Chapter 4.

2.1 Background

Thailand, one of the developing countries in Southeast Asia, has increasingly shifted from agriculture to industrial and manufacturing activities (Viwatpanich, 2012). The conflict of water allocation has become a major problem in the agricultural sector among water users such as the public sector, private sector, and government agencies. Although the government and the provinces make efforts to implement the water resources development projects by promoting engineering infrastructures such as dams and reservoirs, it does not result in a sustainable outcome (Winz, Brierley, & Trowsdale, 2008). Large-scale projects usually not only have a limitation on the development process and budget constraints but also take a long time in the construction phase. This approach does not solve the problem of water resources systematically. Moreover, the lack of linkage between central and local water resources development projects makes the operation complicated. The weakness of the coordination and cooperation between both parties is the cause of water management problems that lead to water shortage (Jampanil, Koontanakulvong, & Sakulthai, 2011).

The government has addressed the problem of water shortage by providing water resources and creating water storage for people in all areas such as dams, reservoirs, irrigation systems, and canal dredging but it failed in the results that were caused by water conflicts between water users, lack of modern management techniques, structure, framework, and integrated water management as well as national research directions on long-term water resources management. These led to inefficient water management in Thailand (NRMS, 2016). Increased water demand and water allocation conflicts between water users become a challenge in managing water resources and deciding how much water each region should receive (Kaosa-Ard et al., 2001).

To address the challenges for sustainable water management in Thailand, the government agencies, policymakers, and stakeholders in water resources management are the important keys that will be considered to reduce the water problem efficiently and effectively (The World Bank, 2011). IWRM approach is one of the ways that should be applied to reduce social conflict between water users by promoting the participation of stakeholders in each level of water management and encouraging countries to shift their paradigms to sustainable water resources development (Fulazzaky, 2014).

2.2 The Current Water Resources Management in Thailand

Thailand is located in the southeastern region of Asia with an area of 531,120 square kilometers. It is bordered in the north and northwest by Myanmar, in the northeast by Laos, in the east by Cambodia, and in the south by Malaysia. Thailand's water bodies include the Mekong River in the east, which forms the country's natural border with Laos, the Gulf of Thailand in the southeast, and the Indian Ocean and the Andaman Sea in the southwest (Figure 22). Thailand has a tropical climate influenced by seasonal monsoons. The southwest monsoon transports warm moist air from the Indian Ocean, resulting in heavy rain (mid-May to mid-October). While the northeast monsoon brings cool dry air from the Chinese mainland (mid-October to mid-February). Summer is the pre-monsoon season (mid-February to mid-May) (FAO, 2011). The average annual rainfall across the country is 1,455 millimeters, ranging from 900 to 4,000 millimeters per year depending on location. This is regarded as a plentiful supply of rainwater (ONWR, 2019). The majority of Thailand's water demand is for domestic use, agriculture, and industry. In 2014, the Department of Water Resources (DWR) classified water demand into four categories: (Franzetti, Pezzoli, & Bagliani, 2017)

1. Water use in agriculture is the group with the highest demand for water, accounting for more than 80% of the country's water use. Irrigated areas are allocated 65 billion cubic meters of water, while non-irrigated agricultural areas will be rain-fed. Some areas use groundwater to support agriculture during the dry season.

2. The demand for water for consumption is 6,490 million cubic meters and is expected to increase to 8,260 million cubic meters by 2027.

3. The industrial sector's water demand is approximately 4,020 million cubic meters, with a projected increase to 7,515 million cubic meters by 2027. This has an impact on many industrial estates in Bangkok and the eastern part of the country.

4. More than 27,090 million cubic meters of water should be required to sustain ecosystems during the dry season.

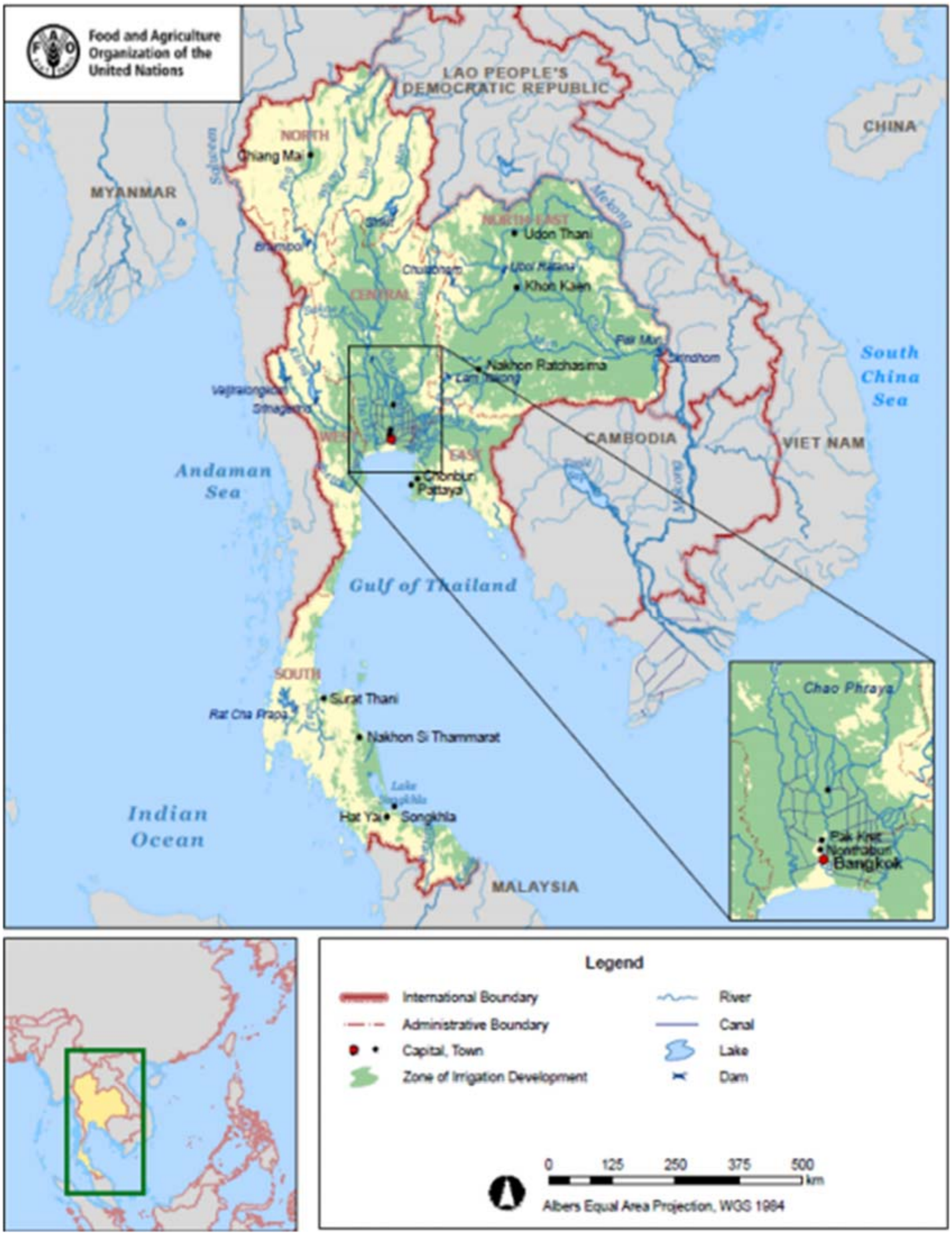

Figure 22. Topographic Map of Thailand

Source: FAO (2011)

Water demand has increased due to rapid economic and social growth. The impacts of climate change put pressure on the use of national water resources. Thailand is experiencing not only droughts but multiple floods that damage lives, property, and the country's economy. In addition, water resource degradation and saltwater encroachment have created growing concerns about water quality. The problem of water resources has become a challenge in water management, affecting the security of economic, social, and quality of life (ONWR, 2019). The government has always prioritized water management, allocating large budgets to solve the problem and provide additional water sources, but it has not been able to solve the problem in a sustainable manner (ONWR, 2020). The lack of clear policies and the lack of coordination between organizations are two of the primary reasons for Thailand's water management ineffectiveness. Many agencies administer and manage water resources, each with its own set of priorities and programs that sometimes overlap or conflict (Sethaputra, Thanopanuwat, Kumpa, & Pattanee, 2001).

On 25 July 2000, the Nation's Water Vision was announced that "By 2025, Thailand will achieve sufficiently good water quality through effective management, organization, and legal systems to create equality and sustainability for the use of water resources, with awareness of people's quality of life and participation at all levels" (TNMCS, 2009). The National Water Resources Committee (NWRC) was established to drive a unified and integrated water resource management strategy at all levels, chaired by the Prime Minister (Figure 23) (TNMCS, 2009).

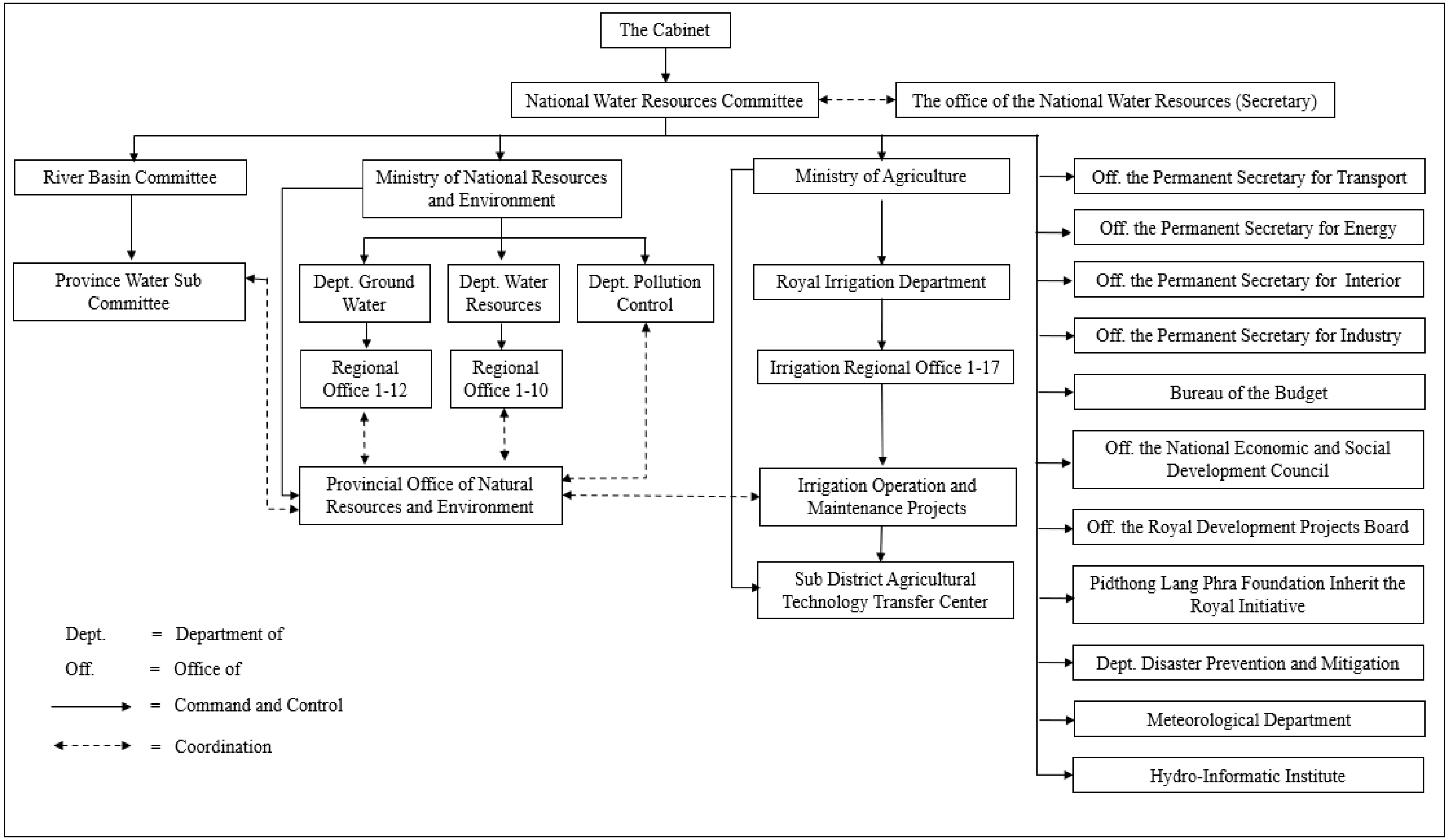

Figure 23. Structure of National Water Resources Committee

Source: Updated from TNMCS (2009) & ONWR (2021)

To achieve the integration of information technology, plans, projects, budgets, and monitoring and evaluation of water management, the Office of National Water Resources (ONWR) was established by the order of the National Council for Peace and Order on 25 October 2017 (ONWR, 2020). Then, the 12-Year Water Resources Management Strategic Plan (2015-2026) was drawn up to effectively manage the country's water resources, but it failed to meet the 20-year national strategy due to the changes in the economy, society, and environment. As a result, it was revised into the 20-Year Master Plan on Water Resources Management (2018-2037) to serve as a framework and guideline for the development of efficient and systematic water management with the aim of ensuring the country's water resource security (ONWR, 2019).

2.3 Thailand's Water Management Policies and Strategies

2.3.1 The 20-Year National Strategy (2018 - 2037)

The 20-Year National Strategy (2018-2037) focuses on maximizing the country's potential in order to achieve the vision of becoming “a developed country with security, prosperity, and sustainability in accordance with the Sufficiency Economy Philosophy,” with the ultimate goal of ensuring the well-being of all Thai. It consists of six strategies as follows: (NESDC, 2019)

1. The National Strategy for Security
2. The National Strategy for Competitiveness Enhancement
3. The National Strategy for Human Capital Development and Strengthening
4. The National Strategy for Social Cohesion and Equity
5. The National Strategy for Eco-Friendly Development and Growth

6. The National Strategy for Rebalancing and Development of the Public Sector

The water resources development of Thailand is linked to Strategy 5. It emphasizes the development of the entire water management system to ensure the country's water security and increase water use productivity across all sectors. Building sustainable development on green growth is promoted by taking into account the conservation and restoration of rivers, canals, and natural water resources (NESDC, 2019). Then, the Master Plan is created as part of the National Strategy, in which water resources are included in the issue of water management throughout the system. It focuses on setting goals and guidelines for the development of efficient and sustainable water management and water use systems. The development approach is divided into three sub-plans as follows: (NESDC, 2019)

1. Developing systematic watershed management by enhancing water security in order to achieve a balance in terms of supply, use, and conservation. It plans to improve the rural water systems, conserve natural water resources, manage water in crisis, and establish effective water management governance.

2. Increasing the overall productivity of the water system in order to use water more efficiently and create added value from water use in order to meet international standards. Modern technologies are used to design integrated water systems and database systems for planning, monitoring, and evaluating. Water reuse and water use restructuring are encouraged and supported in order to increase water use productivity tenfold.

3. Conservation and restoration of rivers, canals, and natural water resources throughout the country by recognizing the importance of surveying and registration of

natural water boundaries, public participation, and creating design requirements for engineering and landscape architecture.

2.3.2 The 20-Year Master Plan on Water Resource Management (2018-2037)

In 2019, the 20-Year Master Plan on Water Management was adopted as a framework and guideline for driving the integration of efficient and sustainable water management in accordance with the national development strategy (Figure 24). It has clearly defined indicators, target areas, and responsible departments to achieve the goal of "every village having clean water for consumption, water for secure production, reducing flood damage, standard water quality, and sustainable water management under balanced development with participation from all sectors". The master plan comprises six strategies as follows: (ONWR, 2019)

Figure 24. Linkage of Water Security Strategy in Thailand Master Plans

Source: Ruangrassamee & Koontanakulvong (2019)

1. Water management for consumption: The goal is to provide safe drinking water to all villages or households, urban communities, tourist attractions, and special economic zones. Providing alternative water sources in water-stressed areas, developing standards-compliant drinking water at reasonable prices, and conserving water by reducing water consumption in households, service sectors, and government sectors.

2. Building water security in the production sector: This is accomplished by fully developing and improving water reservoirs and water delivery systems, as well as finding water supply in rainfed agricultural areas. It also includes improving the structure of water use to boost competitiveness, opportunities, and social equality.

3. Flood management: The purpose of this strategy is to improve drainage efficiency by organizing community flood prevention systems, managing flood areas and flood holding areas, and reducing problems of water obstacles, as well as systematic flood mitigation at both large and tributary river basins, including critical areas.

4. Water quality management and water resource conservation: The goal of this strategy is to develop the community's wastewater treatment system to reuse wastewater, prevent and reduce wastewater at the source, rehabilitate rivers, as well as regulate the volume of water flowing to maintain the ecosystem.

5. Conservation and rehabilitation of degraded watershed forests and soil erosion prevention: This focuses on the rehabilitation of degraded areas in watershed forests and prevention and reduction of soil erosion in upstream and steep land areas.

6. Management: It aims to drive water management organizations along with the improvement of laws and the development of decision-making databases, as well as public

relations plans to increase awareness of water resource conservation and the participation of people and stakeholders in water management.

2.3.3 Water Resources Act B.E. 2561 (2018)

Historically, there have been numerous agencies tasked with managing and resolving water resource issues, each with its own set of legal responsibilities and powers. The Royal Irrigation Department (RID) is responsible for authorizing the use of water for irrigation. The Department of Groundwater Resources (DGR) has the authority to authorize groundwater drilling and use. However, no laws assign responsibility or authority to any agency to allow the use of general surface water outside of the irrigation area. As a result, there is a lack of unity and integration in systematic solutions to water resources, which affects national water security (ONWR, 2019). The National Water Act, B.E. 2561 (2018), was enacted on January 27, 2019, to achieve integrated water resource management, effective database systems among government agencies, and to reduce budget redundancy and water-related action plans. It is Thailand's first water resource law and it consists of nine major chapters: (ONWR, 2020)

1. Management, maintenance, restoration, and conservation of water resources for the benefit of the public in a balanced and sustainable manner.

2. Establishing basic rules for accessing public water resources for all by defining water rights.

3. Establishment of water resource management organizations at the national level, river level, and water user organization level to reflect people's participation.

4. Criteria for water allocation and water use can be divided into three types: 1) the use of public water resources for subsistence, household activities, ecosystem preservation, disaster mitigation, transportation, and small-quantity water use; 2) the use of public water resources for industry, electric power generation, water supply, and other purposes; and 3) the use of public water resources for large enterprises that use large amounts of water or may cause cross-basin impacts.

5. Defining plans for preventing and resolving drought and flooding problems.

6. Determination of conservation, development of public water resources, and land use that may affect public water resources.

7. Determine the duties and powers of competent officials to implement this law.

8. Determination of a civil offense in the event that any person causes damage to a public water source.

9. The setting of penalties includes imprisonment, fines, or both.

2.4 Research Problem

Rayong Province is located in the Eastern part of Thailand, which has a total area of 3,722 square kilometers. The land is used for agriculture, forest, industrial and residential purposes. Approximately 67% of the total area is occupied by agriculture while others are the important industrial zone of the power plant, petrochemical industry, chemicals, fertilizer manufacturing, and households (Jampanil, Suttinon, Seigo, & Koontanakulvong, 2012). Koontanakulvong et al. (2008) stated that Rayong Province utilizes water from two main river basins. One is from the Khlong Yai Sub-basin which consists of three reservoirs: Nong Pla Lai, Khlong Yai, and Dok Krai Reservoirs. The second one is the Prasae River Sub-basin which consists of two reservoirs: Prasae and Khlong Ra Okk Reservoirs (Figure 25).

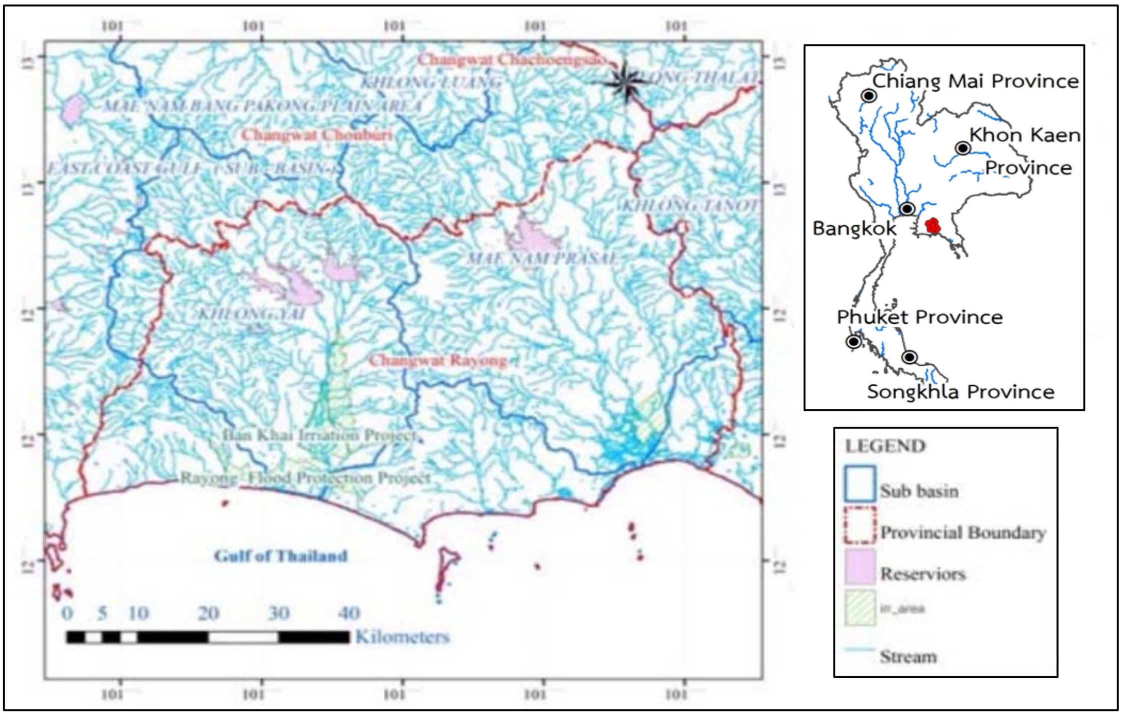

Figure 25. The Geography of Rayong Province

Source: Adapted from Jampanil, Suttinon, Seigo, & Koontanakulvong (2012) & LDD (2007)

In 1982, Rayong was placed as one of the Eastern Seaboard Development Areas or Eastern Seaboard Project to spread prosperity to the region by promoting and supporting industrial activities (Sakpibulrat, 2018). It led to rapid industrial expansion and most people from other provinces moved into Rayong Province to get jobs. This has resulted in rapid population growth and increasing water demand in all sectors (Jindarattanawong, 2011).

In 1992, the government established Eastern Water Resources Development and Management Public Company Limited or East Water, which is responsible for water management in the eastern region (CU, 2010). Water management by East Water is primarily for consumption and industrialization and covers three provinces: Chachoengsao, Chonburi, and Rayong. The company is aware of the importance of water resources that can affect the country's economy. It has implemented its short-term and long-term plans to develop water sources and created security to prevent water shortages in the area for which it is responsible (East Water, 2015).

In 2005, the East Coast Gulf faced extreme water shortages, especially in Rayong Province, which is a significant industrial and agricultural zone and which has contributed substantially to the country's economy (CU, 2010). Changes in precipitation frequency coupled with the expansion of the industry caused the water level in the Rayong reservoir to drop near or below water intake structures. RID constructed a large water pipeline by connecting it from the Prasae Reservoir. This was intended primarily for the allocation of water to the residents and farmers in the Prasae River Sub-basin and for converting water to alleviate water shortages in the agricultural and other sectors. However, this project led to conflicts between agricultural and industrial sectors and which sectors should be first supported by the government. The former is the main source of income for the people in the province, and the latter is the source of income for those in the country (Thejui, 2007). In addition, Sakpibulrat (2018) stated that the 2005 drought crisis illustrated the failure of water management in Rayong Province due to the lack of accurate information on the amount of water stored in the reservoir and the lack of an effective warning system. As a result, the allocation of water to various sectors and the forecast of water uses in the eastern region, especially the Rayong and Chonburi Provinces have been mistaken. The public is not confident in the operation of the government and industry which leads to conflicts in water use.

Currently, the government promotes the Eastern Economic Corridor (EEC), which is a project under the Cabinet of Prime Minister Prayuth Chan-o-cha to propel Thailand into an ASEAN major economic zone. This project covers three provinces that consist of Chachoengsao, Chonburi, and Rayong. The expansion of the industry under the EEC will result in a rapid increase in the demand for water in the short term in line with the expansion of production capacity (Aksornkit, 2018). At present, the demand for water in the eastern region is 739 million cubic meters. It is estimated that when developing the EEC project, water demand will rise to 1,210 million cubic meters. The government needs to formulate a strategy to provide additional water resources to meet future needs (Greennews, 2018).

To achieve the goals of efficiency, sustainability, and equity in water management, water users and other organizations should be involved in all levels of water management that consist of planning, development, implementation, and monitoring. Consequently, the participation of all sectors is an important key to solving water problems efficiently to achieve sustainable water resources management (Earle & Malzbender, 2006).

2.5 Research Scope and Delimitation

This research aims to examine how to manage the available water and excess water of the Prasae Reservoir in order to allocate water efficiently, maximize the benefits to society, and thereby, create fairness between water users, which will aim at achieving sustainable management of water resources. The existing water resources management practices and guidelines will be analyzed and assessed the possibilities of implementing new strategies in water resource management. The EEC will be analyzed to assess the feasibility of capacity enhancement and water management guidelines in the Prasae Reservoir to support the increased water demand. Appropriate technology will be considered in water management to increase the capacity and efficiency of water management. The participation of interested persons relevant to water resource consumption is emphasized to create an understanding between the government and the public in sustainable water management. As the water conflict situation in many areas of Thailand at least the results of this research will be applied based on the area situation.

2.6 Research Objective

The purpose of this study is to examine an in-depth study of water resources management drawing on the case of the Prasae Reservoir in Rayong Province. It focuses on the existing water resources management practices and guidelines, evaluates the current water resource management policies, promotes the public participation process, and evolves a technical solution in order to sustainable water resources management. The objectives of this research are:

1. To study and analyze existing water management policies and plans to provide recommendations for the improvement and development of sustainable water management systems in the Prasae Reservoir, Rayong Province.

2. To analyze and assess the possibilities of implementing new strategies in water resources management to reduce conflicts between water users.

3. To provide appropriate technology that can be applied in water management to increase the capacity and efficiency of water management in the Rayong area to meet the increasing water demand in agriculture, industry, and community.

4. To study the participation of local people and government agencies in water management in the Prasae Reservoir, Rayong Province.

2.7 Research Question

Three main research questions are guiding this study and they are:

1. What is the optimal, just, and sustainable method for managing available and excess water of the Prasae Reservoir, considering balancing the needs to allocate water efficiently, maximize the benefits to society, and, thereby, create fairness between water users?

2. How can appropriate technologies increase the capacity and efficiency of water management in the Rayong area?

3. How does public participation affect the sustainable water management of the Prasae Reservoir? Are most stakeholders able to accept that excess water will be diverted to other areas, depending on the situation and season?

2.8 Research Hypotheses

This research will be analyzed based on the assumption that

1. Appropriate technology can increase the capacity and efficiency of water management in the Rayong area.

2. Public participation affects the sustainable water management of the Prasae Reservoir. Most stakeholders can accept the excess water that will be diverted to other areas, depending on the situation and season.

2.9 General Information of the Prasae River Sub-Basin/Prasae Reservoir

2.9.1 Topography

According to the River Basins Decree B.E. 2564, the river basins in Thailand are separated into 22 main basins. The Prasae River Sub-basin is a part of the East Coast Gulf Basin located in Rayong Province (ONWR, 2021). The Prasae River Sub-basin has origin from the Chanthaburi Mountain Range. Its length is about 120 km. flows through sub-districts in Klaeng District, Rayong Province to the Gulf of Thailand at Pak Nam Prasae Sub-district. The Prasae River Sub-basin has important tributaries such as Khlong Plo, Khlong Ra Okk, and Khlong Saphan (East Water, 2018). The Sub-basin covers some parts of the two provinces as shown in Table 1 and Figure 26.

Table 1. The Characteristics of the Prasae River Sub-Basin

Sub-basin	Area (km^2)	Percentage in the main basin	Coverage Area	
			Province	District
Prasae River	2,143.5	16.33	Chonburi	Nong Yai, Bo Thong
			Rayong	Muaeng Rayong, Klaeng, Wang Chan, Ban Khai, Plouek Daeng, Khao Chamao

Source: ONWR (2020)

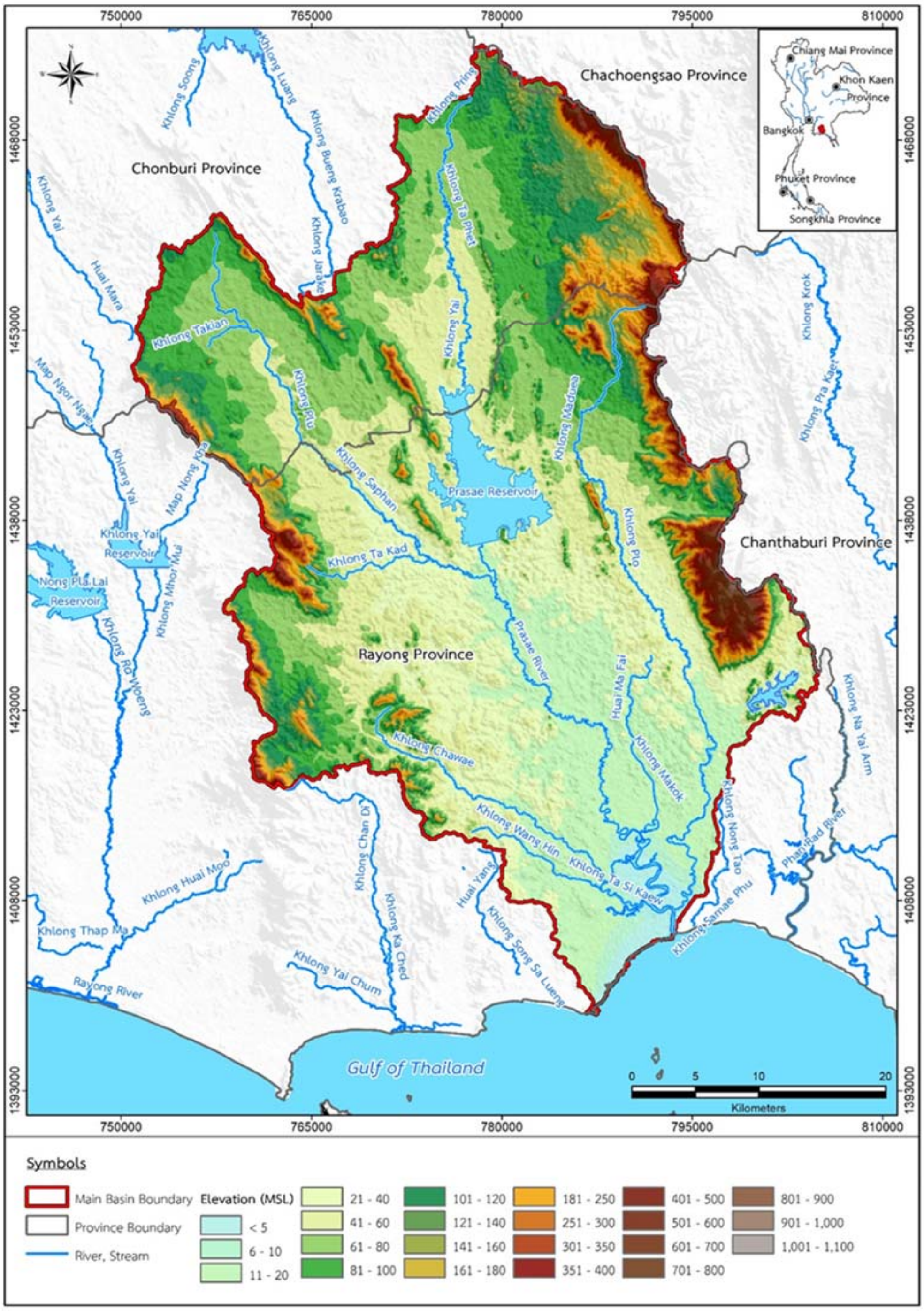

Figure 26. The Prasae River Sub-Basin Topography

Source: LDD (2007)

The Prasae River Sub-basin has an elevation of the area from 1,030 MSL to sea level and comprises three characteristics: (Julnimi, 2015)

1. Mountain and hilly areas with a slope of 20% or more. Most of them are mountain ranges on the eastern edge, oriented north to central, relatively south of the sub-basin area. Followed by a mountain range on the western edge, oriented north to central. The solitary mountain is in the northern relatively central of the sub-basin. The highest point is 1,030 meters above sea level at the Khao Chamao area, bordering Rayong and Chanthaburi Provinces.

2. Highland area has a slope from 5-20%, spreading in the north to the central, relatively south of the sub-basin.

3. Plain and lowland areas have slopes from 0-5% located downstream as flat area.

The Prasae River Sub-basin comprises various ecosystems. It has a freshwater ecosystem in the main river, a brackish water ecosystem in the lower area of the river, and a sea ecosystem in the river mouth area. The water quality of the Prasae River Sub-basin met the water standards audited by the Pollution Control Department. Water quality is tended to affect resources integrity and biodiversity in the Prasae River Sub-basin (DMCR, n.d.). DGR has studied potential groundwater in the country. Data is interpreted and presented in the GIS database for technical review and preliminary guide potential areas to be investigated in the field and drilled later (Buarapha, 2020). The geohydrology map scale of 1:100,000 in the Prasae River Sub-basin is shown in Figure 27.

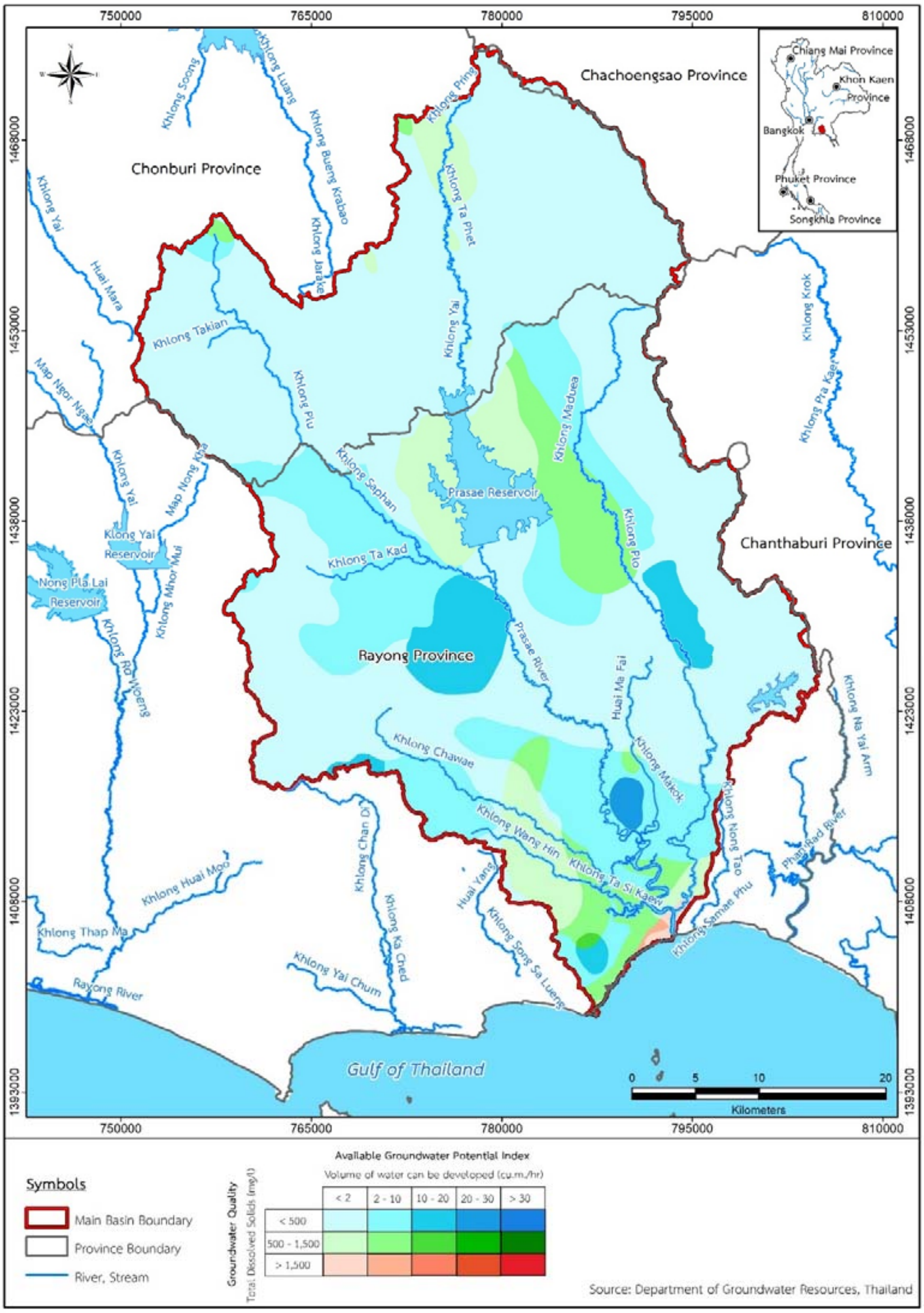

Figure 27. Potential Groundwater in the Prasae River Sub-Basin

Source: DGR (2017

The map presents the relation between total dissolved solids (TDS in ppm) and potential groundwater development (cu.m./hr.). Suitable water quality to be developed for domestic use should be lower than 500 ppm as presented in blue tone in the Figure. The area with TDS < 500 ppm in the Prasae River Sub-basin is about 1,811.10 km^2, TDS 500 – 1,500 ppm is 321.29 km^2, TDS > 1,500 ppm is 10.76 km^2, and no data 0.35 km^2. Therefore, the potential groundwater to be developed with good water quality is about 1,811.10 km^2 or 85% of the Sub-basin area.

2.9.2 Climate and Runoff

The Prasae River Sub-basin locates in a tropical climate with three seasons. The summer season (mid-February to mid-May) has the East and the South wind causing sweltering heat and sometimes has summer storms. The rainy season (mid-May to mid-October) is influenced by the Southwest Monsoon with low pressure through the Central and the Eastern Region of Thailand causing thunderstorms and heavy rainfall in some areas. The Winter season (mid-October to mid-February) is influenced by the Northeast Monsoon during mid-October to February with a high-pressure trough causing clear sky, cool weather, and morning fog. The highest monthly rainfall is in September and the lowest monthly rainfall is in December. The average annual rainfall of the Prasae River Sub-basin is 2,429.2 mm. higher than Thailand’s average annual rainfall in 30 years (1981 – 2010) which is 1,467 mm. (HII, 2019). Wet season rainfall is 87% of annual rainfall, while the dry season is only 13%. Monthly rainfall in the Prasae River Sub-basin is shown in Table 2 (ONWR, 2020).

Table 2. Average Monthly Rainfall

Average Monthly Rainfall in 30 years (mm.)												Annual Rainfall (mm.)	Wet Season (May-Oct)	Dry Season (Nov-Apr)
Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar			
111.4	304.3	366.2	376.5	360.3	438.9	277.0	59.5	9.5	25.3	32.6	67.7	2,429.2	2,123.2	305.9

Source: ONWR (2020)

Based on the ONWR study in 2020, the average annual runoff in 30 years (1988–2017) is 881.3 million cubic meters, October has the highest average runoff 231.3 million cubic meters, and the lowest monthly runoff is in January 12.6 million cubic meters. The percentage of runoff in the wet season is about 87, therefore, reservoir management is important to reduce flood downstream and store potential water for utilization in the dry season. Monthly runoff in the Prasae River Sub-basin is shown in Table 3 (ONWR, 2020).

Table 3. Average Monthly Runoff

Average Monthly Runoff in 30 years (MCM)												Annual Runoff (MCM)	Wet Season (May-Oct)	Dry Season (Nov-Apr)
Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar			
15.9	45.5	74.3	90.1	103.0	205.6	231.3	58.3	17.9	12.6	12.8	14.0	881.3	749.9	131.5

Source: ONWR (2020)

2.9.3 Land Use

Land use in the Prasae River Sub-basin can be categorized into 5 types such as agriculture, water resources, residence and buildings, forest, and others. The largest land use in 2010 is agriculture about 1,666.19 km^2 followed by forest 313.36 km^2, water resources 65.11 km^2, residence and buildings 64.97 km^2, and others 33.87 km^2 respectively. In 2020, the agricultural area is decreased 48.09 km^2 and the forest area 13.86 km^2. Residence and buildings area is increased 38.12 km^2 with a high percentage of urban in the Sub-basin. Water resources area is also increased significantly in 11 years about 18.41 km^2 as 28.3%. Others are increased by 5.42 km^2. The summary of land use changes is presented in Table 4 (LDD, 2011-2021). Following these data are not presented water utilization related to land use changed explicitly. Therefore, the agricultural area as the main water utilization in the Sub-basin is presented in more detail to compare main crops between 2010 and 2020 in Table 5 (LDD, 2011-2021).

Table 4. Summary of Land – Use Change in the Prasae River Sub-Basin

No.	Land Use Type	Land Use		Land Use Changed between 2010 - 2020	
		2010	2020		
		(km^2)	(km^2)	(km^2)	Percentage of change per year
1	Agriculture	1,666.19	1,618.10	- 48.09	-0.26
2	Water Resources	65.11	83.52	18.41	2.57
3	Residence and buildings	64.97	103.09	38.12	5.33
4	Forest	313.36	299.50	- 13.86	-0.40
5	Others	33.87	39.29	5.42	1.45
Total		**2,143.50**	**2,143.50**		

Source: LDD (2011-2021)

According to Table 5, it is presented that total area of agriculture is decreased from 2010 to 2020, paddy field is decreased about 55% also orchards area 61% in 11 years. While durian cultivated area is increased significantly 113% which affected to water consumption, especially in the dry season.

Table 5. Details of Land Use Changed in the Prasae River Sub-Basin

Land Use Type	Land Use		Land Use Changed between 2010 - 2020	
	2010	2020		
	(km^2)	(km^2)	(km^2)	Percentage of change per year
Agriculture	**1,666.19**	**1,618.10**	**- 48.09**	**-0.26**
- Pastures and Sheds	5.90	5.79	- 0.11	-0.17
- Paddy field	45.94	20.76	- 25.18	-4.98
- Oil palm	108.97	148.00	39.03	3.26
- Durian	44.79	95.38	50.59	10.27
- Orchards	185.46	72.47	- 112.99	-5.54
- Parennial	1,061.29	1,088.79	27.51	0.24
- Upland crops	179.56	150.21	- 29.34	-1.49
- Aquatic plants	-	0.04	0.04	0.00
- Horticulture	0.37	0.59	0.22	5.41
- Aquaculture	33.88	36.05	2.17	0.58
Forest	**313.36**	**299.50**	**- 13.86**	**-0.40**
Others	**33.87**	**39.29**	**5.42**	**1.45**
Residence and buildings	**64.97**	**103.09**	**38.12**	**5.33**
Water Resources	**65.11**	**83.52**	**18.41**	**2.57**
Total	**2,143.50**	**2,143.50**		

Source: LDD (2011-2021)

2.9.4 Water Resources Management

The Prasae River Sub-basin is a part of the East Coast Gulf Basin. Water resources management could not consider only the Prasae due to linkage diversion piping system and diversion system among the Prasae and vicinity Sub-basins. The Prasae River Sub-basin has water utilization mainly for irrigation and domestic use while industrial water is a small portion in the area (Updated from East Water, 2018). The Prasae Reservoir installed a hydraulic weir at the spillway which increased storage capacity from 248 million cubic meters to 295 million cubic meters. It has remaining potential water in the Prasae Reservoir diverse to vicinity Sub-basins or receives diversion water from another Sub-basin as the water hub. At present, there are two diversion piping systems from the Prasae Reservoir comprising the Prasae Reservoir – the Khlong Yai Reservoir pipeline managed by RID and the Prasae Reservoir – the Nong Pla Lai Reservoir pipeline managed by East Water. Another diversion system is from the Wang Tanod Sub-basin in Chanthaburi Province through the natural stream to the Prasae Reservoir which operates mostly in the driest year (East Water, 2018).

In 2020, the severe dry season happened in Rayong and Chonburi Provinces, rainfall in the Prasae River Sub-basin was lower than the average. Irrigation water requirement was more than a normal year then the water level in the Prasae Reservoir was near the dead storage. Then water was diverted from the Wang Tanod Sub-basin to the Prasae Reservoir to reduce the water shortage situation (Naewna, 2020). In addition, to increase water storage in the Prasae Reservoir during the 2020 dry season, a temporary pumping station was constructed to pump water from Khlong Saphan, one of the Prasae River tributaries back to the reservoir. At downstream of Khlong Saphan on present-day, RID constructed a pumping station to pump water through pipeline back to the Reservoir. The pumping station is operated in 2021. In the future, RID has a plan to construct the Prasae Reservoir – the Nong Kho Reservoir – the Bang Phra Reservoir diversion project that will be served water demand growth in EEC (Katchwattana, 2020).

The Khlong Yai Sub-basin is close to the Prasae River Sub-basin, which is an important industrial area in Rayong Province. There are three important reservoirs located in the Khlong Yai Sub-basin namely the Khlong Yai Reservoir, the Nong Pla Lai Reservoir, and the Dok Krai Reservoir as the main water sources. RID had constructed a linkage system among three reservoirs by diversion pipe and diversion channel. Water can be diverted from the Dok Krai Reservoir and the Khlong Yai Reservoir to the Nong Pla Lai Reservoir by gravity. Water utilization in the area is for domestic use by tap water pipe, industrial area (especially Map Ta Put Industrial Estate), Ban Khai Irrigation Project, and Ban Khai Extension Project. The remaining water from the Khlong Yai Sub-basin can be diverted from the Nong Pla Lai Reservoir for water utilization in Chonburi Province (Updated from East Water, 2018).

The Chonburi Sub-basin is one of the important economic activity areas in Thailand. It is the location of the city and famous attractive tourism areas such as Chonburi City, Pattaya, Bang Saen, Sriracha, Laem Chabang International Port, and many of industry factories located in this area. Two main water sources are the Bang Phra Reservoir and the Nong Kho Reservoir. These two reservoirs are mainly used for domestic and industrial areas. There are also other small reservoirs in the Sub-basin such as Map Prachan, Huai Saphan, Nong Klang Dong, Huai Khun Jit, Huai Sak Nok, which are used primarily for domestic. Due to urbanization and development area in the upstream affected to decrease inflow to the Bang Phra Reservoir and others. The existing water use activities are over water supply capacity in the Sub-basin. Many diversion projects were developed to supply water from vicinity sub-basins. The existing projects are comprising pipeline network system among the Nong Pla Lai Reservoir – the Nong Kho Reservoir – Laem Chabang, Water Pipeline from the Bangpakong River to the Bang Phra Reservoir, Water Pipeline from Phra-Ong Chaiyanuchit Canal to the Bang Phra Reservoir to increase water supply capacity that meets water demand in the area (Updated from East Water, 2018).

For an overview of existing water sources, important reservoirs in the Prasae River Sub-basin and vicinity sub-basins are summarized in Table 6 and the location of reservoirs and pipeline network system is presented in Figure 28.

Table 6. Existing Reservoirs in the Prasae River Sub-Basin and Vicinity Sub-Basins

No.	Reservoir	Province	Sub-basin	Catchment Area (km^2)	Reservoir Capacity (MCM)	Annual Inflow (MCM)
1	Prasae	Rayong	Prasae	603.00	295.00	274.95
2	Ra Okk	Rayong	Prasae	41.00	19.00	35.49
3	Dok Krai	Rayong	Khlong Yai	291.00	71.40	160.80
4	Nong Plalai	Rayong	Khlong Yai	408.00	163.75	209.52
5	Khlong Yai	Rayong	Khlong Yai	218.00	40.10	56.00
6	Bang Phra	Chonburi	Chonburi	130.00	117.00	42.99
7	Nong Kho	Chonburi	Chonburi	51.00	21.10	19.99
8	Mab Prachan	Chonburi	Chonburi	37.00	15.60	14.54
9	Huai Saphan	Chonburi	Chonburi	14.00	3.84	5.61
10	Nong Klang Dong	Chonburi	Chonburi	18.50	7.90	6.45
11	Huai Khun Jit	Chonburi	Chonburi	11.00	4.87	3.68
12	Huai Sak Nok	Chonburi	Chonburi	17.60	7.03	3.85

Source: Updated from East Water (2018)

Remark: Annual inflow data is average inflow 1978 – 2007

The Prasae Operation and Maintenance Project (the Prasae Irrigation Project) covers a total irrigation area of 28,000 ha (Figure 29). The project comprises three parts as follows: (The Prasae Operation and Maintenance Project, 2020)

1. Right irrigation system is allocated water by pumping high pressure through pipeline 25.824 km, irrigation area 13,280 ha.

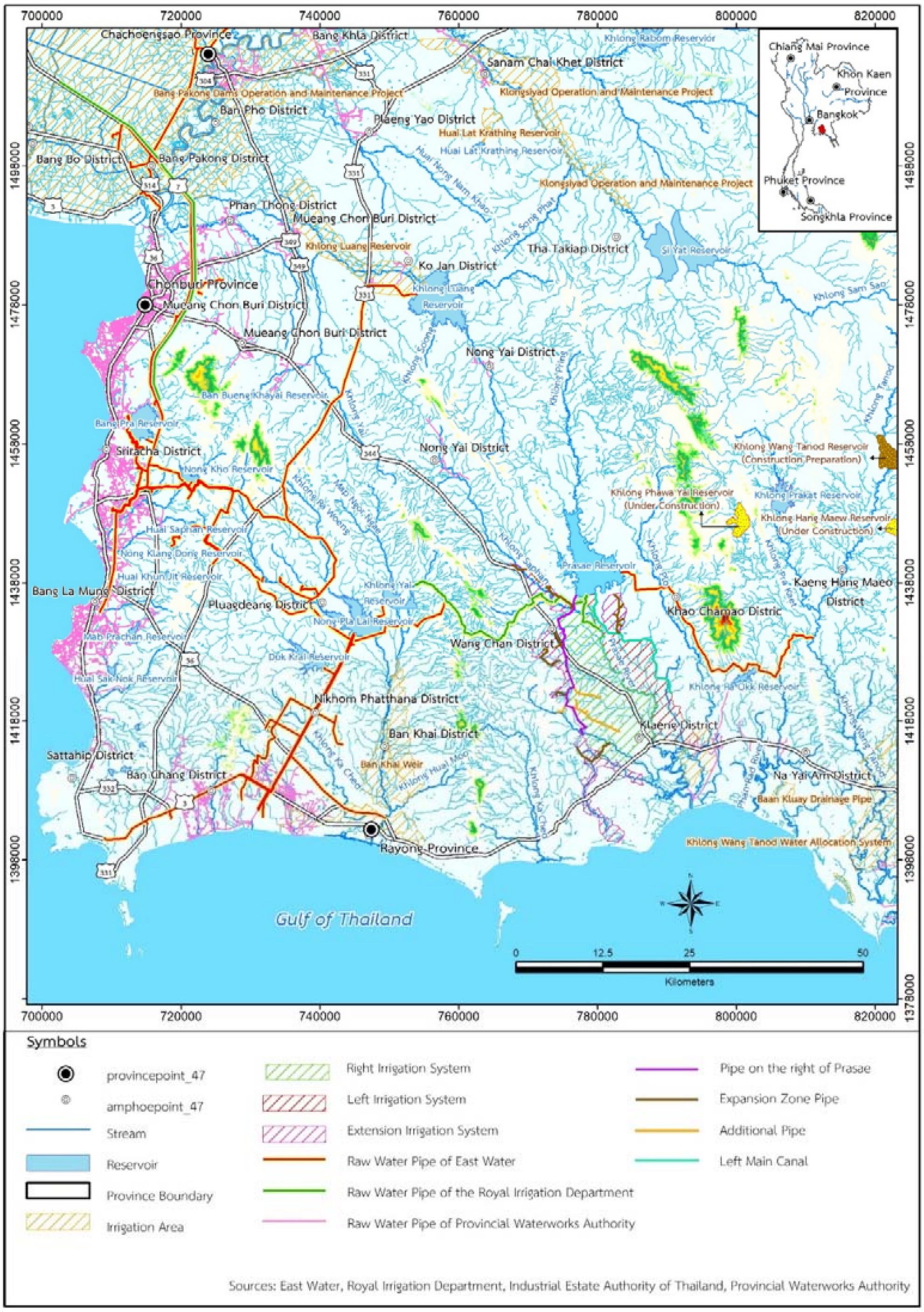

Figure 28. Location of Reservoirs and Pipeline Network System

Source: The Prasae Operation and Maintenance Project (2020)

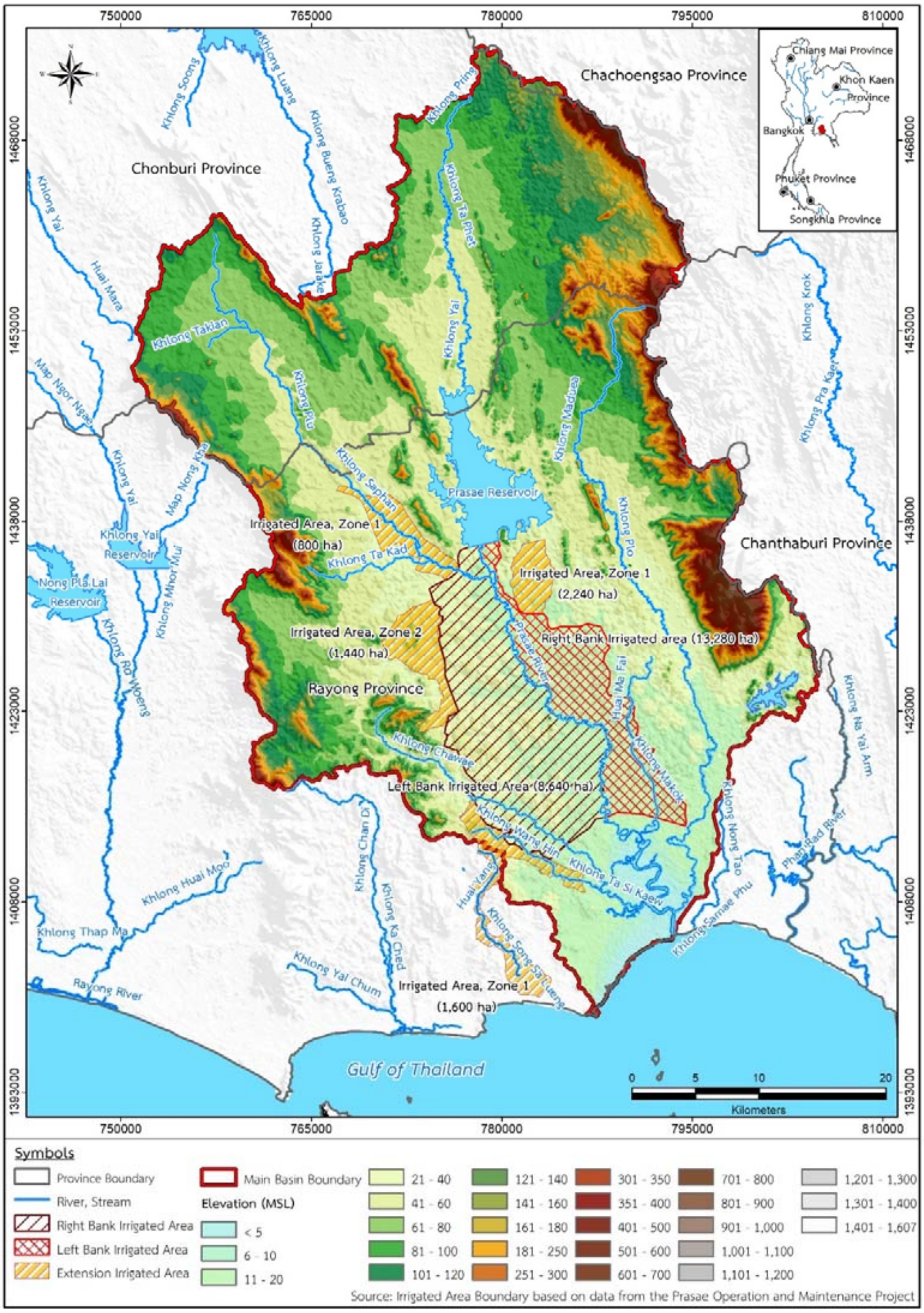

Figure 29. Irrigated Area of the Prasae Operation and Maintenance Project

Source: The Prasae Operation and Maintenance Project (2020)

2. Left irrigation system is allocated water through canal 23.723 km, irrigation area 8,640 ha.

3. Extension irrigation system comprises 4 zones and 5 pumping stations which allocate water through pipeline 40 km, irrigation area of 6,080 ha.

2.9.5 Water Resources Management Organization

Water Resources Act B.E. 2561 (2018) was published in Government Gazette on 28 December 2018 then came into force after 30 days from the date of its publication (ONWR, 2019). In February 2021, the River Basins Decree B.E. 2564 (2021) was published, 22 main basins were identified which were adjusted from the previous 25 main basins. The previous 25 River Basin Committees (RBCs) were established under the Regulations of the Prime Minister’s Office for Water Resources Management B.E. 2550 (2007) with a term of four years each. 25 RBCs finished their term but had been continued working following exemption from Water Resources Act. The new 22 RBCs were selected and are in the process of establishment in September 2021 then will replace previous RBCs. RBC members have a term of three years which could not be continued for more than two periods (ONWR, 2021).

1. Member by position such as governor of the province in the basin and representative from relevant agencies.

2. Member from Local Administrative Organization, each province in the basin has one representative.

3. Member from Water Use Group Organization (WUGO) in the basin, three persons from each sector (agricultural, industrial, and commercial). These members

directly link to Joint Management Committee for Irrigation (JMC) of the Prasae Irrigation Project.

4. Four people with knowledge and experience in water resources.

At the National level, representatives from RBCs six people selected from WUGOs, Local Administrative Organizations, and knowledgeable people members will be members of NWRC. The Prime Minister acts as the Chairman of NWRC and the Secretary-General of ONWR is the secretary of NWRC. NWRC has the authority to appoint Sub-committee at least Water Resources Development and Conservation Sub-Committee, Water Resources Management Sub-committee, and Technical and Academic Sub-committee. Provincial Sub-committee also could be authorized for integrated water resources management at the provincial level (ONWR, 2020). The relation of water resources management organizations from the national to project level is presented in Figure 30

Section 38 and 39 of the Water Resources Act are promoted to register “Water Use Group Organization” with objectives for utilization, development, management, maintenance, rehabilitation, and conservation of water resources (ONWR, 2020). ONWR has been opened to register WUGO since 1 April 2021. Updated data on 25 August 2021 is presented that WUGOs was approved 2,771 organizations comprising agricultural sector 2,263 organizations, industrial sector 272 organizations, and commercial sector 236 organizations. The organizations are spread in 22 main basins and have no deadline for registration (Thairath Online, 2021).

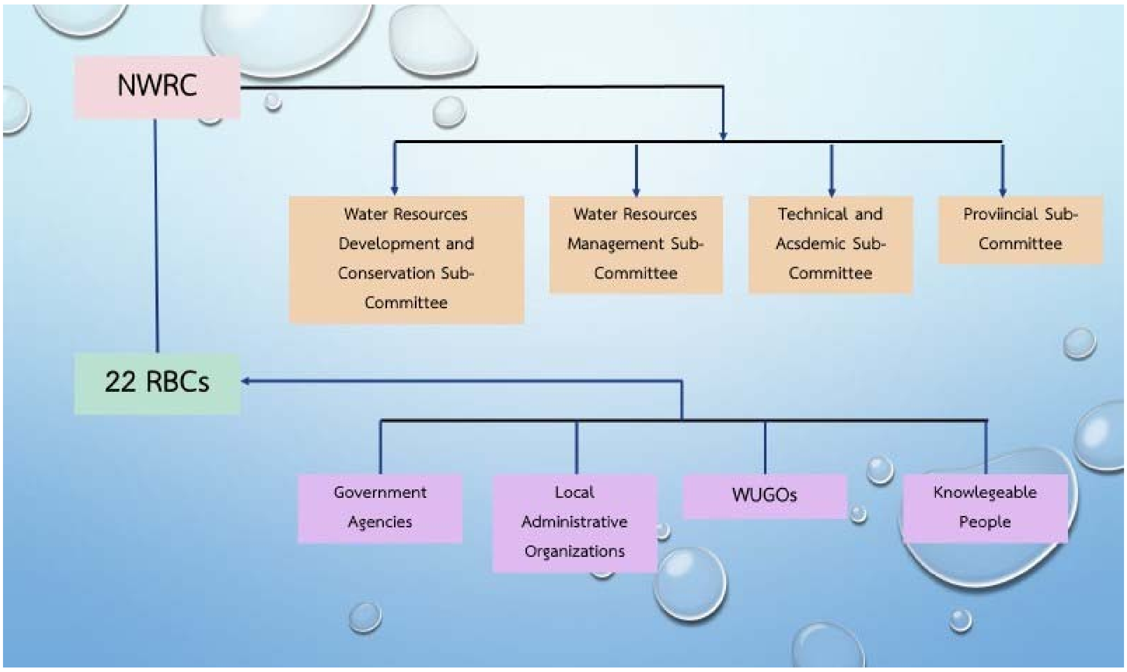

Figure 30. Relation of Water Resources Management Organizations

Source: ONWR (2020)

According to Irrigation Project, Irrigation Water Users Organization (IWUO) establishment is an important activity to promote participation for farmers and community learning and working together solving social problems that lead to sustainable water resources management. Participatory Irrigation Management (PIM) is irrigation management that farmers or irrigation water users are the target group that has participated with RID on management decisions and implement irrigation activities on construction, operation, and maintenance based on set up or agreement. IWUO relates to many laws and regulations. The establishment has a development process from basic to the high-capacity organization. Each level depends on the readiness of members and objectives which can be categorized into two types as follow: (RID, 2005)

1. Non-legal entity comprises 2 sub-types

- Water Users Group (WUG) (basic group) covers an area of one chamfer or one quaternary canal. The organization structure comprises one Chief of the group (assistants may be available as needed) and water user members. The area of WUG should be lower than 160 ha.

- Integrated Water Users Group (IWUG) covers area main canal or distributary canal or tertiary canal or 1 allocation zone or the whole irrigation project but should be lower than 3,200 ha.

2. Legal entity comprises 3 sub-types

- Farmer Group (FP) is registered with Provincial Farmers Group Registrar following Cooperative Registrar set up. It is followed Decree on Farmers Groups B.E. 2547 (2004).

- Water Users Association (WUA) is registered with the Ministry of Interior under Civil and Commercial Code B.E. 2535 (1992).

- Water User Cooperative (WUC) is registered as Irrigation Water Users Cooperative with Cooperative Promotion Department under Cooperative Act B.E. 2542 (1999).

The sequence of IWUO development is presented in Figure 31. It should be developed as this sequence sometimes not always, however, IWUO should be started from the non-legal entity (RID, 2005). In the case of the Prasae Irrigation Project, IWUO is currently set up as a non-legal entity comprised WUGs and IWUGs.

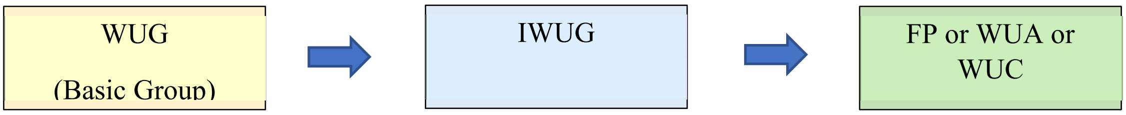

Figure 31. The Sequence of IWUO Development

Source: RID, 2005

IWUO is a part of the agricultural sector in the main basin (East Coast Gulf Basin) and there are many agricultural sector organizations in the main basin. Representatives are selected by the election process in the agricultural sector then proposed to RBC election again. Therefore, this process can be linked between lower water user levels in the basin to RBC.

In 2012, the Governor of Rayong Province had approved Rayong Province Order to appoint JMC of the Prasae Irrigation Project. JMC's objective is to manage irrigation water from the Prasae Reservoir which is related to operation and maintenance, agricultural promotion development, and relevant activities with stakeholders' participation. The working is integrated four parties together such as IWOUs, Local Administrative Organizations, irrigation officers, and government agencies or supporting organizations. JMC comprises two parties such as 1) Advisory Committee from the head of government agencies in the project area; and 2) Prasae Irrigation Management Committee which comprises Chief Executive of Sub-district Administrative Organizations, Mayor of Municipalities, Sub-district Headmen, Chief of government agencies, private sector, Chief of IWUGs, and Chief of water allocation and system improvement of the Prasae Irrigation Project acts as a committee member and secretary (Rayong Province Order, 2012).

2.10 Chapter Conclusion

This chapter provides a review of the relevant literature to demonstrate the significance of developing Thailand's water management policies and strategies to ensure national water security. Governments and water-related organizations have identified a framework and water action plan that align with national strategies for developing sustainable water management. Several water resources laws and regulations have been enacted and implemented in order to integrate water resource allocation, use, conservation and restoration, maintenance, and management. The main organization for the governance of the country's water management was established to achieve the systematic and unified integration of information, plans, projects, and monitoring and evaluation of water management. In addition, this chapter is presented problems and background information on water management at the Prasae Reservoir in Rayong Province, which is the subject of this research. This is to find a suitable, equitable, and long-term approach to allocating water in an efficient and consistent manner across all dimensions in a balanced manner.

3. Methodology

This chapter defines the procedures and techniques used in research and data analysis methods along with justifying the selection of study areas and data collection. A qualitative research method was used in this study to investigate the phenomena and experiences of the interviewees in depth. I focus on detailed descriptions, explanations, and interpretations in order to analyze and understand the meaning of individual experiences. In the descriptive sense, qualitative research reveals the nature of a situation, setting, or process in order to gain new insights, concepts, and uncover problems that exist in a given situation (Njie & Asimiran, 2014). The ability to provide complex textual descriptions of how people experience a given research issue is a strength of qualitative research. It can provide information about a problem's human aspects, such as conflicting behaviors, beliefs, opinions, emotions, and interpersonal relationships. Qualitative research methods can also be used to identify intangible factors like social norms, socioeconomic status, gender, ethnicity, and religion, the role of which in the research issue may not be obvious (Mack et al., 2005).

I chose one case study to investigate the policies, plans, and processes that influence water management. This aims to provide water management for the greatest benefits to society, creating fairness for all sectors, thereby ensuring the stability and sustainability of water resources. Njie and Asimiran (2014) state that case study research is a detailed investigation to provide a contextual and process analysis to clarify the theoretical issues being studied using data collected over a period of time, of phenomena within the context. The systematic analysis is useful for explaining and understanding the meaning of phenomena, events, and processes involved. Therefore, using the case study will provide as much in-depth information about an event, person, or process as possible. As a result, I will conduct a detailed analysis of the events, processes, interpersonal, and organizational relationships that exist within the Prasae Reservoir water management system in my research study. Research data collection will consist of the analysis of data from documents and fieldwork data using in-depth interview techniques and situation map analysis from stakeholders involved in water management. This will result in the search for appropriate and effective solutions for sustainable water management in the area.

3.1 Research Design

I designed my research for the study and analysis of the Prasae Reservoir water management based on a review of the theoretical and conceptual information presented in Chapter 2, before beginning to collect field data for stakeholder group interviews. I explained the rationale for the selection of study areas and participants and human research ethics concerns. These activities will be described in this section. The following section will go into greater detail about data collection, research techniques used in my case studies, and data analysis.

3.1.1 The Selection of Study Area

Thailand's Eastern Coast is an important economic area because it is the country's main industrial production base, especially the petrochemical, energy, and automotive industries. It is also a well-known tourist destination and a rich agricultural resource capable of producing high-quality fruit. Furthermore, the Eastern Region has geographical advantages due to its proximity to the metropolitan area and neighboring countries. It not only has the availability of infrastructures such as roads, railways, ports, and industrial estates, but it is also a shipping hub. This resulted in a connection to the Republic of the Union of Myanmar's Dawei deep seaport, the Kingdom of Cambodia's Sihanoukville port, and the Socialist Republic of Vietnam's Vung Tau port (RID, 2019). The government has initiated the EEC Development project in Chachoengsao, Chonburi, and Rayong Provinces with the goal of promoting industry and investment as an ASEAN-leading economic zone. According to government policy, water resource infrastructure is an important factor in driving various activities in line with the increasing demand for water from economic expansion (The Rayong Provincial, 2017).

In terms of water resource infrastructure, the Prasae Reservoir is the largest reservoir on the Eastern Seaboard. It has a storage capacity of 295 million cubic meters and an average annual natural runoff inflow of up to 280 million cubic meters (East Water, 2018). The Prasae Reservoir can also increase its water supply through major water diversion projects such as the Khlong Saphan – Prasae Reservoir Diversion Pipe Project and the Khlong Wang Tanod – Prasae Reservoir Diversion Project. While the current water demand from the Prasae Reservoir is used for agriculture in the Prasae Reservoir irrigated areas, consumption, maintaining the Prasae River Sub-basin ecosystem, and the diversion of water from the Prasae Reservoir to connect with other reservoirs in the Khlong Yai Sub-basin (known as Rayong River), as well as water use activities in Rayong and Chonburi Provinces (East Water, 2018). The location and irrigated area of the Prasae Operation and Maintenance Project is presented in Figure 32.

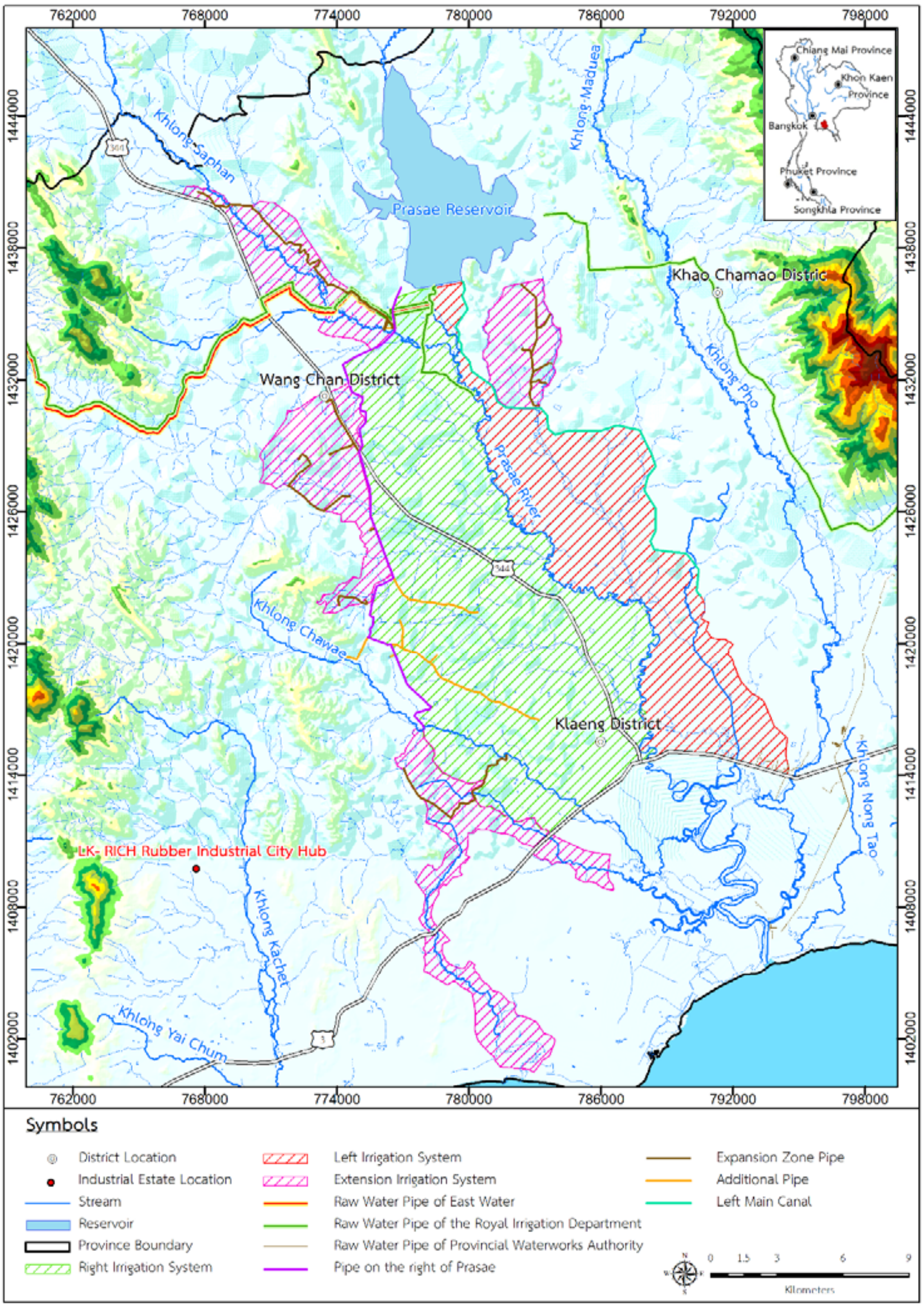

Figure 32. The Location and Irrigated Area of the Prasae Operation and Maintenance Project

Source: The Prasae Operation and Maintenance Project (2020)

It can be seen that the Prasae Reservoir is the Eastern Region Water Management Hub. It has the potential to receive water diversion from vicinity Sub-basins and divert water to other reservoirs connected by pipelines or key water use areas according to government policy. At the same time, there are various water usage activities in the Prasae Reservoir area. As a result, the water management of the Prasae Reservoir affects the water use activities of many involved parties, both water users in the Prasae River Sub-basin and the vicinity Sub-basins. To achieve sustainability and fairness for all parties, the Prasae Reservoir water management requires strategies for integration, collaboration, negotiation, and multi-sector participation along with engineering information in water management.

3.1.2 Participant Selection

The concept of IWRM is the planning and organization of water systems to balance stakeholder perspectives and goals. Water is inextricably linked to other resources such as food, energy, and the environment, so it requires coordination and integration across policy and water sectors (Grigg, 2008). The goal of IWRM is to strengthen governance and promote balanced development. This is to achieve social equality, economic growth, and environmental sustainability (Varis, Enckell, & Keskinen, 2014). Likewise, achieving sustainable water management of the Prasae Reservoir requires coordination and integration at multiple levels, both policy and implementation levels. As a result, the study's target sample population consisted of government agencies and state enterprises related to water management of the Prasae Reservoir, IWUGs, JMC, sub-basin working groups, and private sectors.

The quality of key informant interviews is determined by the selection of appropriate informants based on their specific knowledge of the subject being interviewed, experience, participation in the project, or professional expertise. In project and program settings, key informants typically include government officials, academic scholars and experts, local leaders, representatives of specialized groups, and members of the target populations (Kumar, 1989). In this study, the selection of participants or interviewees was influenced in part by my experience working as an intern with RID and in government agencies at both the Ministry of Natural Resources and Environment and the Ministry of Higher Education, Science, Research and Innovation. Before collecting research data, I gained greater experience through an internship with ONWR, which serves as the main agency for overseeing the water resource management policy of Thailand. I attended the EEC water management meeting, monitoring the water situation in the Eastern Region, and the preliminary field survey on water management in the Prasae Reservoir. To choose my interviewees, I used a combination of these experiences and purposive sampling.

Purposive sampling allows the researcher to select sample members using the researcher's judgment to meet the research objectives. It focuses on individuals or groups with expertise and experience in the phenomenon studied. (Etikan, Abubakar Musa, & Sunusi Alkassim, 2016). One way to find appropriate key informants is to ask local community leaders or government officials (Heath, 2020). As a result, I consulted and received advice on identifying interviewees from experts on water management policies and plans in the Eastern Region and the Prasae Reservoir of ONWR and Regional Irrigation Office 9 (RID 9). In particular, the identification of members of IWUGs received cooperation and advice from experts and staff of the Prasae Operation and Maintenance Project. The sample group of IWUGs chosen is representative of the Prasae Reservoir's irrigated area, which includes the left bank irrigation area, the right bank irrigation area, and the extended irrigation area. This is done so that the study's findings are useful to relevant agencies and can be applied to real-world solutions to improve the efficiency of water management at the Prasae Reservoir in order for it to be sustainable and fair to all parties.

Interviewees from the government sector worked at policy and implementation levels. The former consisted of representatives from two agencies: 1) the Special Advisor in Industrial Development, Eastern Economic Corridor Office of Thailand (EECO); and 2) ONWR such as the Secretary-General ONWR, Executive Advisor on Water Strategy, Expert Irrigation Engineer, Director of the Policy and Master Plan Division, and Director of the Master Plan Sub-Division. The latter consisted of representatives from five agencies such as RID 9, the Prasae Operation and Maintenance Project, Water Resources Region 6 (DWR 6), Bureau of Groundwater Resources Office Region 9 (BGR 9), and Protected Areas Regional Office 2 (Sriracha) (DNP 2).

While promoting and supporting the operation of industrial estates and providing utility services according to the country's area development policy will be the role of the Industrial Estate Authority of Thailand (IEAT), which is a state enterprise under the Ministry of Industry. I sent an official letter by email requesting an interview with the Prasae Reservoir water allocation and water management policy for industrial water users. I received cooperation from the Assistant Governor of IEAT in providing information on water management within the Rayong Industrial Estate, problems, and preparation measures for solving the drought crisis. Participants from other state enterprises consisted of the Provincial Waterworks Authority (PWA) Paknam Prasae Branch and PWA Pattaya Branch.

The next sample group was JMC of the Prasae Irrigation Project, which was formed to promote participation in the water management of Prasae Reservoir. This is to ensure that the water allocation is most beneficial, sufficient, and equitable to all sectors. Interviewees included the Chairman of JMC, the Chairman of the Left Bank Water Management Group, and the Sub-district Headman of Wang Wa. The role of JMC has been reviewed in detail in Chapter 2.

Participants from the Wang Tanod Sub-basin Working Group were considered particularly important due to the impact of the project to divert water from Khlong Wang Tanod to the Prasae Reservoir. Its goal is to increase the water supply in the Prasae Reservoir and connect water networks to key areas for the development of EEC. This is necessary to take into account the potential impacts on water users in the Prasae River Sub-basin and the Wang Tanod Sub-basin, which may turn into water conflicts. I intended to select the participant who is the Chairman of the Wang Tanod Sub-basin because he has extensive experience and knowledge of water management and conflict resolution in the area. He has also gained the respect and trust of Wang Tanod Sub-basin users, industrial water users, and government agencies involved in Eastern Region water management.

For industry interviewees, access to information and interviews with representatives from industrial plants is difficult because the Prasae Reservoir's water management area is a sensitive area between IWUGs and industrial water users. After consulting with water experts from ONWR, I decided to select the Federation of Thai Industries (FTI) participants as a sample group from the industry sector. FTI is a private organization that is generally recognized as a representative of the industry. It serves to coordinate and cooperate between the public and private sectors in the development of domestic and international industrial economies.

Other private sector participants included the Rayong Chamber of Commerce (YEC Rayong) and East Water.

All in all, the total number of interviewees was 37, with a composition presented in Appendix A. The following summarizes the roles and responsibilities of the agencies involved in the Prasae Reservoir water management: (Figure 33)

1. ONWR is responsible for integrating and linking water resource information, plans, projects, budgets, and monitoring and evaluating water resource management (ONWR, 2018).

2. EECO is responsible for preliminary impact analysis, supervision, monitoring, and progress reports on the development of EEC (EECO, 2019).

3. The Eastern Coast River Basin Committee is responsible for prioritizing and determining effective and fair water allocation measures and formulating water management plans in the basin (ONWR, 2021).

4. IEAT is responsible for developing and establishing industrial estates and providing necessary utilities (IEAT, 2015)

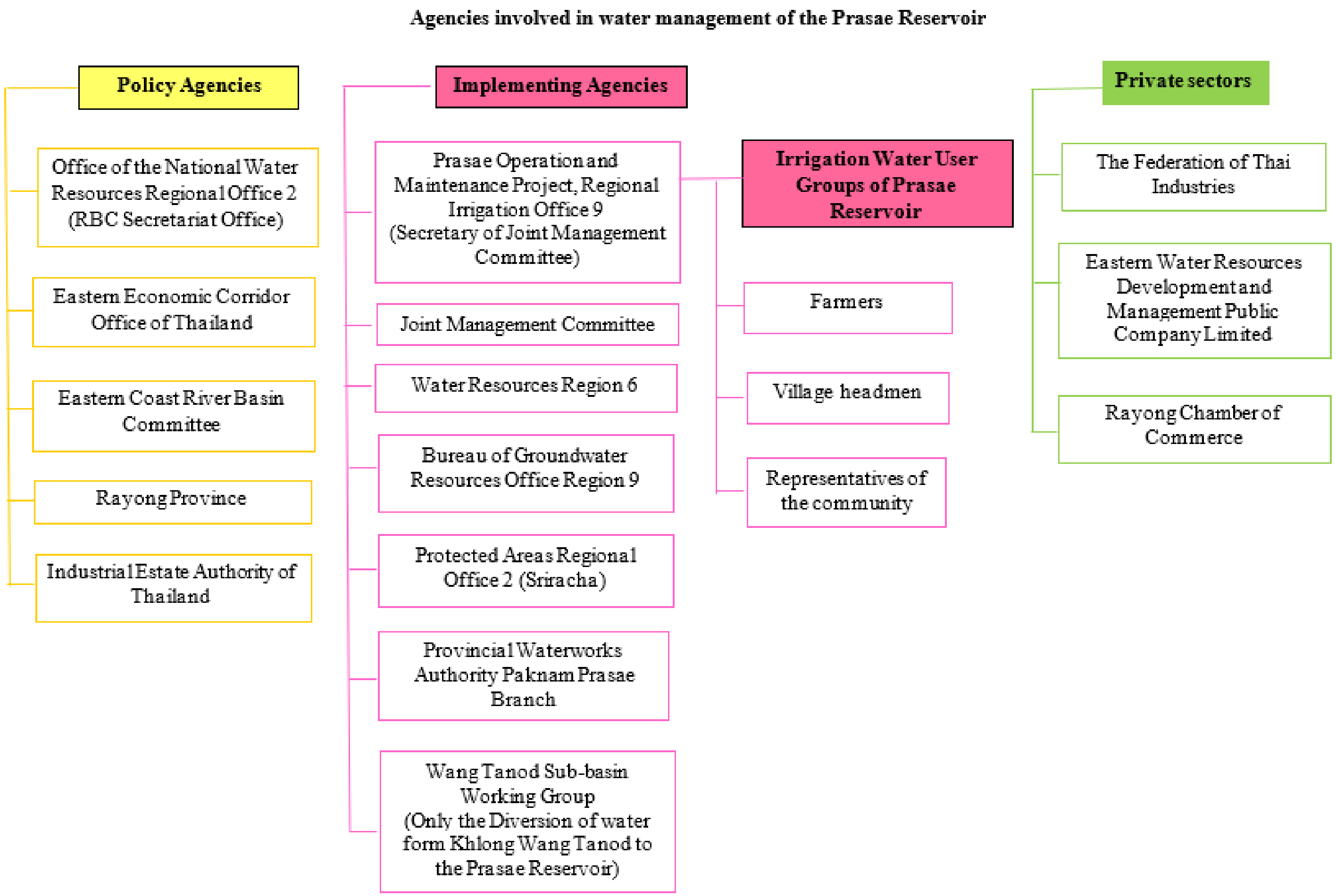

Figure 33. Agencies Involved in Water Management of the Prasae Reservoir

Source: Author (2022)

5. The Prasae Operation and Maintenance Project is responsible for planning, controlling, inspecting, and conducting water delivery and maintenance in the project area, as well as providing advice and disseminating knowledge about water delivery (The Prasae Operation and Maintenance Project, 2021).

6. JMC is responsible for making decisions on the management of water from the Prasae Reservoir and formulating plans and co-operating water storage, water delivery, drainage, and water diversion in both irrigated and non-irrigated areas (Rayong Province Order, 2012).

7. DWR 6 is responsible for developing and conserving water in the rainfed area and disseminating information about water resource management to stakeholders (DWR 6, 2022).

8. BGR 9 is responsible for regulating groundwater operations as well as improving and enforcing laws to meet the water needs of all sectors. It also conducts surveys, developments, and assessments as well as conservation and rehabilitation for the balanced and sustainable utilization of groundwater resources (BGR, 2018).

9. DNP 2 is responsible for the protection, restoration, and conservation of watersheds, forests, and wildlife in conservation areas, including forest fire management (DNP 2, 2015).

10. PWA is responsible for surveying and procuring raw water sources, and producing, delivering, and distributing water supply (PWA, 2020).

11. FTI is responsible for providing advice, promoting and developing industrial operations, as well as disseminating knowledge and technology related to the

industry. It serves as a representative of private sector operators in coordinating policies and taking action with the public sector (FTI, n.d.).

12. East Water operates in water utilities by managing the transportation systems of raw water through large pipelines for industrial and consumption in the Eastern Seaboard (East Water, 2020).

13. YEC Rayong is responsible for promoting various enterprises for trade, industry, agriculture, finance, or economy in Rayong Province and coordinating trade between entrepreneurs and the government (YEC Rayong, 2022).

3.1.3 Human Research Ethics

Before data collection, I consulted the Oregon State University Institutional Review Board (IRB) on research project requirements to be reviewed and approved by IRB to protect the rights and welfare of study subjects. The purpose of this study was to collect only organizational-level data about the Prasae Reservoir's water management policies, procedures, and processes. Participants included representatives from government agencies, state enterprises, the private sector, and IWUGs. As a result, the project would not require IRB review and oversight as it would not meet the federal definition of research involving human subjects.

The interviewees consented to the use of their interview recordings and information in this study, both in written and audio form. Participants were willing to reveal their names and roles because the information gathered from this study was useful to the authorities involved in the Prasae Reservoir's water management. Three participants requested that their names not be revealed.

3.2 Data Collection

The data were collected from a variety of sources, which were divided into secondary and primary data. Secondary data were obtained by analyzing documents from government agencies related to the water management of the Prasae Reservoir, such as existing water management policies and plans, water situation, and preparation of water management measures during drought and flood crises.

The primary data for this study came from in-depth interviews with stakeholders affected by the Prasae Reservoir water management. An in-depth interview was conducted to gain insight and detailed information on the problems and challenges in water management at the Prasae Reservoir. The interviews were recorded using the iPhone 7's Voice Memos app and written notes. Interviewees were not required to provide any unfavorable information, and they could request to end the interview at any time.

3.2.1 Document Analysis

Documents relating to water management of the Eastern Region and the Prasae Reservoir were analyzed in order to identify the strengths and weaknesses of existing policies, plans, and regulations. To optimize the water management of the Prasae Reservoir, precise and accurate data were required for analyzing and forecasting the water situation, water demand, and developing water resource projects. The data used in the Prasae Reservoir's water allocation planning and water management development included data on water volume in the Prasae Reservoir for the past 10 years (2011-2020), water allocation data in 2020, water allocation criteria and water management, and measures to address the drought crisis in 2020.

The Prasae Reservoir Management System information helped in analyzing and understanding the plans, water delivery procedures, and the linkage of water management networks and water diversion from the Prasae Reservoir to other reservoirs. These documents included an assessment of the management quality improvement of the Prasae Operation and Maintenance Project and the Prasae Reservoir Capacity Development Project, both of which aim to increase industrial capacity and support the growing water demand in EEC.

In this study, I collected water allocation and water management of the Prasae Reservoir in 2020, which ran from November 1, 2019, to October 30, 2020. The data were then analyzed by comparing the inflow and outflow of water volumes in the Prasae Reservoir over a decade (2011 – 2020) to forecast drought risk and study drought mitigation measures, such as rules and criteria accepted by all sectors in the case of water diversion. I also compared Prasae Reservoir's water allocation plans and results to forecast actual water demand trends for each activity to improve water allocation planning for the following year. I used data on the allocation of 25 main basins before they were revised down to 22 main basins by the River Basin Decree B.E. 2564 (2021). I also used the previous RBCs before the new selection in 2021. Details on improving the allocation of river basins and the establishment of RBCs are outlined in Chapter 2.

3.2.2 In-Depth Interviews

I gathered data for this study through in-depth interview methods and situation maps to analyze and link relationships within the Prasae Reservoir Management System. This aims to suggest the best, fair and sustainable approach to water management of the

Prasae Reservoir. A total of 37 participants were interviewed, comprising 11 IWUGs, 13 government agencies, 3 state enterprises, 3 JMC, 1 Wang Tanod Sub-basin Working Group, and 6 private sectors. Details of the interviewees are presented in Appendix A. The situation map will be discussed in the next section.

Participant interviews began in August and lasted until October 2020 with the exception of one person with whom I scheduled an interview for March 2021. All interviews were conducted face-to-face in the participant's office or the meeting room of the Prasae Operation and Maintenance Project. Except for some representatives of IWUGs who allowed me to conduct an interview at their homes. To allow participants to feel at ease and to fully discuss their views, I started the interview with a self-introduction and friendly conversation. Then, I described the objectives and goals of this study.

I asked each interviewee if it could record our conversation for transcription and text analysis. Everyone allowed me to record and transcribe our conversation. I also inquired if they would be willing to disclose their names and roles in honor and thanks to those who contributed to this study. All but three people allowed me to disclose the list as the results of the study will reflect their views and benefit the relevant authorities in improving the water allocation and water management of the Prasae Reservoir. Through their interviews, the study helped drive the needs or development projects that local residents want, such as expanding the irrigation area of the Prasae Reservoir, powerful technology for soil moisture measurement, and budget allocation for dredging public pools to store water in dry seasons. In addition to requesting audio recordings and taking notes, I asked participants for permission to take pictures during the interview.

Participants were contacted by email, phone, and LINE app, except for IWUGs, where I was assisted by the Prasae Operation and Maintenance Project staff in coordinating and scheduling interviews. In cases where the information gathered from the interviews conflicted, some participants were contacted for further interviews. Additional interviews were conducted both in person and over the phone.

Interview questions were based on research questions and the interviewee's position and role in the Prasae Reservoir Water Management System (Appendix B). The interview outline included open-ended questions to allow the interviewee to give their opinions on the questions without restriction, bias, or influence of the interviewer. The questionnaire can be classified into four groups: 1) policies and plans for water management of the Prasae Reservoir; 2) technology that helps in water management of the Prasae Reservoir; 3) public participation in water management of the Prasae Reservoir; and 4) conflicts among water users (Appendix C). However, the interview would be conducted from the bottom up. I began interviews with participants at the implementation level and ended with participants from ONWR, the main organization for regulating and overseeing Thailand's water management policy. The responses and feedback I received from IWUGs, local governments, and the private sectors helped me to build on interview questions for policy-level agencies. As a result, I was able to bridge the gap between policy-level and implementation-level agencies to suggest policies and plans for the Prasae Reservoir water management that could truly meet the needs of all sectors in the area.

The date, time, and place of the interview were determined by the participants. The length of the interview ranged from twenty minutes to one hour and forty minutes, depending on the time each participant was able to participate and how deep they wanted to share their thoughts and experiences. When each interview was completed, it was transcribed into Thai and then translated into English. Most of the participants were interested in obtaining a copy of the final report. In-depth interviews enable participants to shed light on the issues and challenges of the most efficient, sustainable, and fair water allocation and management of the Prasae Reservoir.

3.2.3 Situation Map

Improving the Prasae Reservoir's water management policies and plans to make them more effective and reduce conflicts among water user groups requires an in-depth analysis, investigation, and understanding of the overall interrelationships of the relevant elements within the Prasae Reservoir water management system. System thinking is a way of understanding the world by seeing relationships, rather than linear cause-effect chains, and the processes of change rather than static "snapshots" (Daniels & Walker, 2001). In practice, system thinking encourages us to explore inter-relationships, the individual actors' perceptions of situations, and boundaries, agreeing on the scope, scale, and what could lead to improvement. Understanding the system situation and seeing the big picture allows us to identify multiple leverage points that can improve or support joined-up actions to achieve constructive change. System thinking is therefore an appropriate and useful tool to deal with complex or wicked problem situations that cannot be understood and solved by just one actor or one perspective (Learning for Sustainability, 2021).

In this study, I discussed with participants to create a situation map for representing the system. However, I was unable to hold a meeting with all the participants to share and exchange views on the situation map of the Prasae Reservoir water management due to the coronavirus (COVID-19) outbreak and the declaration of the Emergency Decree banning the gathering of people to control the spread of COVID-19 in Thailand. Therefore, I conducted a discussion in which I asked each participant's opinions, and then compiled and outlined a situation map overview based on everyone's ideas. Before becoming the final situation map that they agreed to and accepted as an accurate representation of the system, it was revised three times by the participants.

Participants' knowledge gaps limit their ability to draw a situation map. I needed to co-create a situation map with each participant, beginning by explaining what a situation map was. I then asked the appropriate questions to elicit the participants' perspectives and ideas on the water management of the Prasae Reservoir. The interview continued as an ongoing conversation based on Clarke's analytical approach (Mathar, 2008). I asked who and what was in this situation, who and what was important in this situation, and what elements made a difference or effect in this situation. The details are composed of human elements (water user groups and related organizations) and non-human (technology, regulations, water allocation system, etc.). The next step was to analyze each element of the map in relation to the others and identify the relationship between the interconnected lines (Mathar, 2008).

Situation maps can help participants to share their ideas on connections, trade-offs, and impacts that lead to the disclosure of complex situations. Changes in one part of the system may affect other parts of the system (Brett, 2007). Participants in this study were asked to identify which individuals, groups, and entities were involved in the Prasae

Reservoir's water management. What do they think about the water resources situation? What criteria and regulations must be considered in water allocation and water management? What role do technologies play? What water supply, water delivery systems, and other issues create concerns and conflicts? What are the key sectors that should be involved? How can water resource availability be addressed in the short and long term?

The information from the interviews and situation maps helped me in analyzing and comprehending all of the components of the Prasae Reservoir water management system. Situation maps can be used as a tool to investigate the steps or processes that are the root cause of water management issues and what elements are affected. The systematic analysis also helped me determine what were the strengths and weaknesses of the situation studied. The information gathered from this discussion was analyzed to suggest ways to improve policies and plans to optimize sustainable and equitable water management of the Prasae Reservoir.

3.2.4 Challenges of Data Collection

Before I began gathering the data for this study, there was a global epidemic of COVID-19, which included Thailand. Due to the fact that it is an emerging disease and a lack of sufficient knowledge to develop vaccines and immunization drugs, it is difficult to prepare countermeasures and prevent their impact. The COVID-19 outbreak has an impact on the economy, society, and public health because it spreads quickly through the air. People are concerned in their daily lives. To control and reduce the spread of COVID-19, the Thai government announced an emergency decree prohibiting public gatherings and cross-provincial travel until canceled. As a result, the data collection process was not easy because my interviewees were in Bangkok, Chonburi, Rayong, and Chanthaburi Provinces.

The other barrier was the date and time of the interviews were rescheduled based on the interviewee's availability, particularly the accessibility of top management due to their busy schedule.

3.3 Data Analysis

The data gathered for this study was interpreted and analyzed using qualitative descriptive study analysis techniques. Following each interview, notes and audio recordings will be reviewed before moving on to the next interview as questions or conservation for the next interview session may change and develop as a result of additional insights or the emergence of new data from previous interviews. In the first step, I listened to the audio interview several times and transcribed it into Thai. The transcript and related documentation were then re-read, and the memos were summarized.

The interview responses, situation maps, and important secondary data obtained from relevant documents were categorized for the purposes of this study. It consists of four categories: 1) Policy and plans; 2) Technology; 3) Public participation; and 4) Water conflict. These led to the search for answers to research questions and research hypotheses. The results of the study will be compiled and presented in Chapter 4. I will use SWOT Analysis to assess the strengths, weaknesses, opportunities, and threats of the Prasae Reservoir water management. SWOT Analysis consists of internal and external factors. Internal factors refer to the internal environment of the organization that affects business operations, which consists of 1) Strengths are the advantages of the organization. It refers to the characteristics of the organization contributing to its success; and 2) Weaknesses are the negative effects or problems within the organization that affects its operations. External factors are outside conditions that may affect business operations and they include the following: 1) Opportunities are factors that benefit the Company's business operations. It boosts the organization's competitiveness; and 2) Threats are defined as anything that could have a negative impact on the business. It is an external challenge that your company must face and overcome (Figure 34) (Mind Tools, n.d.).

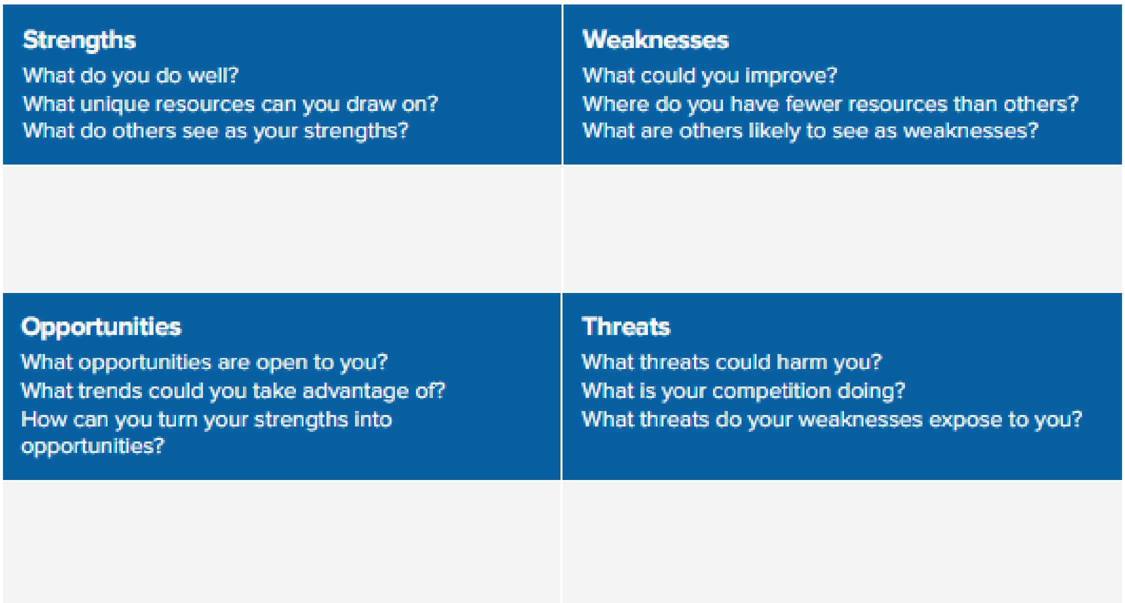

Figure 34. SWOT Analysis Matrix

Source: Mind Tools (n.d.)

In the SWOT analysis, I must point out how special the Prasae Water Operation and Maintenance Project is. What are the organization's strongest resources? How can the agency improve the water management of the Prasae Reservoir? Where does the organization lack knowledge or resources? Is there anything that will increase the water management capacity of the Prasae Reservoir? What changes affect the water management of the Prasae Reservoir?

After completing the SWOT analysis, I will use TOWS Matrix to formulate a strategy for planning the development of water management of the Prasae Reservoir. These questions will be answered to suggest ways to improve the Prasae Reservoir water management policy. How can the relevant authorities use their strengths to optimize the Prasae Reservoir management? How can they avoid their weakness in the water management of Prasae Reservoir? How can they take advantage of external opportunities to optimize the Prasae Reservoir water management? And how do they deal with the threats affecting the water management of the Prasae Reservoir? Once I have answered these questions, I will match external opportunities and threats with internal strengths and weaknesses to create a good Prasae Reservoir water management strategy: (Figure 35) (Mind Tools, n.d.)

	External Opportunities (O)	External Threats (T)
Internal Strengths (S)	**SO** *"Maxi-Maxi Strategy"* Strategies that use strengths to maximize opportunities.	**ST** *"Maxi-Mini Strategy"* Strategies that use strengths to minimize threats.
Internal Weaknesses (W)	**WO** *"Mini-Maxi Strategy"* Strategies that minimize weaknesses by taking advantage of opportunities.	**WT** *"Mini-Mini Strategy"* Strategies that minimize weaknesses and avoid threats.

Figure 35. TOWS Analysis Matrix

Source: Mind Tools (n.d.)

1. Strengths and Opportunities (SO) – How can agencies use their strengths to take advantage of opportunities to improve water management?

2. Strengths and Threats (ST) – How can agencies use their strengths to avoid potential threats?

3. Weaknesses and Opportunities (WO) – How do agencies take advantage of opportunities to overcome their weaknesses?

4. Weaknesses and Threats (WT) – How can agencies minimize their weaknesses and avoid potential threats?

These strategies will lead to the Prasae Reservoir's sustainable water management by promoting social equality and balancing economic and environmental dimensions.

3.4 Potential Research Bias Statement

Because of the difficulty in dealing with research bias, qualitative research is frequently criticized for its lack of transparency and scientific rigor (Shah, 2019). In an effort to avoid or minimize bias for the transparency of this study, I reviewed my work throughout the research process and discovered potential bias. The first is the selection of participants. I stated that the participants were chosen because they had prior experience and had a direct impact on the water management of the Prasae Reservoir. Representatives of IWUGs also cover the irrigated area of the Prasae Operation and Maintenance Project, which includes the left and right banks of the Prasae Reservoir and its extension areas.

The second is the participants' bias in answering the questions. In an effort to be as neutral as possible, I used open-ended questions to prevent participants from agreeing or disagreeing and to avoid leading and negative questions. The length of time to answer each question depends on how much the interviewees want to share their experiences. I had audio recordings and notes during the interview to review and reduce data analysis mistakes. I asked the interviewees if my interpretation seemed representative of their opinion. For the conflicting responses between the interviewees, I proceeded to request an additional interview. In addition, two water resource experts who worked as independent consultants joined me for the interview. After each interview, I discussed with them to interpret and analyze the data with a clear and unbiased mind.

The final point is sympathy and understanding of the Thai government's working system as I am a civil servant who received a scholarship from the Thai government. As a result, I may be hesitant to present data that I believe will have a negative impact on government agencies. Recognizing my potential bias, I present all of my findings honestly, including their benefits and drawbacks. I also double-check my work to ensure that the findings reflect the views and opinions of stakeholders and that the situation map is representative of the Prasae Reservoir Water Management System they agree on.

It is difficult to avoid bias in research, but these guidelines and rationales are my attempt to report findings from interviews and relevant document analysis to all parties in an honest and fair manner.

3.5 Chapter Conclusion

This chapter outlines the processes that will lead to the keys to the development of the Prasae Reservoir water management. I have clarified the data collection and analytics methods used to achieve the objectives and goals of my study. In summary, there were three types of data collection methods (Table 7): 1) document analysis; 2) face-to-face in-depth interviews; and 3) situation map. The qualitative descriptive analysis techniques, SWOT Analysis, and TOWS Matrix are used in data analysis. Data collection procedures are critical in determining the best water management strategy and framework for the Prasae Reservoir. The knowledge, experiences, and responses of the participants influenced the analysis of the interconnected components of the Prasae Reservoir water management system. Each component of the system is investigated in order to achieve the best approach to the Prasae Reservoir water management, taking into account the balance of effective water allocation, maximizing societal benefit, and thereby creating fairness among water users.

Table 7. Summary of the Research Questions, Objectives, and Methods

Research Questions	Research Objectives	Methods
Research Question 1: What is the optimal, just, and sustainable method for managing available and excess water of the Prasae Reservoir, considering balancing the needs to allocate water efficiently, maximize the benefits to society, and, thereby, creating fairness between water users?	***Objective 1:*** Study and analyze existing water management policies and plans to provide recommendations for the improvement and development of sustainable water management systems in the Prasae Reservoir, Rayong Province.	• Review literature and analyze documents to improve sustainable water management policies and plans of the Prasae Reservoir • In-depth interviews with participants from IWUGs, government agencies, state enterprises, JMC, Wang Tanod Sub-basin Working Group, and private sectors • Create a situation map to provide an accurate

Research Questions	Research Objectives	Methods
		representation of the Prasae Reservoir management system that stakeholders agreed to and accepted
	Objective 2: Analyze and assess the possibilities of implementing new strategies in water resources management to reduce conflicts between water users.	• In-depth interviews with participants from IWUGs, government agencies, state enterprises, JMC, Wang Tanod Sub-basin Working Group, and private sectors • Analyze SWOT and TOWS to determine the best strategy and framework for water management of the Prasae Reservoir
Research Question2: How can appropriate technologies increase the capacity and efficiency of water management in the Rayong area?	***Objective 3:*** Provide appropriate technology that can be applied in water management to increase the capacity and efficiency of water management in the Rayong area to meet the increasing water demand in agriculture, industry, and community.	• Review literature and analyze documents to improve sustainable water management plans of the Prasae Reservoir • In-depth interviews with participants from IWUGs, government agencies, state enterprises, JMC, Wang Tanod Sub-basin Working Group, and private sectors
Research Question 3: How does public	***Objective 4:*** Study the participation of local	• In-depth interviews with participants from IWUGs,

Research Questions	Research Objectives	Methods
participation affect the sustainable water management of the Prasae Reservoir? Are most stakeholders able to accept that excess water will be diverted to other areas, depending on the situation and season?	people and government agencies in water management in the Prasae Reservoir, Rayong Province.	government agencies, state enterprises, JMC, Wang Tanod Sub-basin Working Group, and private sectors

4. Results

The results of the study on water management of the Prasae Reservoir are presented in this chapter. The primary data was obtained from fieldwork covering the irrigation area of the Prasae Operation and Maintenance Project and policy and planning officials directly involved in the water management of the Prasae Reservoir. Data were collected from the knowledge, understanding, and experience of stakeholders through in-depth interviews and situation maps, focusing on water situation issues, water management plans, and water allocation in 2020.

In order to optimize the water management of the Prasae Reservoir and create fairness for all sectors, it is important to understand what current water management policies and plans are, what are the problems and barriers to water management, how participatory processes affect water management, and what approaches lead to sustainable water management and water use balance in economic, social and environmental dimensions. Both in-depth interviews and the situation map aim to improve the water management of the Prasae Reservoir. The interview data reveal the perspectives of various sectors on water management policies and plans to create a balance between water users while the situation map focuses on the overview of water management in order to meet the needs of water users and improve the water management system for sustainability.

As stated in Chapter 3, data were collected from a total of 37 interviewees with six questionnaires. They are representatives from various sectors, comprising 11 IWUGs, 13 government agencies, 3 state enterprises, 3 JMC, 1 Wang Tanod Sub-basin Working Group, and 6 private sectors (Appendix A). The questionnaire focuses on policies and plans for water management, water management technology, public participation, and the reduction of conflict among water users in 2020. Different questionnaires are based on the roles and positions of the interviewees (Appendix B). Taken together with secondary data, which are official and electronic documents obtained from agencies involved in water management of the Prasae Reservoir. The secondary data includes the Prasae Reservoir water volume, inflow and outflow, water allocation, water diversion, and Geographic Information Systems (GIS). Both primary and secondary data contribute to better water management in order to achieve sustainability.

The main aim of the in-depth interview was to answer the research questions and hypotheses presented in Chapter 2. The first section begins with policies and plans for water management of the Prasae River Sub-basin and the Prasae Reservoir. Then, I introduce technologies that improve water management efficiency and reduce water use. Next, I provide information on stakeholder participation in water management and water allocation of the Prasae Reservoir. Finally, I describe the causes of water conflict among water users in this area. The results in each section were obtained from interview data, secondary data, or both. In addition, these results are also discussed to analyze ways to improve water management of the Prasae Reservoir towards sustainability, as reported in Chapter 5.

4.1 Policies and Plans for Water Management of the Prasae River Sub-Basin and the Prasae Reservoir

The Prasae Reservoir was built to manage water in the Prasae River Sub-basin to meet the needs of agriculture in irrigated areas and to prevent saltwater intrusion. It is also a raw water reserve for industrial estates on the Eastern Seaboard (Katchwattana, 2020). The Prasae Reservoir has the largest capacity in the Eastern Region, which can hold 248 million cubic meters of water. The average annual runoff that flows into the reservoir is 294.50 million cubic meters. This results in an average annual water overflow from the reservoir of about 47 million cubic meters (RID, 2016).

In order to increase the efficiency and benefits of water management of the Prasae Reservoir, RID has increased the water storage level by installing the flap gate weir on the original ogee weir with a control system for opening and closing the gate (Figure 36). The water level was increased from +35 meters (MSL) to +36 meters. (MSL). As a result, the reservoir's capacity has increased from 248 million cubic meters to 295 million cubic meters (RID 2016).

Figure 36. Flap Gate Weir and Control Room

Source: Author (2020)

The water management of the Prasae Reservoir is divided into two levels which consist of the policy level and the implementation level.

4.1.1 Policy Level

Rayong is the main industrial center of the country. It is one of the provinces under EEC besides Chachoengsao and Chonburi to propel Thailand into an important economic zone of ASEAN. Agriculture has also shifted from rubber plantations to durian plantations which require large amounts of water. This has led to a rapid increase in water demand to support the expansion of agricultural and industrial activities. The government has made efforts to increase the efficiency of water management by interconnecting existing water resources and developing additional water sources to ensure water security. Six strategies for developing water supply resources to meet the growing water demand over the next decade and support the EEC are: 1) Improve the existing water source by increasing the capacity of the existing water source potential; 2) Develop four reservoirs with a total capacity of 308.5 million cubic meters in the Khlong Wang Tanod Sub-basin, Chanthaburi Province; 3) linking water sources and water diversion systems; 4) Pump the water downstream back to the reservoir to make it more usable; 5) Flood prevention through the construction of pumping stations and overflow drains, and industrial flood prevention plans by improving canals and constructing floodgates to alleviate flooding; and 6) Procurement of water reserves of the private sector (Kongwichianwat, 2018).

The Prasae Reservoir is like a hub for the Eastern Region because it can receive water from vicinity Sub-basins and allocate it to agricultural and industrial areas in Rayong and Chonburi Provinces. ONWR, as the national chief of water, serves as the central agency for the integration of national water management and the integration of information, plans, projects, and monitoring and evaluation of water management. They analyzed that the amount of water in the Prasae Reservoir came from two sources:

1) The amount of precipitation in the Prasae River Sub-basin, where the amount of water inflow into the reservoir is uncertain and tends to decrease due to changes in Climate.

2) Water from other water sources is pumped back or diverted into the Prasae Reservoir.

ONWR has developed plans and measures to mitigate the impacts of climate change and forecasts an increase in water demand by 600-700 million cubic meters in the next 20 years. Both new technologies and water source development projects are being driven to enhance integrated water resource management and to reserve approximately 30% of surface water due to uncertainty. The goal of the water management of the Prasae Reservoir is to ensure that all sectors have sufficient water and equal access to water resources while maintaining ecological balance.

To achieve this goal, two aspects of the Prasae Reservoir water management were analyzed as follows:

1) Demand-side management – The demand side will be controlled by reducing the demand for water and increasing the efficiency of water use. In particular, the reduction of water uses in the agricultural sector, which is a large production system, has resulted in more water allocation for industrial purposes. A mechanism to reduce water loss by 20% in the production process was proposed to increase the efficiency of industrial water use.

Water demand in each sub-area and different activities are analyzed to define clear criteria for water use and water allocation. The water allocation plan will allow RBC to determine how much water they need and where to find it. If water demand increases from the water allocation plan, water users need to request water through the RBC's consideration. The results of the analysis of water demand will be considered in comparison with the amount of water available in natural water sources to meet the needs of water users. This will help drive demand-side water management into action.

2) Supply-side management – The challenge of supply-side water management is to balance water demand from different activities that are unequally allocated water resources according to the type of water use activities. The different activities include agriculture, industry, community, and tourism. ONWR seeks to increase water supply through existing water sources or future water development projects to meet the unlimited increase in water demand. The minimum and maximum requirements for water resources in each area will be considered to meet demand. Supply-side management will require reserves of water storage, which will require further long-term investment. Guidelines for water reserves can be carried out as follows:

- Water resource networks will be linked to enable water diversion from areas with excess water supply to other areas for efficient water management. The government must create an understanding among people about water rights. Water resources are public goods and everyone has equal access to water. Water resources are not just for agriculture and all sectors can share the available water resources for maximum benefit. The government has the decision-making power on water management in the event of a water crisis in order to alleviate the suffering and damage that may occur to property and people's lives. However, it is necessary to consider the conditions and compensation arising from the diversion of water from one place to another to the people of the upstream area.

- Providing additional water storage by digging wells or pools as well as dredging water sources.
- 38 Water resource development projects are being implemented to meet the water demand in the EEC. Projects related to improving the efficiency of water management of the Prasae Reservoir, for example, the temporary pumping station to pump water from Khlong Saphan, a tributary of the Prasae River Sub-basin back to the reservoir, the construction of Khlong Wang Tanod Reservoir to divert excess water to the Prasae Reservoir, the construction of Khlong Phlo Reservoir, etc.
- Desalination is in the process of considering investments with the private sector in the future. The suitability of the area and the proportion of freshwater produced from seawater will be considered to reduce the availability of freshwater from other sources and increase the rate of use of freshwater from seawater. Desalination will require planning for water production and use because the private sector may plan to build its own water storage in the future.
- Reusing wastewater not only reduces water demand but also helps alleviate the water shortage crisis in the area. Water reuse is being promoted in the industrial sector, in contrast to domestic water that has not yet been invested in it.

The Prasae Reservoir not only provides water to users in the Prasae River Sub-basin but also diverts the water to other areas in Rayong and Chonburi Provinces, as well as receives water from Khlong Wang Tanod Sub-basin to support the expansion of the industrial sector and the increasing demand for water in the future. In addition, farmers are likely to shift from rubber cultivation, which uses less water, to durian cultivation, which requires a lot of water without the government's land-use change control measures. As a result, the demand for agricultural water in the Prasae River Sub-basin has increased rapidly. The water management of the Prasae Reservoir must balance the water demand from various activities with the available water supply. Therefore, relevant agencies need to consider setting clear rules for water diversion and water allocation in order to ensure fairness for water users in all sectors. The Water Resources Act B.E. 2561 (2018) defines three types of public use of water resources as follows (ONWR, 2018):

- Type One water use refers to the use of public water resources for living, household consumption, agriculture or livestock farming for subsistence, household industry, ecosystem conservation, customs, public disaster mitigation, communications, and small-scale water use. It requires neither the water use license nor the payment of any fees.

- Type Two water use refers to the use of public water resources for industry, tourism industry, electricity generation, waterworks, and other undertakings. It must be licensed by the Director-General of RID, the Director-General of DWR, or the Director-General of DGR, as the case may be, with the approval of RBC where the public water resources are located.

- Type Three water use refers to the use of public water resources for large-scale undertakings that use large amounts of water or may cause cross-basin impacts, or cover large areas. It must be licensed by the Director-General of RID, the Director-General of DWR, or the Director-General of DGR, as the case may be, with the approval of NWRC.

ONWR is currently in the process of considering the criteria and conditions for determining the rate of water use charge. ONWR will also establish measures and registrations for those cultivating crops during the dry season, clearly stating the hectare and the water source used. This aims to make dry season crops consistent with the water supply and to plan water management. Furthermore, ONWR has supported public-private partnerships to reduce government investment and increase water management efficiency in the Eastern Region. A water diversion project, for example, requires significant investment, whereas desalination requires research into a suitable location for investment. This is to ensure that agriculture and industry can coexist and grow. In terms of the water management database, ONWR has coordinated and collaborated with relevant agencies to update the data and provide a standard for forecasting the water situation.

As for the industrial sector, IEAT is responsible for developing and providing utilities based on the needs of entrepreneurs within the industrial estates, with a focus on being a smart eco-industrial estate. Its main revenue comes from the sale of water to industrial plants. IEAT will purchase water from East Water, which is authorized by the RID 9 to manage water for both Khlong Yai and Nong Pla Lai Reservoirs. IEAT, on the other hand, continues to promote and encourage industrial plants to use technology and innovations to save water and recycle wastewater. The current economic situation determines the amount of water used in the industrial estate area.

In 2020, IEAT convened a meeting with entrepreneurs, government agencies, and the private sector involved in water management to assess the water situation and prepare measures to cope with water scarcity. Three industrial-related measures are: 1) all sectors in Rayong and Chonburi Provinces reduce water use by 10%; 2) private power plants in Rayong and Chonburi Provinces must stop operating in standby mode or operate only as far as necessary; and 3) IEAT pumps water from Khlong Nam Hu to reduce the use of water from the Nong Pla Lai Reservoir. Industrial factories are unable to supply water from outside to use in their factories due to IEAT's policies, regulations, and roles, and must instead purchase water from IEAT, unless in an emergency or in the event of a water shortage, in which case industrial factories must first obtain permission from the IEAT. This is to facilitate the traffic in the industrial estates to ensure the safety of transporting water.

Despite the fact that IEAT has responded to the government's policy requiring new industrial plants to have a water reserve of at least 1-2 days, it is difficult to implement due to high land prices. IEAT has therefore studied the procurement of water from the private sectors other than East Water to solve the monopoly problem and may collaborate with industrial factories in the area to set up a desalination plant if necessary. This is to ensure that the industrial sector has an adequate supply of water. IEAT stated that if the government is to drive the country's industrialization, it must consider not only how to support industrial capacity building but also how to optimize available resources, connect water resource networks, and collaborate with relevant agencies and water users to achieve sustainable water management and create fairness in all sectors.

Everyone has heard the phrase “think globally, act locally” when it comes to water management. Water management policies should be established by a central authority acting as the regulator, while implementation must be appropriate in each area. Decentralization of water management will make it easier for people to participate in planning and developing projects with the government. Solutions to improve local water management efficiency will be able to meet the needs of people because local authorities can find the root cause of problems in the area.

Although water management decentralization has advantages in terms of public participation and recognition of the real problems in the area, it lacks the overall linkage of water management at the provincial and national levels. Water resources managed by multiple agencies may result in redundancy or conflict. In addition, local authorities lack the knowledge and experts needed to continuously monitor and maintain water management tools and technology. Therefore, central agencies need to have mechanisms to link water management with local governments for equal access to water resources such as the Provincial Water Management Subcommittee, RBC, and the Water Law.

4.1.2 Implementation Level

As a result of the 2005 drought crisis, all sectors related to Eastern Water Management have jointly established the Water War Room to formulate plans and measures for systematic and sustainable management of Eastern water resources. The Eastern Water War Room Working Group (Keyman Water War Room) consists of RID, Provincial Waterworks Authority, Department of Royal Rainmaking and Agricultural Aviation, Electricity Generating Authority of Thailand, IEAT, East Water, and major industrial water users. The Keyman Water War Room will meet once a month to monitor the water situation and analyze solutions to drought problems in the Eastern Region, especially in the Rayong and Chonburi Provinces (The Secretary of the Eastern Water War Room, 2021). The Prasae Reservoir serves as a water hub for the Eastern Seaboard areas of Rayong and Chonburi due to its ability to receive and divert water to other sources. The water management model is defined by a network of reservoirs linked by pipelines to optimize the management of existing and excess water while meeting the needs of water users. As a result, water management of the Prasae Reservoir must be considered alongside other water resources in Rayong Province, comprising Khlong Yai, Nong Pla Lai, and Dok Krai Reservoirs. To ensure fairness to all sectors and to achieve sustainability in water management, the Prasae Operation and Maintenance Project has established the reservoir operation rule curve for receiving and diverting water to other reservoirs (Figure 37). This aims to prevent floods and water shortages for various activities (East Water, 2018).

East Water (2018) states that the reservoir operation rule curve refers to the criteria to control the water level at different times so that the water level is not lower than or higher than the specified range. It is one of the flood mitigation measures using reservoir management, which consists of: (East Water, 2018)

1) The Normal Storage Level (NSL) is the water storage capacity of the Prasae Reservoir which has a total capacity of 295 million cubic meters.

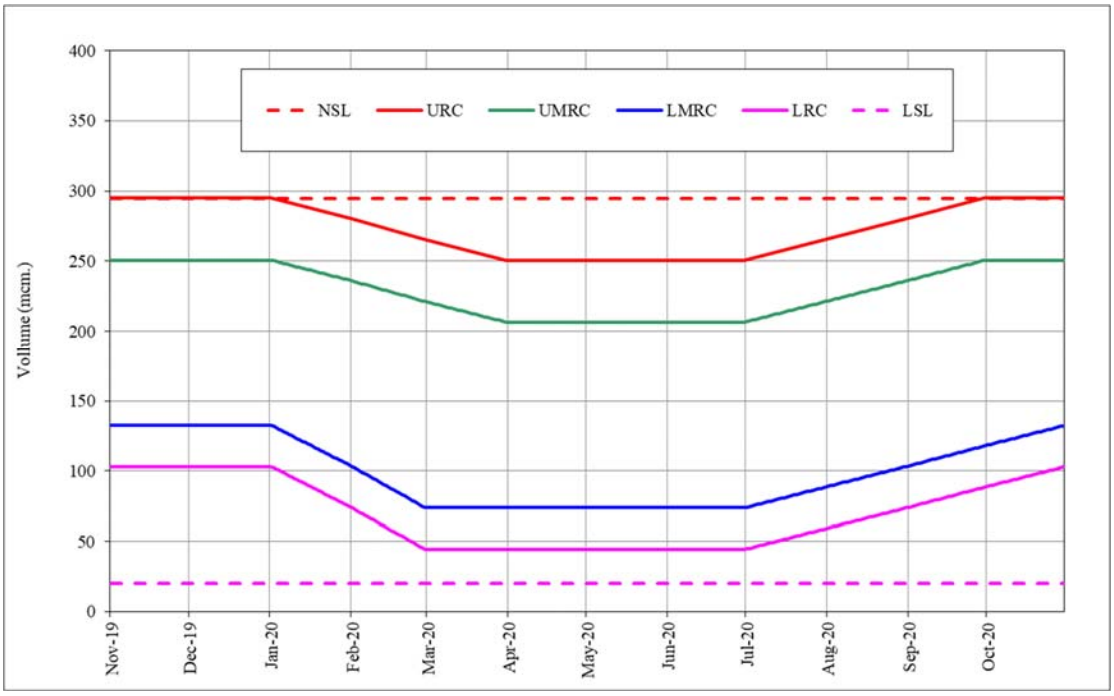

Figure 37. Rule Curve of the Prasae Reservoir

Source: Data from RID 9 (2021)

2) The Upper Rule Curve (URC) not only prepares reservoirs for water inflow during the rainy season without overflowing, which could cause downstream flooding, but it also stores water for use during the dry season. Water management above URC will be able to allocate water into the system and drain water downstream as needed, and divert water to Khlong Yai and Nong Pla Lai Reservoirs according to the conditions of both reservoirs.

3) The Lower Rule Curve (LRC) aims to reduce the risk of water scarcity and low water levels to the lowest water levels during the dry season. If the water level is expected to fall below LRC, the water allocation will be reduced to prevent the water level from falling below LRC. Water management that is lower than LRC or at the Lower

Storage Level (LSL) allocates water into the system as needed and drains only the activities that are required. The diversion of water from Khlong Saphan and Khlong Wang Tanod Sub-basin to the Prasae Reservoir will be considered on condition

4) The Middle Rule Curve (MRC) is designed to control the flow of water from other sources to the Prasae Reservoir to prevent overflow during the rainy season. It also regulates the diversion of water from the Prasae Reservoir to other reservoirs to prevent water shortages of various water use activities managed by the Prasae Reservoir. The Prasae Reservoir has defined the operation rule curve as follows (Table 8):

Table 8. Guidelines for the Management of the Prasae Reservoir in Each Situation

Reservoir level range	Water allocation into the system	Water diversions to Khlong Yai & Nong Pla Lai Reservoirs	Drainage downstream	Water diversion from Khlong Saphan (Condition)	Water diversion from Khlong Wang Tanod (Condition)
Above URC	✓	✓	✓	×	×
URC - UMRC	✓	✓	✓	×	×
UMRC - LMRC	✓	✓	✓	✓	✓
LMRC - LRC	✓	×	✓	✓	✓
Below LRC (at the LSL)	✓ (Only necessary)	×	✓ (Only necessary)	✓	✓

Remark: ✓ can be operated
× unable to perform

- Water management between URC and the Upper Middle Rule Curve (UMRC) will be able to allocate and drain water downstream as needed. The diversion of water to Khlong Yai and Nong Pla Lai Reservoirs will be considered based on the conditions of both reservoirs.
- The water level between UMRC and the Lower Middle Rule Curve (LMRC) will be allocated and drained downstream as needed. The diversion of water to Khlong Yai and Nong Pla Lai Reservoirs can also be carried out, and water from Khlong

Saphan and Khlong Wang Tanod Sub-basin should be diverted to the Prasae Reservoir to increase the reservoir's water under the specified conditions.

- Water management in LMRC and LRC phases is managed by allocating it into the system and draining it downstream as needed without diversion to other water sources. Water from Khlong Saphan and Khlong Wang Tanod Sub-basin will be diverted to the Prasae Reservoir under conditions.

Normally, water management of the Prasae Reservoir starts on November 1 of the previous year until October 31 of the following year. Similarly, in 2020, water management of the Prasae Reservoir began on November 1, 2019, and ended on October 31, 2020.

At the end of the rainy season (October 2019), the Keyman Water War Room held a meeting to plan water allocation and water management in 2020. The water availability of the Prasae Reservoir and water demand data of various sectors were taken into account and analyzed to forecast the water situation throughout the year. They found that the Prasae River Sub-basin experienced lower than average rainfall in 2019 (November 2018 - October 2019), resulting in less than normal water inflow into the Prasae Reservoir (Figure 38). This affects water management during the 2020 dry season.

In 2020, the Prasae Reservoir had the lowest initial water supply in 10 years with a total water volume of 146.49 million cubic meters (Figure 39). It could result in severe water shortages because the Prasae Reservoir is the main water source in the area that not only allocates water to agricultural areas but also diverts the water to other reservoirs or key areas to support industrial activities in Rayong and Chonburi Provinces. If there is no rain in May or June, which is the rainy season, it will result in a long-term drought.

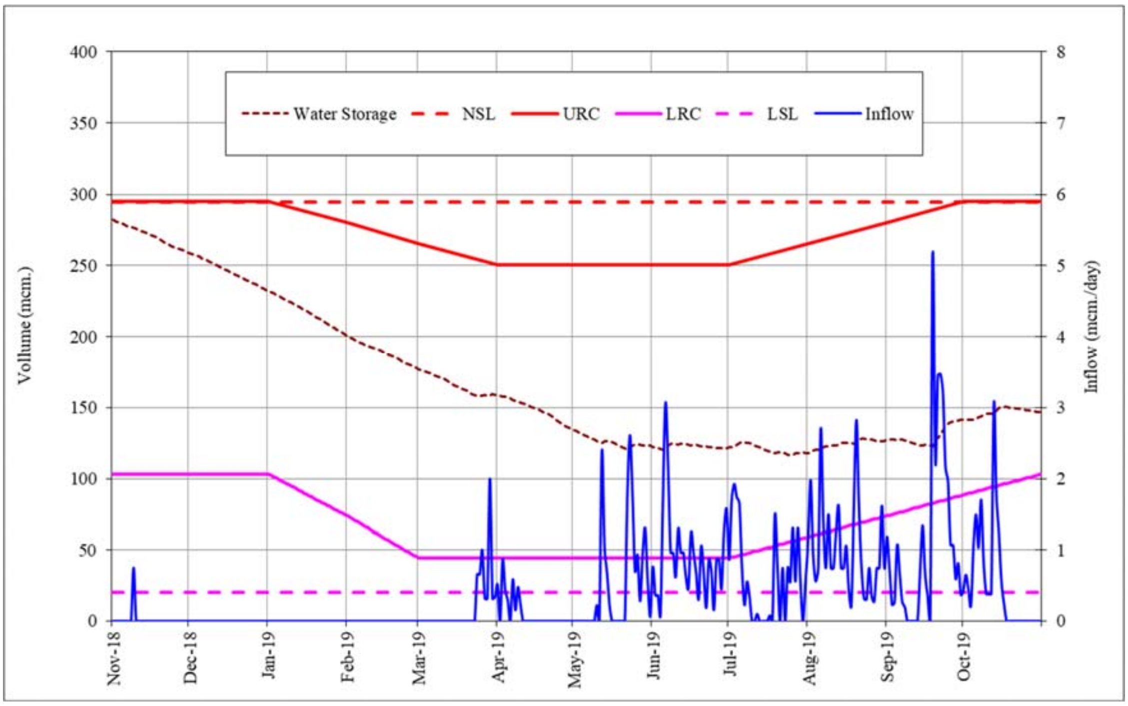

Figure 38: Water Inflow of the Prasae Reservoir in 2019

Source: Data from RID 9 (2021)

To mitigate the impact of water shortage problems, the Keyman Water War Room has established systematic guidelines and measures to deal with drought in Chonburi and Rayong Provinces. 9 of 12 measures were implemented in Rayong Province as follows:

1. Connecting two diversion pipelines of the Prasae Reservoir – the Khlong Yai Reservoir and the Prasae Reservoir – the Nong Pla Lai Reservoir to supply water to the Nong Pla Lai Reservoir
2. Reduce water use in all sectors by 10%
3. Diversion of water from Khlong Wang Tanod to the Prasae Reservoir

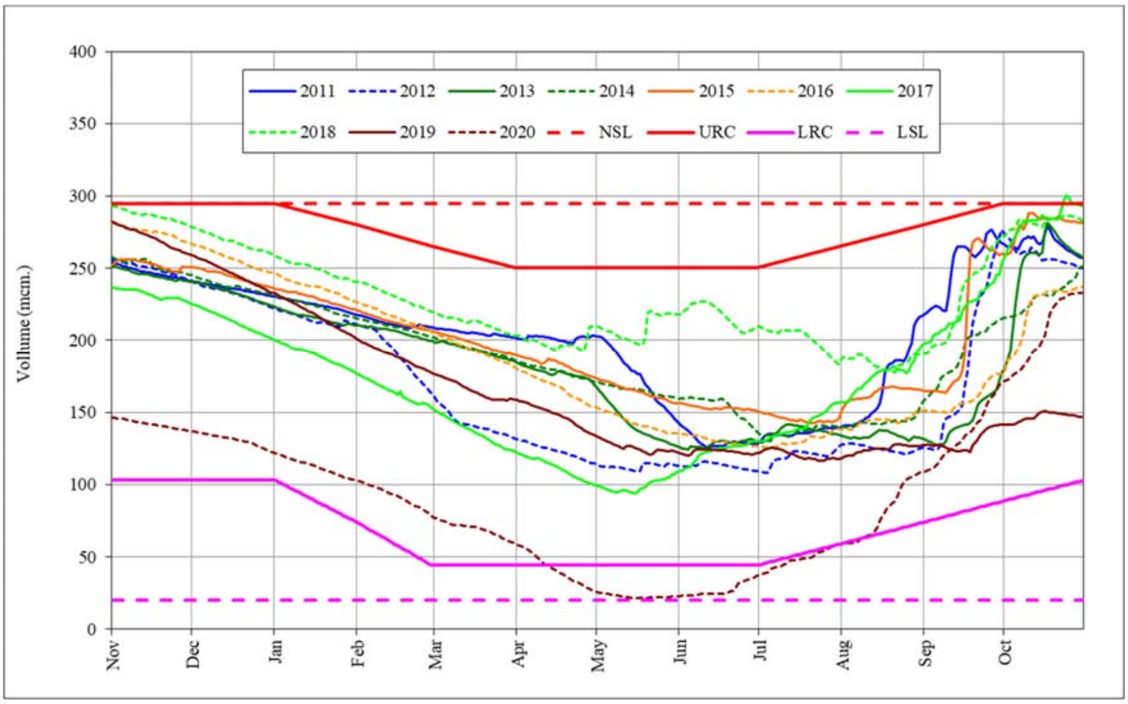

Figure 39. Water Volume in the Prasae Reservoir from 2011-2020

Source: Data from RID 9 (2021)

4. Private power plants are either in standby mode or operate as needed.

5. Diversion of water from the Khlong Yai Reservoir to the Nong Pla Lai Reservoir

6. Laying polyethylene sheets to improve the Nam Daeng Canal, which is located at the end of the Prasae Reservoir - Khlong Yai Reservoir diversion pipe. Water will be directed to the Khlong Yai Reservoir.

7. Map Ta Phut Industrial Estate pumps water from the Khlong Nam Hu to reduce the use of water from the Nong Pla Lai Reservoir.

8. Repairing the water pumping system at Lahan Rai Temple to pump water from the Rayong River (Khlong Yai River) back to the Nong Pla Lai Reservoir.

9. Constructing a temporary pumping station to return water from Khlong Saphan to the Prasae Reservoir.

4.1.3 Water Management in 2020

The Prasae Operation and Maintenance Project primarily surveyed the crop cultivation demand and water demand of farmers to match the available water supply and examined the condition of the irrigation facilities before planning the water allocation. JMC then considered and analyzed the water situation, plans, and agreements on water allocation for five activities, including 1) consumption; 2) agriculture; 3) water diversion of the Prasae Reservoir – the Khlong Yai Reservoir; 4) Water diversion of the Prasae Reservoir – the Nong Pla Lai Reservoir; and 5) ecosystem preservation. Finally, the water allocation plan was informed and publicized to IWUGs and other related water users. However, the Prasae Operation and Maintenance Project monitored field operations once water allocation began. The water allocation plan was revised weekly or monthly based on the needs of local farmers.

Water allocation normally starts on January 10 of every year. In 2020, however, severe droughts have been encountered in Chonburi and Rayong Provinces. Farm pools had run dry and some drilling sites were unable to find groundwater. IWUGs have requested the Prasae Operation and Maintenance Project postpone the water allocation to December 20, 2019. Farmers are more reliant on irrigation water than the usual year due to the expansion of durian plantations and water shortages for durian growth, while the water supply in the Prasae Reservoir has declined to near the dead storage (Figure 40). This has resulted in the relevant water management departments, especially RID, urgently coordinating and cooperating to find immediate solutions.

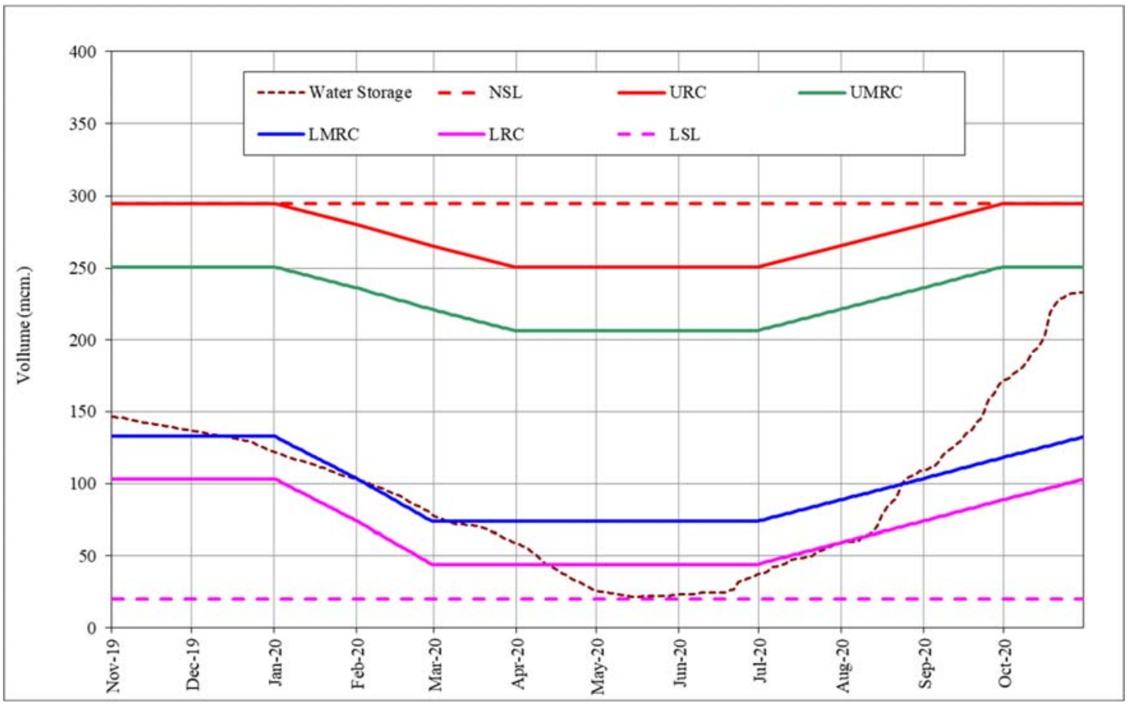

Figure 40. Water Volume of the Prasae Reservoir in 2020 (From November 2019 to October 2020)

Source: Data from RID 9 (2021)

To alleviate the water shortage problem and reduce potential impacts on both agriculture and industry, RID diverted 10 million cubic meters of water from the Khlong Wang Tanod Sub-basin, a nearby sub-basin, to the Prasae Reservoir during the dry season. It was conducted between 1 March and 25 March 2020. A temporary pump station was also constructed to pump 15 million cubic meters of water from Khlong Saphan, a tributary of the Prasae River Sub-basin, back to the Prasae Reservoir to increase water storage in the Prasae Reservoir. It began pumping operations on April 29, 2020 (Figure 41).

At the end of the water allocation season, the Prasae Operation and Maintenance Project gathered data on the water allocation and the amount of water used throughout the year. This was to assess the water management results of the Prasae Reservoir and improve the water allocation plan for the following year. When water allocation plans and results were compared, it was found that the agricultural sector had higher water demand than planned, while other water use activities were either in accordance with the plan or under the water allocation plan (Figure 42). Drought and a delayed rainy season forced farmers to rely more heavily on irrigation water than usual. IWUGs asked the Prasae Operation and Maintenance Project to provide them with water until the end of May, or until the durian harvest was completed. Water trucks were used to distribute water to farmers in rainfed

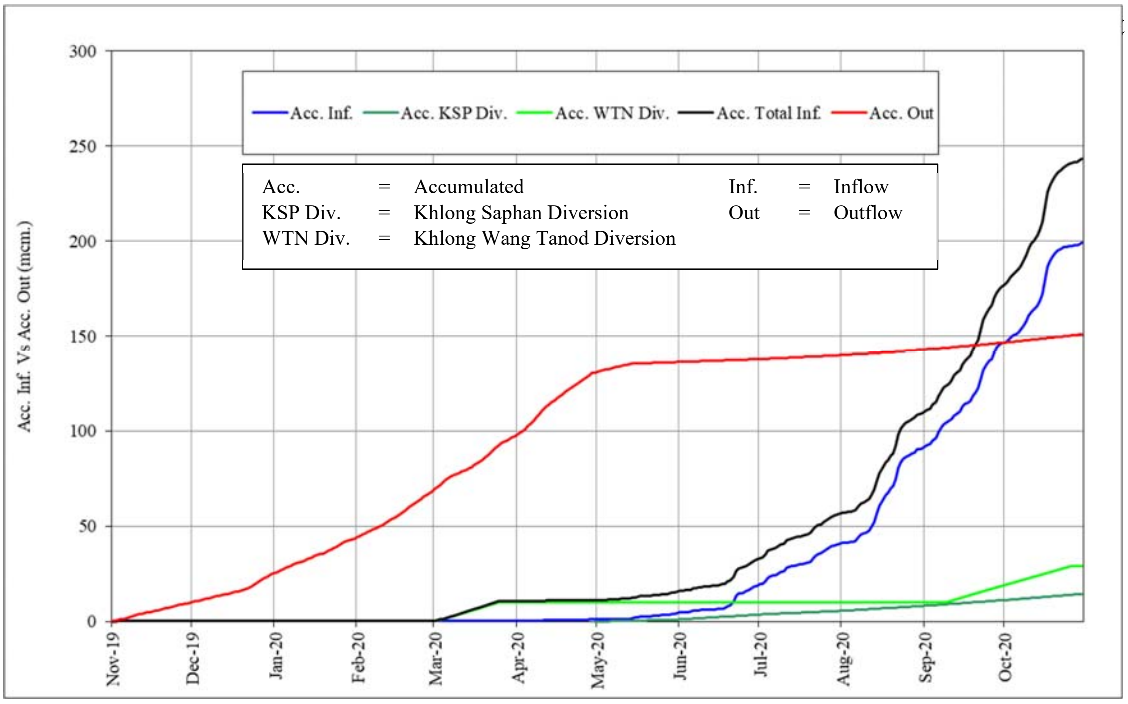

Figure 41. Water Diversion from Khlong Wang Tanod Sub-Basin and Khlong Saphan

Source: Data from the Prasae Operation and Maintenance Project (2020)

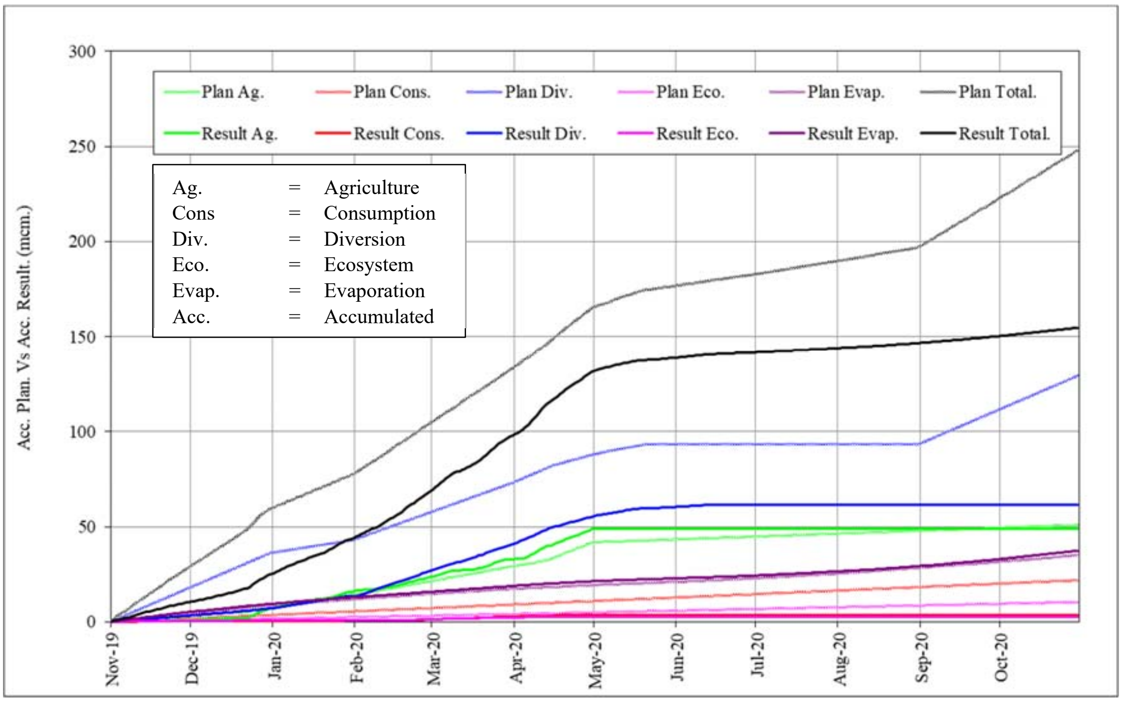

Figure 42. Plans and Results of Water Allocation of the Prasae Reservoir in 2020

Source: Data from the Prasae Operation and Maintenance Project (2020)

As stated in Chapter 3, the interviewees analyzed and proposed their perspectives on developing a situation map to provide an accurate representation of the Prasae Reservoir management system they agreed and accepted. The situation map consists of two parts: 1) the management of the Prasae Reservoir; and 2) the water allocation of the Prasae Reservoir. In the Prasae Reservoir water allocation situation map (Figure 43), climate change plays a key role in rainfall variability in the Prasae River Sub-basin. This affects the amount of water to be stored in the Prasae Reservoir during the rainy season and can lead to water use problems and water shortages during the dry season. The problem of water scarcity not only affects economic activity and people's livelihoods but also leads to water conflicts among water users in the Prasae River Sub-basin.

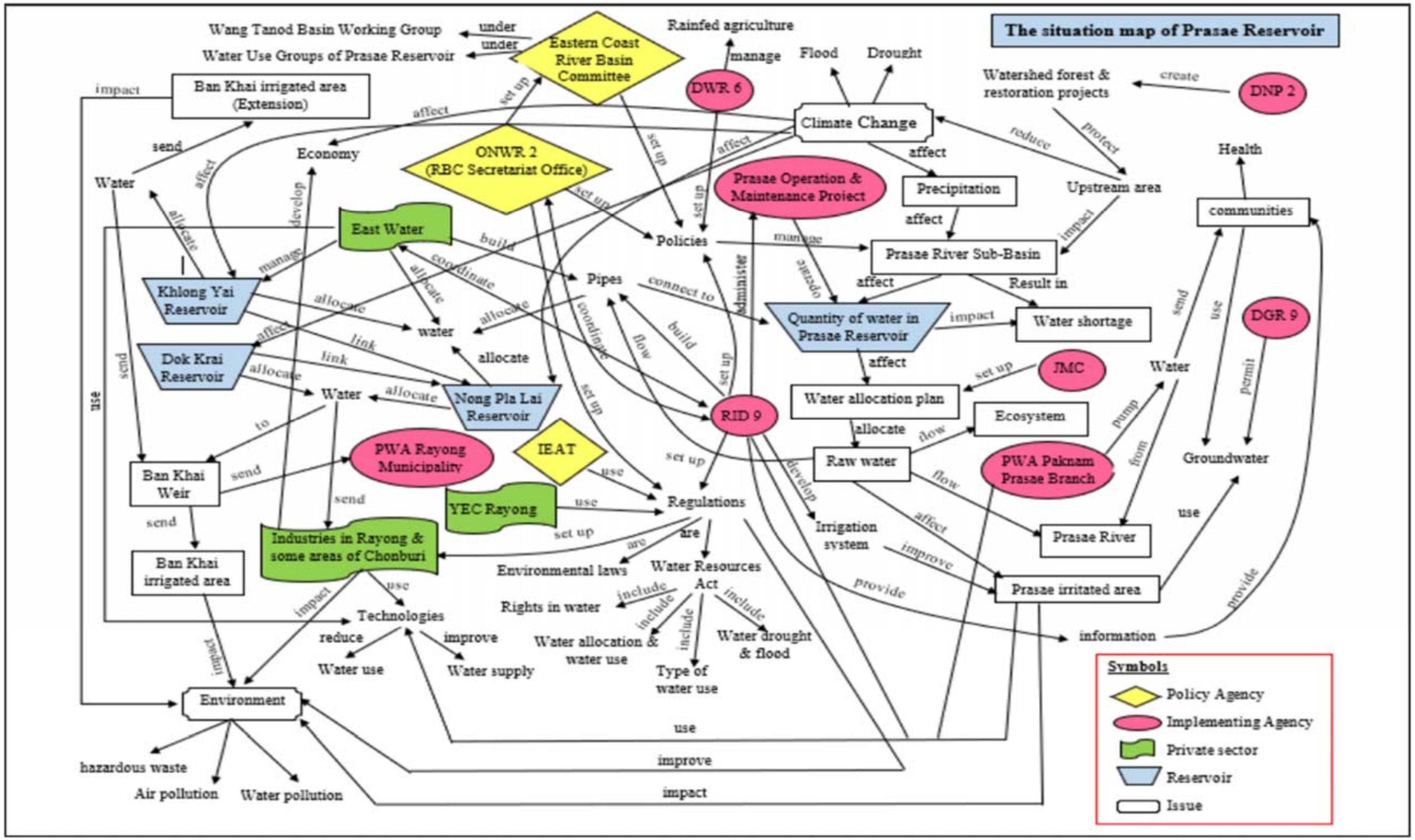

Figure 43. Situation Map of the Prasae Reservoir Water Management

Source: In-depth Interviews (2020)

JMC for Prasae Reservoir Irrigation has formulated a water allocation plan to ensure efficient water management of the Prasae Reservoir, maximize the benefits to society, and, thereby, create fairness among water users in this area. The water allocation plan can be divided according to the water use activities of the Prasae Reservoir into four categories such as 1) for consumption; 2) for agriculture; 3) for diversion to the Khlong Yai Reservoir and the Nong Pla Lai Reservoir; and 4) for maintaining the stability and health of ecosystems. Priority is given to the Prasae Irrigation Project first.

The purpose of the Prasae Reservoir is for consumption and agriculture as well as a reserve for industry and tourism. The Prasae Operation and Maintenance Project, the main agency for the management of the Prasae Reservoir, has developed an irrigation system to increase the efficiency of the water allocation system. Agriculture uses not only water from the Prasae Reservoir but also groundwater wells as a reserve water source in case of water shortages. The groundwater wells must be authorized by BGR 9 before proceeding.

Water from the Prasae Reservoir flows into the Prasae River Sub-basin through the river outlet. PWA Paknam Prasae Branch will then pump water from the Prasae River Sub-basin to produce tap water for the people's consumption in the service area. The remaining water will be used to maintain the ecosystem and diverted to the Khlong Yai Reservoir and the Nong Pla Lai Reservoir with the raw water pipes of RID and East Water, respectively. The diverted water will be allocated to water user groups in the Rayong area outside the Prasae River Sub-basin. This is intended for consumption, agriculture, and industry. The water management model is characterized by a reservoir network. This means that the Khlong Yai and the Dok Krai Reservoirs can divert water to the Nong Pla Lai Reservoir by gravity, which is connected by pipelines. As a result, the management of the Khlong Yai and the Nong Pla Lai Reservoirs must be considered along with the Dok Krai Reservoir to meet the needs of water users in all sectors, especially industrial areas, which are important economic areas of Rayong and the country. RID 9 has closely coordinated and cooperated with East Water in implementing water allocation. This not only improves water management efficiency but also contributes to sustainability and water security. As for rainfed agriculture, it is administered by DWR 6 while DNP 2 is responsible for the conservation and restoration of watershed forests.

ONWR, which is the central organization for regulating and integrating the nation's water management, cooperates with relevant agencies to formulate policies and plans for the water management of the Prasae Reservoir along with the use of appropriate technology such as mathematical models, GIS, and integration with relevant agencies in drought and flood forecasting. IEAT is responsible for developing and providing utility services according to the needs of entrepreneurs within the industrial estates, with the goal of becoming a smart eco-industrial estate. YEC Rayong plays a role in promoting and developing competitiveness for entrepreneurs in Rayong Province by using innovation as a driver for sustainable growth. Both IEAT and YEC Rayong use regulations to promote and control the efficient use of water in the manufacturing process and reduce environmental impact. ONWR has also used a mechanism of RBC, which consists of representatives from government agencies. local administrative organizations, and water users from all sectors. RBC is responsible for determining the allocation of water, prioritizing water use, and dispute resolution between water users.

In the Prasae Reservoir water allocation situation map (Figure 44), the Prasae Operation and Maintenance Project, which is administered by RID 9, is responsible for planning, controlling, and inspecting, as well as water allocation and maintenance of the Prasae Reservoir irrigation system. Water allocation planning during the dry season will be influenced by the amount of water stored in the Prasae Reservoir during the rainy season.

JMC for the Prasae Reservoir Irrigation consists of the Chairmen of IWUGs, local agencies, village headmen, industry representatives, and the head of water management and irrigation system improvement of the Prasae Operation and Maintenance Project. They are responsible for mediating, resolving conflicts, and making decisions on the water management of the Prasae Reservoir as well as preventing flooding and water shortages.

The irrigation system of the Prasae Reservoir is divided into two parts: One is the left bank canal system and another is the right bank pipeline system. Water will flow to the left canal outlet works by gravity system to be allocated to agricultural irrigation on the left bank of the Prasae Reservoir. For the right bank of the Prasae Reservoir, water will be allocated by water pipeline systems with pumping systems to allocate to the right bank irrigated agriculture area. Water from the Prasae Reservoir also flows to the Prasae River Sub-basin through the river outlet. PWA Paknam Prasae Branch will then pump water from the Prasae River Sub-basin to produce tap water for the people's consumption in the service area.

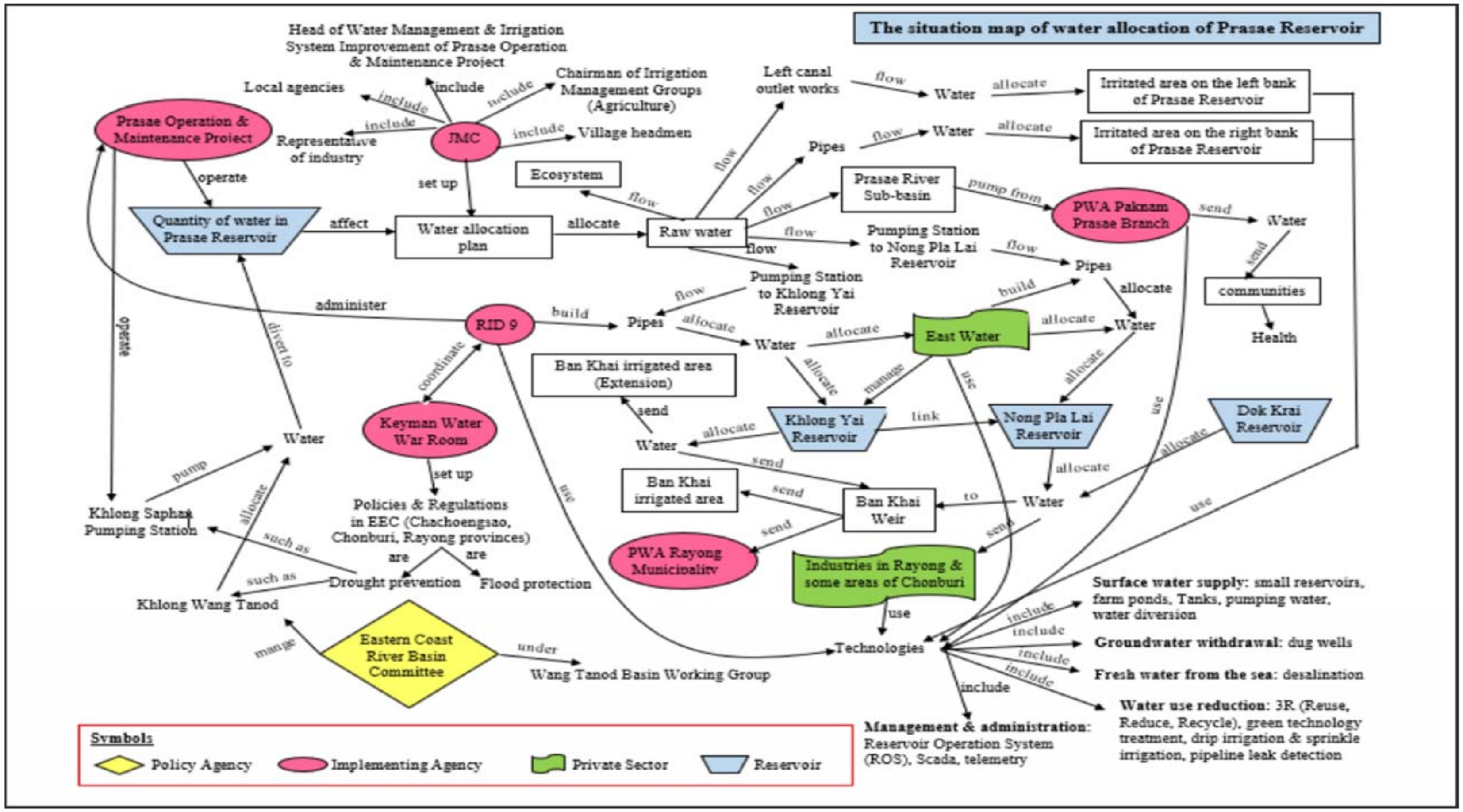

Figure 44. Situation Map of the Prasae Reservoir Water Allocation

Source: In-depth Interviews (2020)

The Prasae Reservoir has also diverted water to the Khlong Yai Reservoir and the Nong Pla Lai Reservoir to promote and support the industrial sector in Rayong Province and some areas in Chonburi Province. The amount of water diverted to the Khlong Yai Reservoir will flow from the Prasae Reservoir into the Khlong Yai Pumping Station. Then, it will be pumped to the Khlong Yai Reservoir by a pipeline system built by RID. Meanwhile, the amount of water diverted to the Nong Pla Lai Reservoir will flow from the Prasae Reservoir into the Nong Pla Lai Pumping Station and then be pumped to the Nong Pla Lai Reservoir with a pipeline system built by East Water.

The management of the Khlong Yai and the Nong Pla Lai Reservoirs needs to be considered alongside the Dok Krai Reservoir as a reservoir network as RID 9 and East Water have developed a piping system by connecting them to enhance water management efficiency. Water can then be diverted from the Khlong Yai and the Dok Krai Reservoirs to the Nong Pla Lai Reservoir by gravity through this pipeline system. As a result, East Water has received permission from RID 9 to manage water for both the Khlong Yai Reservoir and the Nong Pla Lai Reservoir. The amount of water from the Khlong Yai Reservoir will be allocated for agriculture in the Ban Khai Extended Irrigation Area, while the amount of water from the Dok Krai Reservoir will be allocated directly to the industrial area. The water management of the Nong Pla Lai Reservoir will be allocated to various water user groups, comprising consumption, agriculture, and industry. The water from the three reservoirs flows into natural waterways, namely the Khlong Yai River (Rayong River). It then flows to the Ban Khai weir, where it is used for two purposes: 1) producing tap water for PWA Rayong Municipality; and 2) irrigation for agriculture. The remaining water will be allocated to industrial areas in Rayong and certain areas in Chonburi.

Technology has been used by both public and private organizations to improve water management. These technologies consist of surface water procurement, groundwater withdrawal, desalination, and water use reduction, as well as water management and administration. The Prasae Reservoir is the Eastern Region Water Management Hub. RID 9 cooperates with the Eastern Water Operations Center (Keyman Water War Room) to formulate policies and plans for water resources development projects and drought prevention measures to support the development of EEC. It is expected to increase industrial capacity and reduce the risk of water shortages during the dry season, which will aim at sustainable water management. The water resource development project that will increase the amount of water supply for the Prasae Reservoir consists of two projects: 1) the project of pumping water back from Khlong Saphan to the Prasae Reservoir; and 2) the project of water diversion from the Khlong Wang Tanod Sub-basin to the Prasae Reservoir. It is a water diversion within the same basin because both the Prasae River Sub-basin and the Khlong Wang Tanod Sub-basin are parts of the East Coast Gulf Basin. Both projects will be implemented during the rainy season. Due to the severe drought, however, there have been negotiations and agreements with water users to request temporary water pumping and water diversion as a special case during the 2020 dry season.

4.1.4 The Linkage of the Water Resources Network

The water management model in the Eastern Region, especially the provinces of Chonburi and Rayong, must be considered as a reservoir network system to increase water management efficiency and create water security with the goal of achieving water sustainability (Figure 45). The Prasae Reservoir serves as the Eastern Region Water Management Hub because it not only receives water from vicinity Sub-basins to increase its water supply but also diverts the water to other reservoirs or key areas for the maximum benefit of society and to alleviate drought and flood prevention. Its maximum storage is 295 million cubic meters of water and can be allocated water for consumption and agriculture and as a reserve for the industry. The Prasae Reservoir discharges water into the Prasae River basin through the river outlet to maintain the natural flow. At the downstream area, PWA Paknam Prasae Branch then pumps water from the Prasae River Sub-basin at the area in front of the Nong Waen Regulator to produce tap water for consumption.

RID built a water pipeline to divert the remaining water in the area from the Prasae Reservoir to the Khlong Yai Reservoir, while the pipeline connection between the Prasae Reservoir and the Nong Pla Lai Reservoir was invested by East Water. However, both RID and East Water have closely coordinated and collaborated on water management. RID also built a water pipe connecting the Khlong Yai and the Dok Krai Reservoirs to the Nong Pla Lai Reservoir with a total capacity of 269 million cubic meters. This water will be allocated to water users in Rayong, an area outside the Prasae River Sub-basin, and to support industrial areas in Rayong and some areas in Chonburi Province. In addition, RID has renovated the pumping station located at Lahan Rai Temple to pump water from the Rayong River back to the Nong Pla Lai Reservoir during the rainy season to increase water storage to meet the needs of water users.

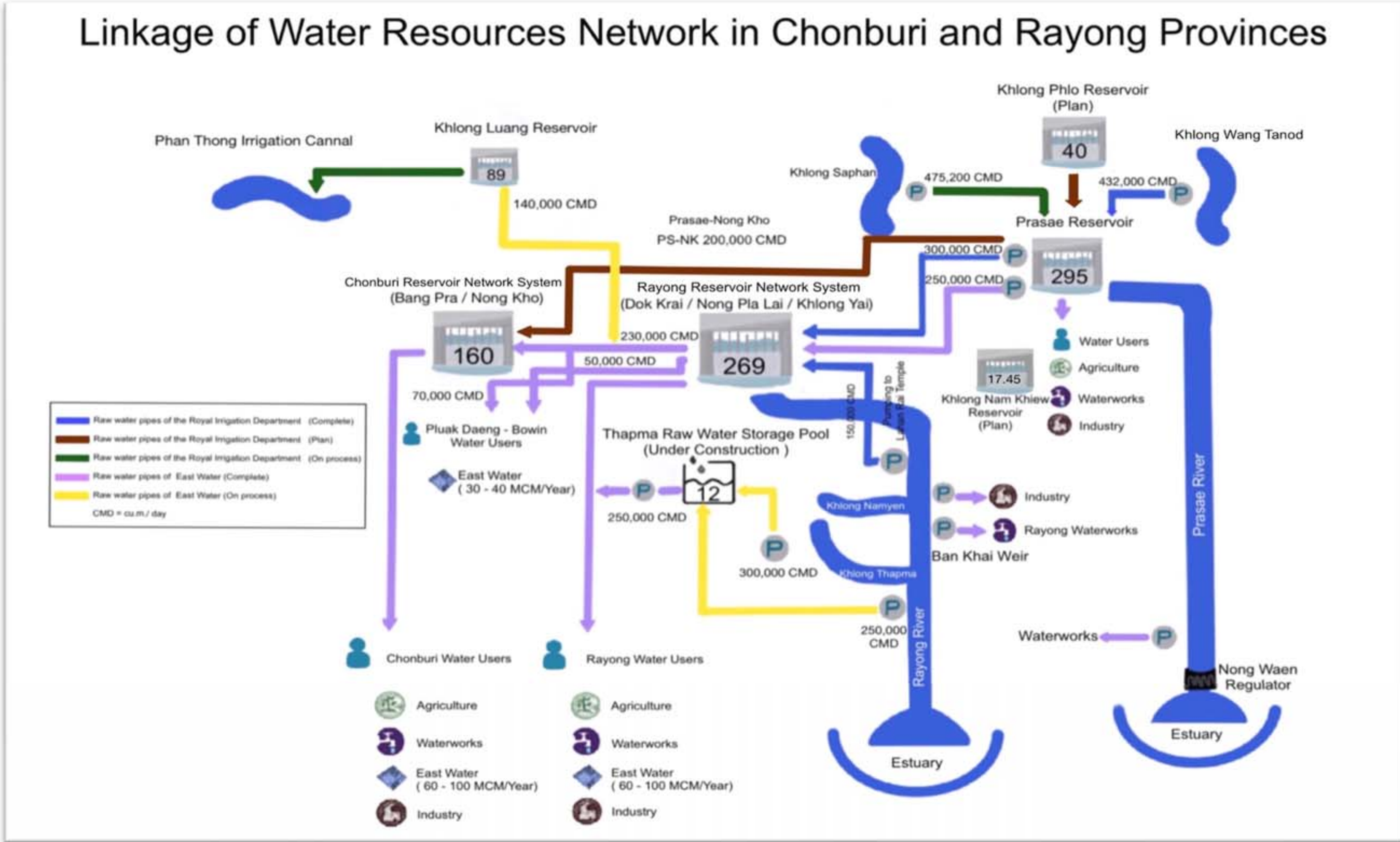

Figure 45. The Linkage of the Water Resources Network in Chonburi and Rayong Provinces

Source: Adapted from ONWR (2020)

The excess water in Rayong Province can be diverted from the Rayong reservoir network system to the Bang Phra and Nong Kho Reservoirs to help water users in Chonburi with the existing pipeline system built by East Water. The government has promoted EEC, which covers three Provinces such as Chachoengsao, Chonburi, and Rayong. It increases the capacity of the industrial sector and propels Thailand into an ASEAN major economic zone. This has resulted in a rapid increase in water demand. ONWR, a central organization for integrated water management, cooperates with relevant agencies to plan water resources development projects to increase water supply and resolve droughts in the area. Water resources development projects are as follows:

1. The construction of a pumping station to pump water from the Khlong Saphan back into the Prasae Reservoir, which is in the process of construction. After the construction is completed, it will pump water during the rainy season.

2. The water diversion project from the Khlong Wang Tanod Sub-basin in Chanthaburi Province to the Prasae Reservoir. The water diversion will be carried out during the rainy season.

3. The construction of the Khlong Phlo and Khlong Nam Khiew Reservoirs, with a capacity of 40 million cubic meters and 17.45 million cubic meters, respectively. It is expected to start construction in 2022. As for Klong Phlo Reservoir, it will be able to divert water to the Prasae Reservoir by gravity after its completion.

4. The construction planning of water pipelines from the Prasae Reservoir to the Nong Kho and the Bang Phra Reservoirs in Chonburi Province. This is to increase the

amount of water supply for consumption, industry, and tourism to meet the current and future water needs.

Moreover, East Water is in the process of constructing the Thapma raw water storage pool with a capacity of 12 million cubic meters. Water is pumped from the Rayong River and Khlong Thapma to this pool during the rainy season as a water reserve in the dry season. The Eastern Region, however, experienced a drought in 2020. RID collaborated with East Water and the industrial sector to construct a temporary pumping station to pump water from Khlong Saphan back to the Prasae Reservoir to increase water storage in the reservoir. RID also diverted water from Khlong Wang Tanod Sub-basin to the Prasae Reservoir to alleviate drought problems for water users in Rayong Province.

The main problem in the Eastern Region is heavy rainfall during the rainy season, but it lacks water storage. This results in water scarcity during the dry season. A Reservoir network system is the management of water from one reservoir with a large volume of water to another with a small volume of water by connecting pipes. This is to ensure that people have enough water throughout the year. It not only optimizes the management of existing or excess water to meet water demand and mitigate drought and flood prevention but also maximizes benefits for society and creates fairness for all sectors. This will achieve sustainable water management and create water resource security in the area.

4.2 Water Management Technology for the Prasae Reservoir and Water Users

Technological advances play an important role in water management planning and water security – from collecting and analyzing data on water resources and increasing water supply, to reducing water use and wastewater reuse. To increase the capacity and efficiency of water management of the Prasae Reservoir, appropriate technologies are considered and implemented by the area conditions and water use activities. These technologies consist of surface water procurement, groundwater withdrawal, desalination, and water use reduction, as well as water management and administration. In this study, the stakeholders selected and applied the technology to suit the water situation, water use activities, water demand and budget, as well as cost-effectiveness as follows:

1. **Government agencies**

ONWR, as the national water management regulator, has developed a water resource database to forecast the water situation, which contains statistical data and forecast data. Data collection is performed under the same standards to provide accurate forecasting of the water situation. Water management is analyzed and planned using remote sensing and satellite imagery. The National Water Administration Center was created to monitor, prevent, and warn about water emergencies. To integrate the Water Resources Action Plan, ONWR has also created a website called Thai Water Plan. Local governments and the public can contribute to the development of work plans and closely monitor the water situation.

RID 9 and the Prasae Operation and Maintenance Project have installed the rain gauge station, automatic rain gauge system, evaporation measurement station, and telemetry system. Rainfall and runoff statistics and water volumes in the Prasae Reservoir are stored in an information database system to analyze and plan Prasae Reservoir water management. Daily water condition observations and reports are available for monitoring and decision-making in the Prasae Reservoir water management. GIS is used in the mapping of the Prasae Operation and Maintenance Project and agricultural maps. Statistical data on reservoir inflow and water consumption of each plant species were also used to analyze the water supply of the Prasae Reservoir by using the Reservoir Operation System (ROS) to formulate policies and plan water allocation.

To increase water storage capacity, the Prasae Reservoir installed a flap gate weir with a hydraulic system. A temporary pumping station (Figure 46) and a water diversion pipe system connecting the Prasae Reservoir and other reservoirs were built along with the establishment of the reservoir operation rule curve criteria to alleviate water shortages during the dry season, prevent flooding during the rainy season, and reduce the conflict between water user groups. Meanwhile, the Khlong Saphan pumping station is in the process of construction and is expected to be operational in 2021. In addition, RID 9 has planned to construct two additional smaller reservoirs: 1) the Khlong Phlo Reservoir, which can divert water to the Prasae Reservoir by gravity, and 2) the Khlong Nam Khiew Reservoir, which can help to reduce the water use of the Prasae Reservoir.

DWR 6 is responsible for non-irrigated areas by developing small water resources with a capacity of more than two million cubic meters. Pumps were installed to alleviate water shortages and check dams were built to store water, slow water flows, and increase soil moisture in the area. DWR 6 also has water risk assessments and supports water trucks and low-water farming. While the local government develops small water resources with capacities of less than two million cubic meters and constructs check dams.

Figure 46. Khlong Saphan Temporary Pumping Station

Source: Author (2020)

BGR 9 has established a project to drill groundwater wells for agriculture and survey and analyze suitable areas for shallow groundwater filling in the Prasae River Sub-basin and Rayong Province.

2. **State enterprises**

IEAT has formed the Plant Manager Club to monitor the water situation and find solutions to water shortage issues. It has a small water reserve pool with a capacity of 1.6 million cubic meters and a water pump was installed to pump water from Khlong

Thapma to use within the industrial estate area. IEAT also recycles water through reverse osmosis and procurement and purchase of water from the private sector.

PWA has installed a pumping station to pump water from the Prasae River Sub-basin to produce tap water and purchase raw water from the private sector. PWA also recycles water in the manufacturing process and uses the District Metering Areas system to inspect pipe leaks and reduce water loss. Chemicals are used to disinfect the water and the water quality is monitored to standards.

3. Agriculture sector

The agricultural sector is the largest user of irrigation water from the Prasae Reservoir. Farmers in the Prasae River Sub-basin primarily cultivate fruit, particularly durian, which is an important economic crop in the province and generates a lot of income for farmers. The expansion of durian plantation areas and the shift in land use from rubber plantations, which use little water, to durian planting, which requires a lot of water, has increased water demand. The increasing trend in the severity of climate change has resulted in flooding during the rainy season and water shortages during the dry season.

From planting to harvesting, durian requires a lot of water. When water resources are limited, one method of optimizing plant water demand and reducing excess water use is to use technology in water management. According to the findings of the interviews, IWUGs developed a plant watering system using sprinklers to reduce labor and water consumption. Farmers' knowledge and experience determined the amount of water and duration of crop irrigation because they lacked tools to analyze soil moisture. Some farmers continue to doubt the accuracy of soil moisture measurement technology and lack the knowledge to maintain it. Others, on the other hand, would prefer that the relevant agencies provide them with knowledge, training, and investment in moisture measuring instruments.

IWUGs have at least one farm pond to store water during the rainy season and use it to grow crops during the dry season (Figure 47). It could be used for about three months before being allocated water from the Prasae Operation and Maintenance Project.

Figure 47. Plantation Pond

Source: Author (2020)

In 2020, IWUGs faced severe droughts and water shortages. The water in the farm pond had run out. Even though they pooled their personal funds to pump water from public water sources to their farm pond, it was insufficient to meet their water needs. They also drilled groundwater wells to alleviate water shortages. Some drilling sites, however, were unable to find groundwater.

To prepare for future droughts, IWUGs have asked the government to dredge public pools so that more water can be stored during the rainy season. The chairmen of IWUGs asked for cooperation from members to build one farm pond per 1.6 ha (10 rai) of durian planting area.

4. Industrial sector

Water risk assessments are performed in industrial plants, and several water scenario examples are analyzed to plan water use and propose solutions. Industrial plants use the 3R (Recycle, Reduce and Reuse) principle to increase water efficiency. Industrial plants also have water reserve tanks that can be used within 5-7 days but most of them are intended for firefighting purposes. It is difficult to store water within factories due to the high cost of land, and IEAT is responsible for providing utilities to factories located within industrial estates. Desalination is used in some large factories.

5. Private sector

East Water holds a monthly Keyman Water War Room meeting to analyze and monitor the Prasae Reservoir's water situation. East Water invests in the Eastern Region's water security by constructing a large water pipeline network or Water Grid to effectively manage the entire water system. It can divert water from the Prasae Reservoir to the Khlong Yai, the Nong Pla Lai, and the Dok Krai Reservoirs to alleviate water shortages and support industrial activities. The remaining water can also be diverted for use in Chonburi and Chachoengsao provinces to support the development of EEC.

East Water has increased water management efficiency by using the control center system to manage the pumping system. It uses Supervisory Control And Data Acquisition (SCADA) to provide real-time monitoring of the pressure and volume of water in the pipeline and the volume of water in various water sources, which can reduce water loss in the pipeline by less than 3%. In addition, East Water has built a 12 million cubic meter Thapma raw water storage pool to store water during the dry season (Figure 48). It has also procured and purchased additional raw water from other private wells.

Figure 48. Thapma Raw Water Storage Pool

Source: Author (2020)

In terms of desalination, desalination's feasibility and cost-effectiveness are being studied in comparison to the use of other technologies and the supply of water from other existing water sources. The interview results revealed that government agencies, the private sector, and industrial water users stated that the eastern region and Rayong Province had quite a lot of rainfall but they were unable to manage the side flow of water back into the reservoir to increase water storage in the reservoir. If the government can find a way to manage water from downstream back into the reservoir before going out to the sea, Rayong Province will have sufficient water available throughout the year and will be able to meet future water demand. The Eastern Region can also develop low-cost surface water resources and wastewater recycling. Desalination, on the other hand, is still expensive and may not be worth the current investment.

4.3 Participation of Stakeholders in the Prasae River Sub-Basin and the Prasae Reservoir

Before and during the water allocation in 2020, The Prasae Reservoir Operation and Maintenance staff informed water users about the water available situation of the Prasae Reservoir through a two-step water management meeting. The first step was a meeting of IWUGs, who were farmers in the Prasae River Sub-basin. The objective was to clarify and forecast the water situation in the Prasae Reservoir and inquire about water demand for agricultural water use planning. The second step was a meeting of JMC to consider and plan water allocation for consumption, agriculture, water diversion to support industrial activities, and ecological preservation. The water users were aware of the agreement and the water allocation plan obtained from the meeting before implementing the water allocation during the dry season.

Representatives from each IWUG also participated in farm management to control self-irrigation structures in coordination with irrigation projects to control water allocation (Figure 49).

Figure 49. Public Participation in Opening – Closing Irrigation Structures.

Source: The Prasae Operation and Maintenance Project (2021)

IWUGs can currently set up meetings to discuss water solutions for crop cultivation with the irrigation staff by using the headman's office. The Prasae Operation and Maintenance Project has published the daily water volume in the Prasae Reservoir on Facebook so that the public can participate in monitoring the water situation and water management in the Prasae Reservoir. It also creates channels for stakeholder feedback through phone, mail, organizing meetings, social media, and comment boxes, as well as a survey of farmers' satisfaction with irrigation staff water management.

It is important to communicate and create an understanding of water management between all sectors. Water management must be considered in a holistic manner as farmers need water for agriculture while the industry is vital to the country's gross domestic product and foreign investor confidence. The water allocation of the Prasae Reservoir is requested to be allocated to the people in the Prasae River Sub-basin first. If there is any remaining water, it can be diverted to other reservoirs or other areas.

Water is a basic human right that can be shared. Farmers agree and accept to divert the remaining water for various purposes based on JMC rules and reservoir operation rule curve criteria. Farmers were compensated for the loss of opportunity to divert water from the Prasae Reservoir to the Khlong Yai and the Nong Pla Lai Reservoirs. The compensation is received in the form of Corporate Social Responsibility (CSR). This means that farmers who want to use this budget must submit plans and projects to improve the water efficiency of the Prasae Operation and Maintenance Project through the CSR Committee. Water is a public good, so its allocation must be equitable. Successful sustainable water management requires negotiation between management and water users.

For the conservation and restoration of watershed forests, farmers have collaborated with local authorities to reforest and vetiver grass to reduce soil erosion and to build weirs in watershed areas.

4.4 Conflict among Water Users of the Prasae Reservoir

Conflicts in water use and water allocation have become major problems between agriculture and industry. The problem is deciding how much water each sector should get. Although agriculture is the main occupation of the Rayong people, the industry is the primary source of income for provinces and countries (Thejui, 2007). The main cause of the conflict stems from the government's policy to support the Eastern Economic Corridor project, which aims to drive Thailand into the key economic zones of ASEAN. As production capacity expands, it has resulted in a sharp increase in short-term water demand (Aksornkit, 2018). Moreover, the Rayong and Chonburi Provinces experienced a severe dry season in 2020. Rainfall in the Prasae River Sub-basin was lower than the average. Irrigation water requirement was more than a normal year then the water level in the Prasae Reservoir was near the dead storage. Farmers protested and urged the government to suspend water allocation to the industrial sector until durian harvesting was completed in May. Although farmers were also compensated for diverting water from the Prasae Reservoir to the Khlong Yai and the Nong Pla Lai Reservoirs, they remained concerned that the available water supply might be insufficient and affect agricultural productivity.

Relevant agencies have negotiated between agricultural and industrial water users to find solutions to alleviate the problem of water scarcity. As a result of the negotiations, RID signed a memorandum of understanding with the chairman of the Wang Tanod Sub-basin Working Group to divert the remaining 10 million cubic meters of water from Khlong Wang Tanod Sub-basin to the Prasae Reservoir during the dry season. Farmers in the Khlong Wang Tanod Sub-basin were also compensated for the opportunity cost of water diversion. This water was allocated for all water use activities of the Prasae Reservoir. Furthermore, a temporary pumping station was constructed to pump water from

Khlong Saphan, one of the Prasae River Sub-basin tributaries back to the reservoir to increase water storage in the Prasae Reservoir during the 2020 dry season.

Conflicts between farmers and government agencies in the case of the diversion of water to solve the water shortage problem of industrial sectors are one of the deep-rooted administrative problems. The negotiating process between management and water users is the key to reducing the water conflict efficiently and effectively, better than regulation or the law.

Water allocation for agriculture has clearly set the date and time for the opening and closing of irrigation structures in each area so that the water pipe system of the Prasae Reservoir has enough water pressure to allocate water to farmers downstream. However, some upstream farmers opened irrigation structures to pump water into their farms without permission, resulting in conflicts among agricultural water users. In this connection, the meeting to solve the problem was conducted with the village headman or irrigation project staff acting as a mediator.

4.5 Discussion of Findings for Research Questions

This section illustrates the findings of in-depth interviews and data analysis to provide answers to research questions and research hypotheses. The interviewees had good knowledge and experience in water management and the water user organization was strong. All sectors are aware of the importance of technology and participation in the water management of the Prasae Reservoir. These findings will contribute to the success of the Prasae Reservoir's sustainable water management and the reduction of water conflicts in Rayong Province.

4.5.1 Research Question 1

My first research question is "what is the optimal, just, and sustainable method for managing available and excess water of the Prasae Reservoir, considering balancing the needs to allocate water efficiently, maximize the benefits to society, and, thereby, create fairness between water users?" Challenges in water management of the Prasae Reservoir to meet the water needs of all sectors are identified in sections 4.1 to 4.4. Based on the water challenges identified by this research in answering this research question, Rayong Province has a high potential for both agricultural productivity and industrial capacity enhancement. It significantly increased water demand. The government recognizes the importance of water management as water is the primary driver of production and use in human activities. Systematic water management will reduce conflicts between the industrial and agricultural sectors. Decision-makers and relevant agencies need to consider from the policy level to laying out water management guidelines for sustainability and water security in the Eastern Region and Rayong Province.

The water management of the Prasae Reservoir requires consideration of the elements and relationships that exist within the system because the Prasae Reservoir is interconnected by a large pipeline system. It can receive water from vicinity Sub-basins to increase water storage and divert water to other reservoirs and key areas in Rayong and some areas in Chonburi Province. This is for the benefit of consumption, agriculture, and support for industrial activities.

Before allocating water from the Prasae Reservoir, officials from the Prasae Operation and Maintenance Project met with IWUGs to inquire about agricultural water demand. JMC will then make a water allocation plan that includes consumption, agriculture, water diversion, and ecosystem preservation based on the water situation and water available in the Prasae Reservoir. The water allocation plan will be published to IWUGs before implementing the water allocation process.

The diversion of water from the Prasae Reservoir to other reservoirs and the control of water allocation to farmers will be considered in accordance with JMC's regulations and the reservoir operation rule curve criteria which are accepted by all sectors. As a result, conflicts between agricultural and industrial water users can be reduced. The remaining water is diverted to other reservoirs to maximize water use, while farmers in the Prasae River Sub-basin are compensated for the loss of opportunity.

The linkage of the water management network and the clear water diversion criteria of the Prasae Reservoir can not only alleviate the problem of water scarcity during the dry season and prevent flooding during the rainy season but also increase the efficiency of water management for maximizing benefits to society and creating fairness for water users

4.5.2 Research Question 2 and Research Hypothesis 1

In section 4.2, I attempted to find an answer to my second research question, “how can appropriate technologies increase the capacity and efficiency of water management in the Rayong area?” along with the assumption that “appropriate technology can increase the capacity and efficiency of water management in the Rayong area”. The main economic base of Rayong Province is agriculture and industry. Economic development and industrial expansion have resulted in increased demand for water (RID, 2019). Climate change also affects rainfall variability, which increases the risk of drought and flooding.

The Prasae Reservoir serves as the Eastern Region water management hub. Both water scarcity and flooding have become challenges in Prasae Reservoir's water management, requiring systematic solutions for long-term water management. Technology plays an important role in planning and increasing the water management efficiency of the Prasae Reservoir. The technology chosen will be determined by the site conditions, water use activities, and the cost-benefit analysis of the investment.

Effective planning of the Prasae Reservoir water management requires a database of reservoir water volumes, rainfall, and runoff to provide accurate analysis and forecasting of the water situation. This allows relevant agencies to develop plans and measures to meet growing water demand while also reducing the risk of water shortages. The Prasae Reservoir is connected to other water management networks by pipelines with a control center. It can remotely command and control water delivery with the SCADA system, which can closely monitor and solve water delivery problems. It also reduces water leaks in the pipelines. Water diversion has the potential to improve water management efficiency in both dry and wet seasons. The remaining water can be diverted to other sources to alleviate drought and flooding.

In terms of developing water management structures, the relevant agencies have built a pumping station to pump water from Khlong Saphan back to the Prasae Reservoir. They also planned to construct more small reservoirs and check dams. Agricultural water users have poods to store water for use during the dry season to reduce the use of irrigation water from the Prasae Reservoir, while industrial water users use the 3R (reuse, reduce, recycle) principle and wastewater reuse to maximize water use.

Appropriate technology not only improves the Prasae Reservoir's water management capacity but also results in sustainable water management and water security in Rayong Province.

4.5.3 Research Question 3 and Research Hypothesis 2

I also responded to my third research question, “how does public participation affect the sustainable water management of the Prasae Reservoir? Are most stakeholders able to accept that excess water will be diverted to other areas, depending on the situation and season?” along with the research hypothesis that “public participation affects the sustainable water management of the Prasae Reservoir. Most stakeholders can accept the excess water that will be diverted to other areas, depending on the situation and season” in section 4.3. As stated in Chapter 2, the Prasae Operation and Maintenance Project has developed and strengthened water management by establishing IWUGs and JMC to ensure efficiency and maximize benefit in the water management of the Prasae Reservoir. The public can participate in the Prasae Reservoir's water management, from water allocation planning and control to monitoring and evaluation. The Prasae Operation and Maintenance Project will inform water users about the current water situation, available water supply, and water forecasts of the Prasae Reservoir through meetings, community leaders, and social media. Water situation information will help water users understand the problem and create a mutually acceptable solution.

The water allocation plan of the Prasae Reservoir will survey the farmland and inquire about the water needs of farmers as well as the water demand for consumption. During water allocation, the Prasae Operation and Maintenance Project reports the daily water situation of the Prasae Reservoir on Facebook so that water users can closely monitor the water situation. It also holds monthly meetings with water users.

Water management should promote communication and create understanding among water users to reduce water conflicts. The Prasae Reservoir's water allocation should be firstly allocated to farmers and water users in the area.

Water is a public resource that everyone has the right to use and access. Farmers and water users in the Prasae River Sub-basin agree and accept that any remaining or excess water can be diverted to other reservoirs or key areas in order to alleviate water shortages. The water diversion is controlled by JMC's rules and the reservoir operation rule curve criteria.

The Prasae Operation and Maintenance Project staff have monitored and assessed water management through the farmers' satisfaction survey. Feedback will be considered to improve water management efficiency in the following years. The public is also involved in the conservation and restoration of watershed forests and the construction of check dams to provide water for use during the dry season and to increase soil moisture.

Promoting public participation in water management will provide water users with knowledge and understanding of water situations and water allocation plans, as well as suggest valuable perspectives to increase the Prasae Reservoir's water management efficiency. It also reduces conflicts between water users, which will aim at achieving sustainable water management.

4.6 Review of the Prasae Reservoir's Existing Water Management Plan Using SWOT Analysis

The purpose of SWOT analysis is to help organizations in developing a complete understanding of all factors involved in decision-making, with an emphasis on leveraging strengths and opportunities to overcome weaknesses and threats (Schooley, 2022). It is a strategic planning technique that looks deep into your organization to determine strengths, weaknesses, opportunities, and threats. This will help in analyzing and assessing the organization's overall situation. Your organization's strengths and opportunities provide avenues for growth, while its weaknesses and threats drive improvements and help organizations identify emerging competition (Weston, 2018).

As stated in Chapter 3, I conducted a series of possible questions to analyze the strengths, weaknesses, opportunities, and threats in the water management of the Prasae Reservoir based on the results of an in-depth interview and literature review. The results of the SWOT analysis are presented in Table 9.

Table 9. A SWOT Analysis Matrix for the Prasae Reservoir Water Management

Strengths (S)	Weaknesses (W)
1. Organization 1.1 Personnel who have knowledge and competence to manage water are available. 1.2 The Prasae Operation and Maintenance Project has a strong water user organization and a competent JMC.	**1. Organization** 1.1 Lack of building confidence and understanding among people about the approach to prioritizing water allocation. 1.2 Lack of systematic data collection for water management analysis 1.3 Lack of monitoring and maintenance of the availability of tools to assist in water management 1.4 Lack of studies, analysis, and knowledge gathering on the daily water demand of durian

Strengths (S)	Weaknesses (W)
2. Budget 2.1 Budgets have been allocated for water resource development projects to increase the water supply for the Prasae Reservoir, and the adoption of appropriate technology to optimize water management.	**2. Budget** 2.1 The government's budget is insufficient to fully expand the water allocation system for farmers in irrigated areas, including the cost of electricity used to pump water to them.
3. Management and administration 3.1 The Prasae Reservoir is the Eastern Region Water Management Hub. 3.2 Government agencies have close cooperation with the private sector in water management. 3.3 Before moving forward with annual water allocation, a meeting will be held with water users from all sectors to determine the water allocation criteria for each activity. 3.4 Coordination is in place with water management agencies and water users from all sectors to monitor the water situation each month and disseminate information through social media. 3.5 Preparatory measures are in place to prevent drought and flood, including an annual water risk assessment. 3.6 The future trend of increased water use is being studied and analyzed to develop effective and sustainable water management methods, as well as to build water security. 3.7 Coordination with the water user group chairman in each area to determine the allocation intervals in the irrigation canals, enabling the equitable allocation of water.	**3. Management and administration** 3.1 Inadequate measures to control land-use change, particularly the rapidly increasing demand for durian cultivation, a water-intensive crop. 3.2 Some of the regulations are complex and hinder coordination between government agencies, thereby delaying implementation. 3.3 Some agricultural water users fail to comply with the group's agreement on water allocation periods, resulting in conflicts between water users. 3.4 Water user groups provide information on the cultivation and use of water inaccuracies.
Opportunities (O)	**Threats (T)**
1. Organization 1.1 Information technology and social media advancements can be used to boost work productivity. 1.2 Thailand has the National Water Act B.E. 2561 (2018) and water management master plans as tools for water management.	**1. Organization** 1.1 Government agencies and Local Administrative Organizations do not understand the decentralization policy, resulting in ineffective overall water management and maintenance.
2. Budget 2.1 The Government promotes EEC, which emphasizes enhancing the capacity of the industrial sector and propelling Thailand into an ASEAN major economic zone. 2.2 Public-private partnerships (PPPs) improve water management efficiency, make water resources more cost-effective, and decrease the cost of water resource development projects.	**2. Budget** 2.1 The development and management of water cannot be carried out as planned due to the limited budget each year.
3. Management and administration 3.1 The nearby sub-basins have the potential to divert water to the Prasae Reservoir. 3.2 Businesses and industries that use excess water from the Prasae Reservoir have implemented appropriate technology to increase water supply and efficiency. 3.3 The industrial sector recognizes the importance of water use and thereby takes water-saving measures.	**3. Management and administration** 3.1 Climate change makes it difficult to forecast available water, which has an impact on water management. 3.2 The price of agricultural products has resulted in the increasing trend of farmers to shift from rubber cultivation which uses less water to durian planting which requires a lot of water.

Opportunities (O)	Threats (T)
3.4 The government recognizes the importance of water management of the Prasae Reservoir, which serves as a hub for water allocation to industrial and consumer areas in the Rayong and Chonburi Provinces.	3.3 Farmers in the Prasae River Sub-basin lack confidence that the agricultural sector will be considered the first for water allocation as the government promotes industrial development in the EEC. 3.4 Political instability affects the continuity of water resources development projects. 3.5 Other agencies involved in the implementation of water resources development projects have complicated procedures in considering laws and regulations, causing delays in their implementation. 3.6 Ineffective law enforcement has resulted in encroachment on public waterways, which impedes drainage. 3.7 All sectors have increased water demand.

As a result of the analysis, it is clear that the strengths of Prasae Reservoir's water management are that relevant personnel and agencies have expertise in water management. All sectors coordinate and cooperate in planning, analyzing, and closely monitoring the water situation. It has also invested in furthering the potential of the Prasae River Sub-basin and the Prasae Reservoir. The weaknesses are the need to create a database of Prasae Reservoir water management, particularly changes in land use and actual water demand for durian cultivation. It must also improve systematic water management and continuously promote water management knowledge and understanding. It necessitates the enforcement of rules among water users and clear penalties for offenders. There are opportunities to invest in water resource development projects with the private sector due to the development of important economic zones. Technological advances increase the potential for water use. Threats require measures to prepare for climate change. It also requires strict land-use controls and the determination of water rights.

4.7 Strategic Planning for Water Management Development of the Prasae Reservoir Using TOWS Matrix

The TOWS Matrix is a tool for comparing and contrasting different strategies to select the best one for the organization based on the interaction of internal and external factors (e.g., strengths-opportunities, weaknesses-threats) (Praxie, n.d.). Internally, an organization leverages its strengths and overcomes weaknesses, while externally, it seeks business opportunities and possibilities and learns how to control and mitigate potential threats (Mulder, 2017). A TOWS Matrix's purpose is to help organizations in developing strategic options based on their SWOT analysis (EPM, 2019).

After summarizing all of the information gathered in the SWOT Matrix, my next step is to develop strategic options and choose one or more of them to pursue using the question guide outlined in Chapter 3. Table 10 shows how the TOWS analysis connects extrinsic and intrinsic factors.

Table 10. TOWS Matrix for the Prasae Reservoir water management

Internal Factors / External Factors	Strengths (S)	Weaknesses (W)
Opportunities (O)	**S1.1, S3.1 + O3.1** Build a linkage of the water management network project in the form of a reservoir network system for sustainable water management. **S1.2 + O3.4** Established the Prasae Reservoir Water Resource Development Fund to improve and optimize the water use of the Prasae Reservoir. **S2.1, S3.2, S3.6 + O1.2, O2.1, O2.2** Increase the capacity of the Prasae Reservoir by developing water resource infrastructure and additional water resource development projects. **S3.3, S3.4, S3.5, S3.7 + O1.1, O3.2, O3.3** Build cooperation and promote participation between the government and water users from all sectors in planning	**W1.1, W1.2, W3.4 + O1.1** Create a database system, agricultural water user registration system, and decision support system, as well as a monitoring system for transparency and fairness in water management of the Prasae Reservoir. **W1.3, W2.1 + O2.1, O2.2** Encourage and support cooperation with the private sector in implementing water resources development projects to reduce problems in the government's budget, technology, and manpower. **W1.4, W3.3 + O3.1, O3.4** Study and analyze water demand in each activity and land-use change to forecast increased water demand for water resource planning and development.

Internal Factors / External Factors	Strengths (S)	Weaknesses (W)
Opportunities (O)	urgent water management, short- and long-term plans for sustainable water management, and reducing water conflict.	**W3.1, W3.2 + O1.2, O3.2, O3.3** Review and modernize laws related to water management, promote smart farming, and measures to promote the improvement of production efficiency for tax benefits.
Threats (T)	**S1.1 + T1.1** Build knowledge and understanding of budget regulations and the preparation of integrated water management plans with relevant agencies to support the decentralization into Local Administrative Organizations. **S3.1, S3.2 + T2.1, T3.4, T3.5** Build international cooperation to find funding for water resources development and apply the appropriate technology. **S3.5, S3.6 + T3.1, T3.2, T3.7** Build a drought-flood forecast system, develop a model for forecasting water demand, and a model to predict the impact of land-use change, as well as a decision support system for water management of the Prasae Reservoir. **S1.2, S3.3, S3.4, S3.7 + T3.3, T3.6** Promote public relations and public participation in monitoring and offering opinions on water management of the Prasae Reservoir using social media such as Facebook, Chat, and the agency's website, including disseminating monthly the water situation and water allocation of the Prasae Reservoir to the public in simple language.	**W1.1 + T3.2, T3.3, T3.4, T3.7** Develop irrigation of the left-bank water pipeline to reduce water consumption, increase water storage, water allocation system, and water linkage system, as well as potential groundwater sources, to reduce conflicts among water users and ensure water security. **W1.2, W1.4, W3.1, W3.3, W3.4 + T3.1** Create a database system, a strong community network, and an information center linking the Prasae Reservoir water management network, as well as a climate change adaptation plan. **W1.3, W2.1 + T2.1** Develop personnel and knowledge in the maintenance of tools that help in water management. **W3.2 + T3.5, T3.6** Reduce work-in-process and create awareness among local people on the importance of public waterways for drainage. **W3.2 + T1.1** Increase Local Administrative Organizations' knowledge of understanding budgeting methods.

The TOWS analysis sheds light on effective strategies for developing a sustainable water management system for the Prasae Reservoir, resulting in water sustainability in Rayong and the Eastern Region.

4.8 Chapter Conclusion

This chapter presented results from an in-depth interview on the water management of the Prasae Reservoir. The data were divided into four groups: water policies and plans, technology, public participation, and water conflict.

Water management policies and plans must be considered and analyzed at both the policy and implementation levels. At the policy level, two aspects of water management are analyzed, comprising demand-side management and supply-side management, to ensure that all sectors have sufficient water and equal access to water resources while maintaining ecological balance. Drought mitigation strategies and guidelines are developed at the implementation level. The water management efficiency of the Prasae Reservoir is improved by analyzing its strengths, weaknesses, opportunities, and threats. To improve Prasae Reservoir's water management capacity, appropriate technology is essential in surface water procurement, groundwater withdrawal, and water use reduction, as well as water management and administration. Promoting public participation contributes to greater knowledge and understanding of the Prasae Reservoir's water situation and water management, resulting in more sustainable water management. Moreover, effective communication and negotiation between management and water users can help to reduce water conflicts and find mutually acceptable water solutions.

5. Results Analysis

Building on the preceding research, this chapter presents my preliminary analysis to examine what aspects of the process can be improved and developed to ensure water security, with the goal of sustainable water management of the Prasae Reservoir in Rayong Province. I considered the literature review in Chapter 2 and reflected on my findings in Chapter 4, focusing on the results of in-depth interviews and answers to my research questions. I will then provide recommendations and guidelines for improving the existing plans to increase the capacity and efficiency of the Prasae Reservoir water management.

5.1 Improving the Efficiency of Water Management of the Prasae Reservoir and Building Water Security in Rayong and the Eastern Region.

This study shows that the management of Prasae Reservoir's water for sustainability and fairness for all sectors still faces significant challenges because the Prasae Reservoir is linked to other reservoirs or vicinity Sub-basins by a large diversion pipe system. Therefore, the water management of the Prasae Reservoir must be considered in a holistic manner by emphasizing the system's interrelated components. I will consider factors and elements that can create water security to shift the paradigm towards sustainable water management of Prasae Reservoir in Rayon and the Eastern Region.

This discussion is structured from the perspective of a literature review and the empirical findings of this study, which are divided into five areas (Figure 50): 1) policy; 2) organization; 3) natural resources; 4) management; and 5) participation

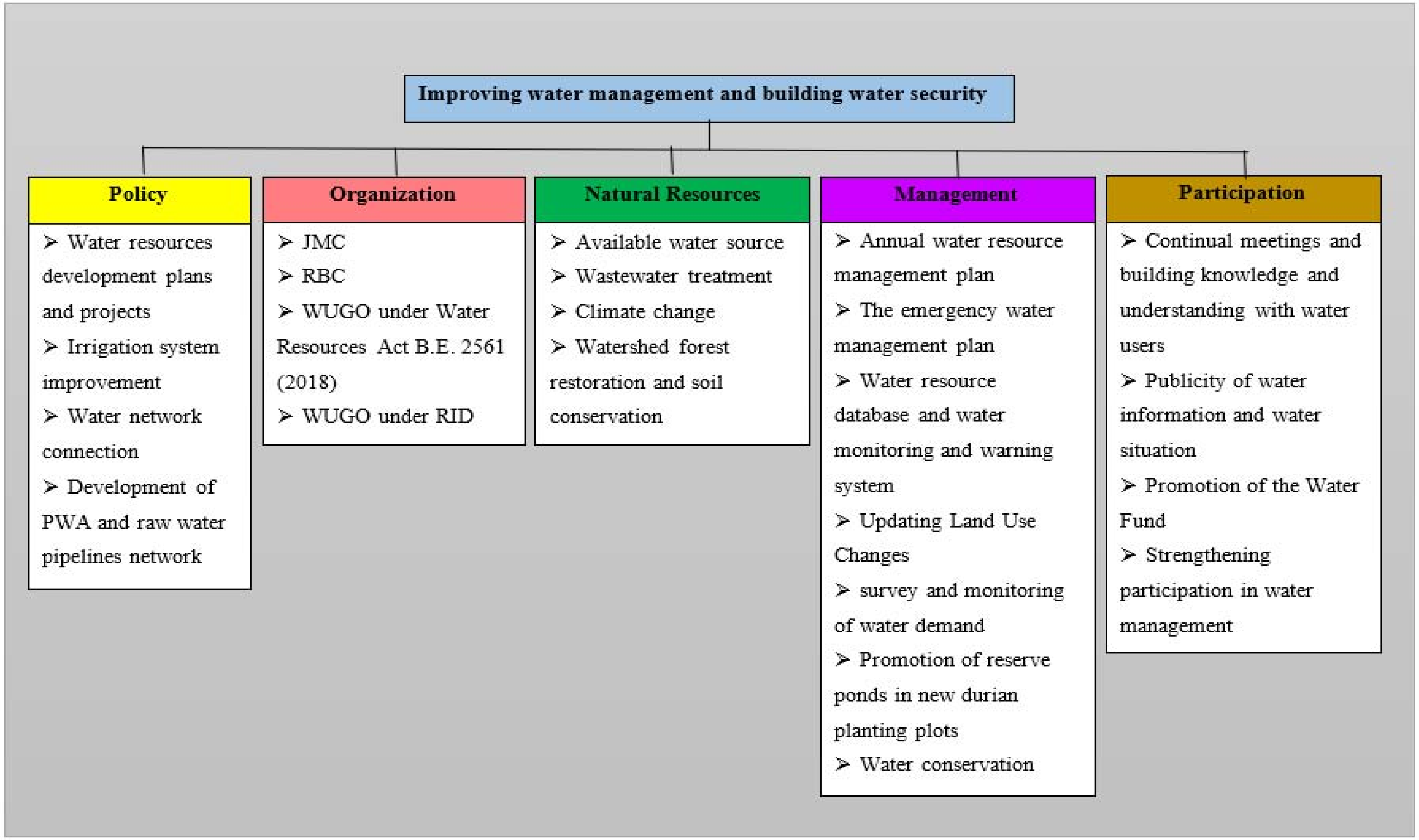

Figure 50. Improving Water Management and Building Water Security

Source: Author (2022)

5.1.1 Policy

The empirical findings in chapters 2 and 4 revealed that the government has promoted and supported EEC to enhance industrial capacity, especially in Rayong, Chonburi, and Chachoengsao Provinces. This resulted in a rapid increase in water demand. ONWR assessed the water demand in the EEC and discovered that all three provinces had a total water demand of 3,089 million cubic meters in 2037, representing a 670 million cubic meter increase from 2017. The domestic sector has the highest demand for water at 56%, followed by industry and agriculture at 43% and 17%, respectively (Prachachat, 2022). The Prasae Reservoir serves as the Eastern Region Water Management Hub. The challenge in water management is to manage a reservoir network connected by a large diversion pipe system to meet the needs, maximize benefits to society and create fairness for all sectors.

To meet future water demand and avoid water shortages, the government has implemented a water diversion project from Khlong Wang Tanod Sub-basin to Prasae Reservoir and built reservoirs in the Wang Tanod Sub-basin, including Khlong Wang Tanod Reservoir, Khlong Hang Maew Reservoir, Khlong Phawa Yai Reservoir, and Khlong Prakaet Reservoir. When all construction is completed, the Prasae Reservoir's water supply will be increased by 140 million cubic meters per year (Watcharasin, 2017). They have also developed two pumping systems from Khlong Saphan back to the Prasae Reservoir, which will increase Prasae Reservoir's water supply by 100 million cubic meters per year (Naewna, 2020 & Khaosod, 2021). Furthermore, the Khlong Phlo Reservoir and Khlong Nam Khiew Reservoir projects were considered to increase the amount of water supply in the Rayong area. Meanwhile, the Prasae – Nong Kho – Bang Phra Reservoir Water Diversion Project will increase the water supply to the Bang Phra Reservoir by 80 million cubic meters per year, alleviating Chonburi Province's water shortage (Khaosod, 2021). The promotion of the industrial sector's capacity for economic development also provides the government with an opportunity to form partnerships with international countries or the private sector in the development of water resource structures and the exchange of knowledge and water management technologies. This not only reduces the financial burden but also encourages job creation and income generation in the country.

For irrigation, RID should consider improving and developing water allocation on the left bank of the Prasae Reservoir with a water delivery system to reduce water evaporation and increase water allocation to more water users in the area. At the same time, PWA must develop its own reservoir to produce drinking water and improve the management network of the raw water pipeline to link both the Rayong and Chonburi areas. In addition, PWA should study the potential and guidelines for using groundwater in drinking water production.

5.1.2 Organization

JMC is the most important organization in the water management of the Prasae Reservoir, which coordinates and operates water allocation with the Prasae Operation and Maintenance Project staff. The first right to use water from the Prasae Reservoir will belong to IWUGs and water users in the area. A survey of IWUGs' initial opinions and needs is used to plan water allocation. The decision-making power on water allocation is primarily based on the consideration of JMC. The remaining water can be diverted to other areas according to the reservoir operation rule curve, which is accepted by all water users.

The National Water Resources Act B.E. 2561 (2018) mandates the formation of RBC and WUGO to ensure efficiency and sustainability in water resource management, procurement, utilization, conservation, and restoration, as well as other water-related actions. The Prasae River Sub-basin is part of the East Coast Gulf Basin. The Eastern Coast River Basin Committee will consider policy formulation, work plans, monitoring and evaluation, and the resolution of water management problems in the area. Another organization that will play an important role in driving the water management plan, integrating water resource information, and evaluating water management in Rayong for reporting to NWRC is the Rayong Provincial Water Resources Subcommittee (NWRC Order, 2020). In addition, from April 1, 2021, WUGO has been established and registered to enable all sectors to participate in water management, which is managed by ONWR (Thairath Online, 2021). At the same time, the current WUGOs, which are registered with RID continue to work. In my opinion, ONWR and RID should integrate all WUGO information and registrations to ensure clarity and reduce redundancy in water management.

The organizations mentioned above should synchronize their efforts and identify points of coordination to reduce conflict at the sub-basin and provincial levels. The water conflict will have a national impact because Rayong has the highest GDP in the country. ONWR plays an important role in water management policy, collaborating and coordinating with other agencies. While RID is the most important operation agency in the area, with practical water management knowledge and management tools to operate water flow, including close collaboration with farmers in the project.

5.1.3 Natural Resources

According to the literature review and study results, Rayong currently has four major reservoirs, namely Khlong Yai Reservoir, Nong Pla Lai Reservoir, Dok Krai Reservoir, and Prasae Reservoir. It has a total capacity of 564 million cubic meters. In 2037, Rayong Province's water demand will be 749 million cubic meters, up 52% from 2017. Water demand is being driven up by the industrial sector (Bangkokbiznews,2019). Rayong Province is one of the EEC that needs to develop water resources to meet the growing demand in the future caused by population growth and economic development. The government has developed new reservoirs in the area, improved the water network, and installed a pumping system to pump water from downstream back to the reservoir. It has also developed additional reservoirs in the Wang Tanod Sub-basin and connected an additional water network between Prasae Reservoir and Khlong Wang Tanod Sub-basin.

Water quality and the degradation of water resources caused by economic growth and industrial expansion are becoming urgent issues that need to be addressed to balance water resources ecosystems. Water quality should be monitored and controlled to meet standards before releasing into public water bodies. Wastewater treatment systems should be installed and promoted for the domestic, agricultural, industrial, and service sectors. The government should also consider reusing treated water in the agricultural sector.

Climate change has an impact on water resources and availability. The government should provide measures to manage both drought and flooding to mitigate potential impacts. Upstream forest conservation and restoration should be encouraged to slow water flow rates and reduce soil erosion.

The challenge of water management during a drought is allocating water to meet needs while remaining fair to all water users. The government should promote and push for water rights determination to improve water management efficiency and reduce water conflicts. At the same time, managing excess water to prevent flooding and establishing compensation measures for those affected is one of the keys to achieving sustainable water management.

5.1.4 Management

Climate change and ineffective water resource management have exacerbated water resource issues such as scarcity, flooding, water quality, and water conflicts. The government lacks coordination, communication, and integration of water resource information. These are obstacles to effective water management.

To ensure that the water management of the Prasae Reservoir and Rayong Province is effective, balanced, and sustainable, relevant agencies should improve and review water resource rules and regulations. Policy and action agencies should collaborate and develop an annual water resource management plan and emergency water management plan in drought and flood crises. The water resource database of the Prasae Reservoir and other reservoirs in the Rayong area should be developed and linked to the Eastern Water Resources Management Center for decision-making. Water resource monitoring and warning systems should be installed to enhance water management efficiency and reduce water disasters.

Land use should be updated in irrigation project areas to ensure accurate water allocation planning and water demand analysis. Water needs of water users should be continuously surveyed and monitored to improve the efficiency of the Prasae Reservoir's water management. Reserve ponds in new durian plantation plots should be encouraged to alleviate water shortages in the agriculture sector. According to the findings of the study, the chairman of the water user group in each area and community leaders promoted and supported the establishment of one reserve pond per 1.6 ha (10 rai) of the durian planting area.

Relevant agencies should provide farmers with knowledge and understanding of the water use process of durian trees to adjust their water use behavior. The results of studies on planting and real water use of durian showed that farmers gave the durian trees more water than the plant's need for water. Farmers should be provided with knowledge and understanding of the water use process of durian trees so that they can adjust their water use behavior. According to Farm Channel (2020), the findings of studies on durian planting and actual water use, farmers gave the durian trees more water than the plant required. Water is not the only factor that influences durian quality; other production factors include soil, nutrients, water quality, and climate. Giving durians too much water does not mean they will improve in quality. Farmers, however, continue to believe that as the durian trees receive more water, the durian yields will be of higher quality, despite knowing the actual water needs of the durians. In addition, appropriate water-saving technology in planting fields should be encouraged to reduce water use, such as micro-sprinklers, tensiometers, smart watering systems, etc.

Water scarcity risks can arise even if the government has plans to meet the growing water demand. The industry should assess its water use and improve water use efficiency. The 3 R (Reduce, Reuse, Recycle) policies, water technology, and tax incentives should be promoted to reduce water use and potential impacts.

5.1.5 Participation

Rayong Province is a delicate area in terms of water allocation and management because all reservoirs are linked to the water network by a large pipeline system. The Prasae Reservoir serves as a water hub that can receive water from the vicinity of the Sub-basins and divert water to help other areas, especially industrial areas. The majority of Prasae Reservoir's water management issues are caused by conflicts between the agricultural and industrial sectors. Farmers require water to grow cash crops, particularly durian, which generates a significant amount of income for them. While the industry is a major contributor to regional and national revenue. The challenge in Prasae Reservoir water management is to find a suitable way to allocate the available water to meet the needs with efficiency and maximize the benefit of society, thereby creating fairness among water users.

Public participation is key to reducing water conflicts and achieving sustainable water management. RID and related agencies should continually conduct meetings to increase water users' basic knowledge and understanding of water planning and allocation. Water information and the Prasae Reservoir's water situation should be disseminated in simple language through social media so that people can access it easily, conveniently, and quickly such as websites, Facebook, Line, etc.

Water funds should be promoted to assist local farmers and create an agreement among stakeholders on the water use of the Prasae Reservoir to increase transparency in water management. Mechanisms of RBC, JMC, and water user organizations should be promoted with the public sector as an important element to increase the efficiency of the Prasae Reservoir's water management and strengthen the community. Water users should be trained and educated about their participation in the water management of the Prasae Reservoir such as planning and monitoring water management, crisis water management, water surveillance and warning, and formulation of measures to solve water problems, as well as channels for suggesting and improving water management

5.2 Chapter Conclusion

Based on the literature review in Chapter 2 and the empirical findings in Chapter 4 , the challenge in Prasae Reservoir water management is to find a suitable way to effectively manage existing and excess water while maximizing benefits to society and fairness to water users.

Improving water management policies and plans, technological advancement, and public participation play a key role in providing additional water supply, increasing water use efficiency, and reducing water conflicts.

This chapter provides recommendations on how to increase the capacity and efficiency of the Prasae Reservoir water management for a paradigm shift toward water security and sustainable water management.

6. Conclusion

This final chapter reflects the aims, objectives, and summary of the findings from this thesis, explaining the limitations, providing recommendations, and outlining potential ideas for future research.

6.1 Summary

The main objective of this thesis was to analyze the policy framework and water management plan of the Prasae Reservoir in Rayong Province to achieve sustainable water management. Identifying challenges in Prasae Reservoir water management and appropriate, fair, and sustainable ways to manage the existing and excess water of the Prasae Reservoir was a key area of this research. The in-depth interview, therefore, focused on examining the relationship and interconnection within the Prasae Reservoir water management system to balance the efficient water allocation, maximize the benefit to society, and, thereby create fairness between water users

The study and analysis of water resource management practices and guidelines, along with the assessment of current water resource management policies, helped water resource managers better understand problems and formulate new strategies to improve and develop an efficient and sustainable water management system for the Prasae Reservoir. In addition, the increasing uncertainty and severity of climate change put pressure on adaptation and preparedness to cope with the potential impacts of drought and flooding. The relevant national, regional and local authorities must integrate both vertical and horizontal internal and cross-sector collaboration in the water management of the Prasae Reservoir. The policy level must focus on supply and demand management and provide a framework for action. At the implementation level, it is necessary to study and analyze policies and plans to find mechanisms, guidelines, and measures for water allocation and effective water management to create fairness for all sectors.

Another important factor in the water management of the Prasae Reservoir and Rayong Province is the study and development of technological solutions to increase the capacity and efficiency of water use. Investing in additional water resources, pumping system installations, and reservoir network linkages will increase the Prasae Reservoir's water supply to meet growing current and future water demand in agriculture, industry, and communities. Furthermore, water reserves should be promoted in agriculture and industry to reduce the risks and potential impacts of drought. The Prasae Reservoir water management database system should be developed to precisely and accurately forecast the water situation and trend of water demand. The water allocation model in various situations increases the efficiency of water allocation planning to ensure fairness between water users and establish preparedness and resolution measures in the event of an emergency or water crisis. To reduce water consumption, 3R policies (Reduce, Reuse, Recycle) and water leak monitoring within the system should be promoted. The tax incentives will encourage entrepreneurs to consider investments in water efficiency improvements to reduce water demand and plan sustainable water use for their businesses and the environment.

Public participation is a process that plays an important role in planning effective water management by focusing on equality and fairness among water users. The Prasae Operation and Maintenance Project officials will visit the field to clarify and create understanding, and to formulate guidelines for integrating work and crop cultivation plans with local farmers to reduce the risk of drought. Before and during water allocation, project officials meet with IWUGs to clarify the water situation of the Prasae Reservoir, water allocation plans, and survey water needs. This is to reduce issues that may arise as a result of water allocation, either insufficient or excessive water allocation. Project officials have also communicated with and coordinated with IWUGs to ensure that water allocation is consistent with mutually agreed-upon plans and agreements. Farmers and IWUGs can share ideas and suggestions for better water allocation and management through various channels such as social media, websites, surveys, etc. In addition, the National Water Resources Act B.E. 2561 (2018) has encouraged water users to register and establish WUGO to provide information and recommendations to RBC and the Provincial Water Resources Subcommittee.

Supporting the industrial sector's capacity building in the EEC has resulted in the rapid expansion of industrial plants and the increasing demand for water while the availability of water is limited. This has led to conflicts among water users. The water management of the Prasae Reservoir cannot be considered only within the project area or Prasae River Sub-basin because it is connected to other water sources by large pipes. This allows it to divert water to other areas to alleviate drought and flooding. In 2020, Rayong Province experienced a severe drought and the water volume in the Prasae Reservoir was declining to near dead storage. This has resulted in conflicts between agricultural and industrial water users. Negotiation is one effective method for resolving water disputes. RID and related agencies have collaborated with stakeholders to find solutions and mitigate the consequences. RID has signed a memorandum of understanding with the Wang Tanod

Sub-basin Working Group to divert excess water from the Khlong Wang Tanod Sub-basin to the Prasae Reservoir to alleviate drought in Rayong. Water users in the Khlong Wang Tanod Sub-basin will be compensated for lost opportunities, just as the diversion of water from the Prasae Reservoir to other areas. Farmers can use this budget if the CSR committee approves their project proposals for better water management or CSR projects.

I will summarize the final reflections on the principal findings by answering the three research questions and why I came to the above-mentioned conclusions. The following Table 11 summarizes the research questions and objectives and indicates where each question was answered in the thesis. The associated subsections below summarize the answers to the research questions.

Table 11. Summary of the Research Questions, Objectives, and Findings

Research Questions	Research Objectives	Chapter Location
Research Question 1: What is the optimal, just, and sustainable method for managing available and excess water of the Prasae Reservoir, considering balancing the needs to allocate water efficiently, maximize the benefits to society, and, thereby, create fairness between water users?	***Objective 1:*** Study and analyze existing water management policies and plans to provide recommendations for the improvement and development of sustainable water management systems in the Prasae Reservoir, Rayong Province.	Chapter 2 (Sections 2.2 and 2.3) and Chapter 4
	Objective 2: Analyze and assess the possibilities of implementing new strategies in water resources management to reduce conflicts between water users.	Chapter 3 (Section 3.3), Chapter 4 (Sections 4.6 and 4.7), and Chapter 5

Research Questions	Research Objectives	Chapter Location
Research Question 2: How can appropriate technologies increase the capacity and efficiency of water management in the Rayong area?	***Objective 3:*** Provide appropriate technology that can be applied in water management to increase the capacity and efficiency of water management in the Rayong area to meet the increasing water demand in agriculture, industry, and community.	Chapter 4 and Chapter 5
Research Question 3: How does public participation affect the sustainable water management of the Prasae Reservoir? Are most stakeholders able to accept that excess water will be diverted to other areas, depending on the situation and season?	***Objective 4:*** Study the participation of local people and government agencies in water management in the Prasae Reservoir, Rayong Province.	Chapter 2 (Section 2.9.5), Chapter 4, and Chapter 5

1. What is the optimal, just, and sustainable method for managing available and excess water of the Prasae Reservoir, considering balancing the needs to allocate water efficiently, maximize the benefits to society, and, thereby, creating fairness between water users?

a. Before planning the water allocation, project officials explain the Prasae Reservoir's water situation and surveyed crop cultivation needs and the water needs of farmers and IWUGs.

b. Prior to water allocation, water allocation plans are published, and project staff and IWUGs collaborate to adjust plans between water allocations to meet actual water needs.

c. The pipeline system connects the reservoir network, allowing excess water to be diverted to other areas to alleviate drought and flooding. Installing a back-pumping system in the downstream area improves water storage in the Prasae Reservoir and water management efficiency.

d. The diversion of water from the Prasae Reservoir to other water sources must comply with JMC's regulations and the reservoir operation rule curve criteria. Farmers were compensated for the opportunity cost.

2. How can appropriate technologies increase the capacity and efficiency of water management in the Rayong area?

a. The water resource information database system will increase efficiency and accuracy in planning, analyzing, and forecasting water situations, while also reducing the risk of water disasters and establishing measures to deal with and solve problems on time.

b. Water management technology can improve the potential and efficiency of water resource procurement, reserve water resources, and reduce water consumption, as well as provide close control, monitoring, and troubleshooting of water allocation and water management.

3. How does public participation affect the sustainable water management of the Prasae Reservoir? Are most stakeholders able to accept that excess water will be diverted to other areas, depending on the situation and season?

a. IWUGs and JMC were established to strengthen community and public participation in the efficient water management of the Prasae Reservoir and reduce conflicts between water users.

b. Project staff have created knowledge and understanding about water management and continuously update the water situation of the Prasae Reservoir to water users.

c. The project allows people to participate in the planning and control of water allocation, as well as monitoring and evaluation to improve water management at the end of water allocation.

d. Excess water can be diverted to other areas under JMC's rules and the reservoir operation rule curve, which is accepted by all sectors.

Overall, relevant agencies should integrate information and coordinate in planning, analyzing, and monitoring the water management of the Prasae Reservoir by emphasizing continual public participation to increase efficiency in water management and creating fairness between water users, which aims to create sustainability and water security in Rayong and the Eastern Region.

6.2 Limitations

Consideration of the study's limitations focuses on collecting data on water management of the Prasae Reservoir, some of which were identified in Chapter 3. First of all, data were collected during the COVID-19 epidemic, which has an impact on people's health and daily lives. To control and reduce the spread of COVID-19, the Thai government issued an emergency decree prohibiting public gatherings and cross-provincial travel until canceled, particularly in Rayong Province, which is a high-risk area. Coordinating with local authorities and interviewees to stay at the same time to reduce travel time and health impact risks was difficult as interviewees were in Bangkok, Chonburi, Rayong, and Chanthaburi. In addition, heavy rains were also a barrier between interviewing farmers and surveying the study area.

Second, interview dates and times were rescheduled based on the COVID-19 epidemic situation and interviewee availability, particularly access to senior management due to their heavy workload and busy schedule. Their availability for interviews varied according to their priorities, urgency, and various work-related commitments. Furthermore, some interviewees provided contradictory information, necessitating additional interview appointments.

Third, general information about the Prasae River Sub-basin and the Prasae Reservoir is limited and distributed among various water management departments. The majority of the data is presented in the form of GIS, maps, tables, and presentations, as well as meeting minutes. I had to study and analyze it to explain and compile it in understandable language.

Lastly, I was unable to hold a meeting with all interviewees to exchange opinions and draw up a situation map of the Prasae Reservoir water management due to the Emergency Decree prohibiting public gatherings to reduce the spread of COVID-19. I solicited opinions and co-created a situation map with each interviewee as their knowledge gap limited their ability to draw a situation map. However, the interviewees made three revisions before agreeing on and accepting the final situation map as an accurate representation of the system

6.3 Recommendations

Here are some recommendations for policymakers and academics to improve the water management of the Prasae Reservoir to achieve balance and sustainability.

1. The Prasae Reservoir is currently an important water resource allocation hub in the Eastern Region. Water can be diverted to other reservoirs through Nong Pla Lai and Khlong Yai pipeline systems. Nong Kho is another reservoir in the future that will divert water. Due to the water shortage in 2020, a return pumping station was built in Khlong Saphan, a tributary of the Prasae River Sub-basin to pump water from downstream to reservoirs. The Wang Tanod pumping station was also used to divert water to the Prasae Reservoir during severe droughts. However, the people of the Wang Tanod Sub-basin still receive unbalanced benefits from water diversion and require sustainable water use. According to the Cabinet resolution, RID must complete four reservoirs, Khlong Prakaet Reservoir, Khlong Phawa Yai Reservoir, Khlong Hang Maew Reservoir, and Khlong Wang Tanod Reservoir, as well as the irrigation system, before diverting water to other areas to provide water security and fairness to the people of the Khlong Wang Tanod Sub-

basin, Chanthaburi Province. However, Khlong Wang Tanod Reservoir, which has the largest capacity, cannot currently be constructed because the construction site is in a national park. NWRC is considering it, despite the fact that the project has passed an environmental and health impact assessment (Prachachat, 2022). As a result, the Wang Tanod Reservoir should clarify the outstanding issues, and the construction of other water reserves in the region should be accelerated to prevent water shortages that directly affect the EEC.

2. The upstream area of the Prasae Reservoir has abundant natural forests where important water sources flow into the reservoir, especially during the dry season. This area should be continuously protected to prevent future water quality problems and reduce soil erosion into the reservoir.

3. The Prasae Reservoir has been used to store water since 2005. Sedimentation is a common problem in reservoirs when water is stored for a long time. As a result, the reservoir's available capacity should be investigated. RID should have a dredging plan to increase the reservoir's water holding capacity while carefully considering relevant issues such as relevant laws and appropriate soil dumping areas. In addition, the Prasae Operation and Maintenance Project should update the land use map in the project area to increase efficiency in water allocation planning and water management by supporting the use of remote sensing and drone surveys due to human resource constraints.

4. The water diversion of the Prasae Reservoir is an important lesson learned to be applied to the other areas in Thailand. Particularly, in the view of benefit sharing among the stakeholders, water resources management, and organization management

before and after the Water Resources Act, B.E.2561 (2018) was enforced. Climate change is one-factor influencing water management because rainfall instability can cause severe drought or flooding in the Prasae River Sub-basin. Risk management plans should be prepared in advance, such as the Khlong Wang Tanod water diversion plan, the reservoir drainage plan, compensation plans for those affected, etc.

5. The Prasae Operation and Maintenance Project staff have communicated and coordinated with water users through ongoing meetings to discuss and plan water allocation during the dry season. Based on the interviews, there were some technical terms that needed to be interpreted for the farmers to simply understand. Currently, project staff communicates with water use groups through social media, especially LINE. Important information is sent and updated, then two-way communication is working. Moreover, under the Water Resources Act B.E. 2561 (2018), water user groups are registered which are different from water user groups in the project area. This issue should be clarified and communicated to the existing water user groups in the project to create mutual understanding.

6. Based on the interviews with IWUGs in the project, it was found that some farmers switched from rubber plantations to durians, which increased their water demand. To reduce the risk of water shortages during the dry season, farm pond reservations should be promoted on all farms. However, the market mechanism is very important. Durian oversupply may occur again in the future, as other Southeast Asian countries also promote durian plantations. Government agencies should maintain and guarantee product quality. Alternative plantation and adaptation plans should be acknowledged to farmers in advance.

6.4 Currents of the Future

Although water is an important resource for economic and social development and ecosystem preservation, water availability is frequently insufficient to meet demand, both quantitatively and qualitatively. As a result, water users face intense competition. Rayong is a province with high potential both in agriculture and main industry, which is a mechanism to drive regional and national income. The EEC development policy has resulted in a sharp increase in water demand, coupled with climate change causing variability in rainfall. Even if the government has plans and measures to acquire and develop additional water resources, there is still a risk of drought.

The Prasae Reservoir serves as the hub of water in the Eastern Region. The water management of the Prasae Reservoir needs to consider its linkages with other water sources in an efficient manner for maximum benefit and fairness. Areas with plenty of water and low demand are less likely to encounter water disputes, whereas, in areas with high water demand such as Rayong, water conflicts are a determinant factor in the success or failure of agricultural enterprises, industrial development, and national income generation. Water conflicts are less likely in areas with plenty of water and low demand, whereas in areas with high water demand, such as Rayong, water conflicts are a determinant factor in the success or failure of agricultural enterprises, industrial development, and national income generation (AQUAOSO, n.d.).

The purpose of water management is efficiency, sustainability, and fairness. Determination of water rights and water trading is one approach to alleviating water scarcity that requires further study to ensure transparency and fairness by considering regulations, laws, and public participation. Water resources will be utilized in the most beneficial activities. If there is any remaining water, it can be sold. The water market is therefore an incentive for water users to invest in water-saving technologies and to plan water use to reduce the impact of water shortages in the dry season.

In addition, the establishment of Water Funds may become an answer to the challenges of ensuring water security and sustainable water management in the Eastern Region. The strength of the Water Funds is that they are managed through a transparent and secure financial mechanism that can be sustained over the long term, in collaboration with public, private, and civil society stakeholders. This initiative aims to provide science-based water solutions and best practices for ensuring water security (Latin American Water Funds Partnership, 2022). Water allocation and water management of the Prasae Reservoir affect a wide range of water users. During the dry season or a drought crisis, water conflicts often occur between agriculture and industry water users. Water Funds will serve as a bridge between the various sectors involved and create the necessary negotiation conditions to enhance the governance of water resources (Latin American Water Funds Partnership, 2022).

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Appendices

Appendix A – List of Participants

Organization	Interviewee' role	Total Participants
Government Agencies		**13**
The Office of National Water Resources	Secretary-General Executive Advisor on Water Strategy Expert Irrigation Engineer Director of the Policy and Master Plan Division Director of the Master Plan Sub-Division	5
Eastern Economic Corridor Office of Thailand	Special Advisor in Industrial Development	1
Regional Irrigation Office 9	Director of Water Management and Maintenance Division	1
The Prasae Operation and Maintenance Project	Director Water Management and Irrigation System Improvement Branch Head of Operation and Maintenance Branch 1	3
Water Resources Region 6	Director	1
Bureau of Groundwater Resources Office Region 9	Director	1
Protected Areas Regional Office 2 (Sriracha)	Head of Khao Po Watershed Management Unit	1
State Enterprises		**3**
Industrial Estate Authority of Thailand	Assistant to Governor	1
The Provincial Waterworks Authority Paknam Prasae Branch	Manager	1
The Provincial Waterworks Authority Pattaya Branch	Manager	1
Private Sectors		**6**
The Federation of Thai Industries	Committee of Water and Environmental Institute for Sustainability Technical Working Group of Water and Environmental Institute for Sustainability	2
Rayong Chamber of Commerce	Secretary-General	1

Organization	Interviewee' role	Total Participants
Eastern Water Resources Development and Management Public Company Limited	Senior Executive Vice President and Chief Strategy and Business Development Officer	3
	Project Planning Division management and Acting Vice President Corporate Strategy Department	
	Representative	
Other Agencies		**15**
Joint Management Committees	Chairman of Joint Management Committee	3
	Chairman of the Left Bank Water Management Group	
	Sub-district Headman of Wang Wa	
Wang Tanod Sub-basin Working Group	Chairman of the Wang Tanod Sub-basin	1
Irrigation Water User Groups of the Prasae Reservoir	Chairman of the Chum Saeng Sub-district Water User Group	11
	Chairman of the Wang Wa Sub-district Water User Group	
	Chairman of the Water User Group on the left bank of the Prasae Reservoir	
	Chairman of the Cham Kho Sub-district Water User Group	
	Chairman of the Wang Chan Sub-district Water User Group	
	Chairman of the Thang Kwian Sub-district Water User Group	
	Chairman of the Ban Na Sub-district Water User Group	
	President of Song Salung Sub-district Municipality	
	Representative of Water Users in Plong Ta Iam Sub-district	
	Representatives of irrigation water users on the left bank of Prasae Reservoir	
	Representative of farmers	
Total Participants		**37**

Appendix B – In-Depth Interview Questions

1. Questions for the Office of National Water Resources (ONWR)

I would like to thank you for taking the time to meet with me. My name is Sarintip Phadungsontikul, a Ph.D. student at Oregon State University, and I would like to interview on water resources management in Rayong, especially the Prasae River Sub-basin. As your organization is one of the key agencies in water resources management policy, I am currently studying water resources management policies and plans in the Prasae River Sub-basin and public participation. In your opinion, what are the goals of water resources management policies and plans in the Prasae River Sub-basin?

The interview should take less than an hour and will be recorded. Although I will be taking some notes during the interview, I do not want to miss any of your comments.

I will ensure that any information I include in my research does not identify you as the respondent. Remember that you do not have to talk about anything you do not want and you may end the interview anytime.

Are there any questions about my explanation?

Are you willing to participate in this interview?

Name of Interviewee: ____

Address: ____

Phone: ____

Email: ____

Date: ____

1A What about the water situation in Rayong Province (Eastern Region) in your opinion?

1A1 What is the ONWR plan/ project for water resources management in the Eastern Region? Does water risk be assessed each year?

1A2 What is the water resources management goal in the Eastern Region?

1A3 What is the linkage between 20-Years National Strategy and Water Resources Management Master Plan to implementation in the Eastern Region?

2A What does your point of view to manage water resources in Rayong Province (Eastern Region, irrigation project)?

2A1 What are the concerned issues of water management and water diversion in Rayong Province and the Prasae River Sub-basin?

2A2 What are the challenges of water management in the Eastern region?

3A What are the measures of ONWR to increase the potential of water resources and the efficiency of Eastern Region water management to meet the increasing demand and be able to support economic growth?

3A1 What is ONWR's role to support the Eastern Economic Corridor (EEC)?

3A2 What is River Basin Committee's role (RBC) in water resources management?

4A How about the public participation process to develop water resources for new projects?

5A How to manage water requirements among various stakeholders in the Eastern Region?

6A How to balance requirements among water user groups in the Eastern Region Coastal Basin/ Rayong Province?

7A How to promote Water Resources Act B.E.2561 to the public on various levels?

8A Reference is made to Water Resources Act B.E.2561 RBC will prepare prevention and mitigation plans for drought and flood situations. How to integrate with the EEC development plan?

9A At present, there is a process to prepare Ministerial Regulation on the water use category. Based on Water Resources Act B.E.2561, Water Use Category 2 and 3 will be permitted by the head of responsible agencies, and water fees will be set. How to implement it effectively in your view?

10A What are the policies and measures for using appropriate technology for water management and water-saving? Is there any technology used in water management planning and water scarcity problems in the eastern region? Where does the funding source for technology come from?

11A What are the action plans/ measures for solving the water shortage problem in the Eastern region? Is there any compensation for the affected people? Where does the funding for compensation come from?

12A Are there plans for allocation, control, and conservation of groundwater in the Eastern region?

13A Do you think decentralization is a good goal to have for water management?

2. Questions for the Thai Government Agency or State Enterprise

I would like to thank you for taking the time to meet with me. My name is Sarintip Phadungsontikul, a Ph.D. student at Oregon State University, and I would like to interview on water resources management in Rayong, especially the Prasae River Sub-basin. As your organization is one of the key agencies in water resources management policy, I am currently studying water resources management policies and plans in the Prasae River Sub-basin and public participation. In your opinion, what are the goals of water resources management policies and plans in the Prasae River Sub-basin?

The interview should take less than an hour and will be recorded. Although I will be taking some notes during the interview, I do not want to miss any of your comments.

I will ensure that any information I include in my research does not identify you as the respondent. Remember that you do not have to talk about anything you do not want and you may end the interview anytime.

Are there any questions about my explanation?

Are you willing to participate in this interview?

Name of Interviewee: ____

Address: ____

Phone: ____

Email: ____

Date: ____

1B What about the water situation in Rayong Province (Eastern Region) in your opinion?

1B1 What is your role in water resources management in the Eastern Region Coastal Basin/ Rayong Province?

2B What does your point of view to manage water resources in Rayong Province (Eastern Region, irrigation project)?

2B1 What are the concerned issues of water management and water diversion in Rayong Province and the Prasae River Sub-basin?

2B2 What is the key success of water resources management in your view?

2B3 There are many challenging issues for water resources management at present. What is the most important challenging issue in your view (for example climate change, public participation, rules and regulations, economic growth, environment, etc.), and how to manage this issue?

3B In terms of implementing agency, what is your role to support the Eastern Economic Corridor (EEC)?

4B What is your agency's role in River Basin Committee (RBC)?

5B What is the top priority of water use in the Eastern Region Coastal Basin/ Rayong Province?

6B What are the water management policies and plans for the Prasae River Sub-basin?

6B1 Does water risk be assessed each year?

6B2 Does the government notify the public about the water situation?

6B3 What measures does your office have to increase the capacity and efficiency of the Prasae Reservoir to meet the increasing water demand?

7B Please explain how to allocate water to water users in the rainy and dry seasons.

7B1 Which month or season did you have the most problems in allocating water in the Prasae Reservoir? How did you solve the problem?

7B2 What are the challenges in water allocation?

7B3 When experiencing a water shortage in the Prasae Reservoir, how do you allocate water to achieve maximum efficiency, equality, and fairness?

7B4 How do you communicate to the stakeholder groups to accept your decision?

8B What are the policies and measures for using appropriate technology for water management and water-saving?

8B1 Is there any technology used in water management planning and water scarcity problems in the Prasae River Sub-basin? Where does the funding source for technology come from?

8B2 Does the government encourage farmers to grow plants that use less water?

9B Is groundwater used in the Prasae River Sub-basin?

10B Does your agency provide water management information to stakeholders?

10B1 How does the government give an opportunity to water users for water management involvement in the Prasae Reservoir/ Prasae River Sub-basin?

11B How frequently do water management disputes arise?

11B1 How were the disputes resolved?

11B2 Were the measures you have implemented accepted by stakeholders?

12B What are the conservation plans and measures for the rehabilitation of degraded upstream areas?

13B What factors will help promote water governance at the local level to be appropriate and sustainable?

14B From the government's perspective, what is the best way to solve the water shortage and sustainable water management of the Prasae River Sub-basin and the Eastern region?

3. Questions for Joint Management Committee

I would like to thank you for taking the time to meet with me. My name is Sarintip Phadungsontikul, a Ph.D. student at Oregon State University, and I would like to interview on water resources management in Rayong, especially the Prasae River Sub-basin. As your organization is one of the key agencies in water resources management, I am currently studying water resources management policies and plans in the Prasae River Sub-basin and public participation. In your opinion, what are the goals of water resources management policies and plans in the Prasae River Sub-basin?

The interview should take less than an hour and will be recorded. Although I will be taking some notes during the interview, I do not want to miss any of your comments.

I will ensure that any information I include in my research does not identify you as the respondent. Remember that you do not have to talk about anything you do not want and you may end the interview anytime.

Are there any questions about my explanation?

Are you willing to participate in this interview?

Name of Interviewee: ____

Address: ____

Phone: ____

Email: ____

Date: ____

1C What about the water situation in Rayong Province (Eastern Region) in your opinion?

1C1 What is your role to formulate a water management plan in the Prasae River Sub-basin under the Water Resources Act?

2C What does your point of view to manage water resources in Rayong Province (Eastern Region, irrigation project)?

2C1 What are the concerned issues of water management and water diversion in Rayong Province and the Prasae River Sub-basin?

2C2 What is the key success of water resources management in your view?

3C What is your role to support the Eastern Economic Corridor (EEC)? What is your opinion on the EEC project?

4C What is your role in water resources management in the Prasae River Sub-basin/ Prasae Reservoir? Does water risk be assessed each year?

5C Please describe the water situation and access to water information from the government?

6C What is the top priority of water use in the Prasae River Sub-basin/ Prasae Reservoir? How do you prioritize water use?

7C Please explain how to allocate water to water users in the rainy and dry seasons.

7C1 Which month or season did you have the most problems in allocating water in the Prasae Reservoir? How did you solve the problem?

7C2 What is the major challenge in water management and water allocation in the Prasae Reservoir/ Prasae River Sub-basin? How do manage this issue?

7C3 When experiencing a water shortage in the Prasae Reservoir, how do you allocate water to achieve maximum efficiency, equality, and fairness?

7C4 How do you communicate to the stakeholder groups to accept your decision?

8C What are your measures to increase the capacity and efficiency of the Prasae Reservoir to meet the increasing water demand?

9C How will you encourage everyone to have equal and fair access to water resources?

10C What are the policies and measures for using appropriate technology for water management and water-saving?

10C1 Is there any technology used in water management planning and water scarcity problems in the Prasae River Sub-basin? Where does the funding source for technology come from?

11C How frequently do water management disputes arise?

11C1 How were the disputes resolved?

11C2 Were the measures you have implemented accepted by stakeholders?

11C3 Do you have measures to resolve disputes that may occur in the future?

12C What is your opinion on water allocation decisions?

12C1 In your opinion, is the government transparent on water allocation decisions? If not, why not?

12C2 What is your opinion on water diversion from the Prasae Reservoir to other areas? What conditions will you accept for water diversion?

12C3 What is your opinion on water diversion from Wang Tanod Sub-basin to the Prasae Reservoir?

13C In your view, what is the best way to solve the water shortage and sustainable water management in the Prasae River Sub-basin?

4. Questions for Wang Tanod Sub-basin Working Group

I would like to thank you for taking the time to meet with me. My name is Sarintip Phadungsontikul, a Ph.D. student at Oregon State University, and I would like to interview on water resources management in Rayong, especially the Prasae River Sub-basin. As your organization is one of the key agencies in water resources management, I am currently studying water resources management policies and plans in the Prasae River Sub-basin and public participation. In your opinion, what are the goals of water resources management policies and plans in the Prasae River Sub-basin?

The interview should take less than an hour and will be recorded. Although I will be taking some notes during the interview, I do not want to miss any of your comments.

I will ensure that any information I include in my research does not identify you as the respondent. Remember that you do not have to talk about anything you do not want and you may end the interview anytime.

Are there any questions about my explanation?

Are you willing to participate in this interview?

Name of Interviewee: ____

Address: ____

Phone: ____

Email: ____

Date: ____

1D What about the water situation in Rayong Province (Eastern Region) in your opinion?

2D What does your point of view to manage water resources in Rayong Province (Eastern Region, irrigation project)?

2D1 What are the concerned issues of water management and water diversion in Rayong Province and the Prasae River Sub-basin?

3D What is your opinion on the Eastern Economic Corridor (EEC) project?

4D What is your opinion on water allocation decisions?

4D1 What is your opinion on water diversion from Wang Tanod Sub-basin to the Prasae Reservoir?

4D2 What ways can you accept the diversion of water from the Wang Tanod Sub-basin to the Prasae Reservoir?

4D3 Do you have measures to resolve disputes between watersheds that may occur in the future?

5. Questions for Private Sector

I would like to thank you for taking the time to meet with me. My name is Sarintip Phadungsontikul, a Ph.D. student at Oregon State University, and I would like to interview on water resources management in Rayong, especially the Prasae River Sub-basin. As your organization is one of the key agencies in water resources management, I am currently studying water resources management policies and plans in the Prasae River Sub-basin and public participation. In your opinion, what are the goals of water resources management policies and plans in the Prasae River Sub-basin?

The interview should take less than an hour and will be recorded. Although I will be taking some notes during the interview, I do not want to miss any of your comments.

I will ensure that any information I include in my research does not identify you as the respondent. Remember that you do not have to talk about anything you do not want and you may end the interview anytime.

Are there any questions about my explanation?

Are you willing to participate in this interview?

Name of Interviewee: ____

Address: ____

Phone: ____

Email: ____

Date: ____

1E What about the water situation in Rayong Province (Eastern Region) in your opinion?

1E1 What is your organization's role in water resources management?

2E What does your point of view to manage water resources in Rayong Province (Eastern Region, irrigation project)?

2E1 What are the concerned issues of water management in Rayong Province and the Prasae River Sub-basin?

2E2 Previously, what did your involvement in water resources management in the Eastern Region Coastal Basin/ Rayong Province?

3E Is water important in your manufacturing process?

3E1 Do you have enough water throughout the year? Does your organization have a water risk assessment?

3E2 Do you have reserve water when water deficit or drought period?

3E3 What is your measure/ technology for water saving in your factory? Where does the funding source for technology come from?

3E4 What is your requirement from the government agency to support water resources management to your factory/ organization?

4E Previously did your organization implement a Corporate Social Responsibility (CSR) project related to water resources/ environment. If yes, could you give an example? Is it accomplished?

5E Please describe the water situation and access to water information from the government?

5E1 Have you participated in water management planning, water allocation, and monitoring of water resources problems with the relevant agencies?

5E2 What urgent measures do you need the government to take to address water shortages?

6E What is your opinion on water allocation decisions?

6E1 Which months or seasons do you think are at risk of water shortage? Do you have an action plan/ measure to solve the problem?

6E2 In your opinion, is the government transparent on water allocation decisions? If not, why not?

7E If the government promotes co-funding for water-saving transfer to irrigation water user groups in the Prasae Reservoir. does your organization interesting to join the project?

8E Have you followed up drafting the water use fee process based on Water Resources Act B.E.2561? If yes, what do you think to improve this process?

9E Have you ever had a dispute with other groups of water users about water (both quantity and quality)? How were the problems resolved?

10E What are your preferred solutions for water scarcity and sustainable water management in the Prasae River Sub-basin/ Rayong Province?

6. Questions for Irrigation Water User Groups of the Prasae Reservoir

I would like to thank you for taking the time to meet with me. My name is Sarintip Phadungsontikul, a Ph.D. student at Oregon State University, and I would like to interview on water resources management in Rayong, especially the Prasae River Sub-basin. As your organization is one of the key agencies in water resources management, I am currently studying water resources management policies and plans in the Prasae River Sub-basin and public participation. In your opinion, what are the goals of water resources management policies and plans in the Prasae River Sub-basin?

The interview should take less than an hour and will be recorded. Although I will be taking some notes during the interview, I do not want to miss any of your comments.

I will ensure that any information I include in my research does not identify you as the respondent. Remember that you do not have to talk about anything you do not want and you may end the interview anytime.

Are there any questions about my explanation?

Are you willing to participate in this interview?

Name of Interviewee: ____

Address: ____

Phone: ____

Email: ____

Date: ____

1F What about the water situation in Rayong Province (Eastern Region) in your opinion?

2F What does your point of view to manage water resources in Rayong Province (Eastern Region, irrigation project)?

2F1 What are the concerned issues of water management and water diversion in Rayong Province and the Prasae River Sub-basin?

2F2 Do you concern about climate change or other influence issues on water use? What is most important in your view?

3F. What is the top priority of water use in the Eastern Region Coastal Basin/ Rayong Province?

4F What is the main crop in your area?

4F1 At present, do you use water-saving technology/ methodology in your farm/ group?

4F2 What is the technology/ methodology that you use? Where does the funding source for technology come from?

4F3 What is your requirement from the government agency to support water resources management on your farm?

5F Did you receive sufficient water from the Prasae Operation and Maintenance Project for your activity?

5F1 Which months or seasons did you have the most problems with getting water? How did you solve the problem?

5F2 What measures did the government have to help and compensate you? Do you think it is effective?

5F3 In terms of water shortage, where is the water source that you use for supplementary? Is it enough? If not, what is your response?

6F What is your opinion on water allocation decisions?

6F1 In your opinion, is the government transparent on water allocation decisions? If not, why not?

6F2 In your view, how are you able to allocate water to all stakeholders equally and fairly, and maximize their benefits under a drought situation?

6F3 What is your opinion on water diversion from the Prasae Reservoir to other areas?

6F4 If the Prasae Reservoir has excess water and has the potential to divert water to other areas in the Eastern Region, what is the condition for your acceptance for water diversion?

7F How frequently do water management disputes arise?

7F1 How were the disputes resolved?

7F2 What conditions made you accept?

8F Do you think water funding is important for water diversion in your view?

8F1 Can you present the project in your area which was granted by water funding previously?

8F2 Do you think the existing water funding request process is good? If not, what is your suggestion?

9F Please describe the water situation and access to water information from the government?

9F1 Have you participated in water management planning, water allocation, and monitoring of water resources problems with the relevant agencies?

9F2 What is the preference public participation process in your view?

10F How do your groups maintain and create networks for efficient and sustainable water management?

10F1 Is there a learning network and database system for water management development in the Prasae Reservoir/ Prasae River Sub-basin?

11F What are your preferred solutions for water scarcity and sustainable water management in the Prasae River Sub-basin?

Appendix C – Grouping of Questions for Analysis

Objective Agencies	Policy	technology	Public participation	Water conflict
Government agencies				
The Office of National Water Resources (Use the questionnaire only for ONWR)	1A, 1A1,1A2, 1A3, 2A, 2A1, 2A2, 3A, 3A1, 3A2, 5A, 8A, 11A, 12A, 13A	3A, 10A	1A, 2A, 2A1, 2A2, 4A, 5A, 6A, 7A, 9A, 13A	2A1, 3A2, 6A
Eastern Economic Corridor Office of Thailand	1B, 1B1, 2B, 2B1, 2B2, 2B3, 3B, 4B, 5B, 6B1, 6B3, 14B	7B1, 8B, 8B1	1B, 2B, 2B1, 2B2, 3B, 5B, 6B2, 6B3, 10 B, 13B, 14B	2B1, 11B, 11B1, 11B2,
Regional Irrigation Office 9	1B, 1B1, 2B, 2B1, 2B2, 2B3, 3B, 4B, 5B, 6B, 6B1, 6B3, 7B, 7B1, 7B2, 7B3, 8B2, 14B	7B1, 8B, 8B1	1B, 2B, 2B1, 2B2, 3B, 5B, 6B2, 6B3, 7B1, 7B4, 10B, 10B1, 13B, 14B	2B1, 11B, 11B1, 11B2,
The Prasae Operation and Maintenance Project	1B, 1B1, 2B, 2B1, 2B2, 2B3, 3B, 4B, 5B, 6B, 6B1, 6B3, 7B, 7B1, 7B2, 7B3, 8B2, 14B	7B1, 8B, 8B1	1B, 2B, 2B1, 2B2, 3B, 5B, 6B2, 6B3, 7B1, 7B4, 10B, 10B1, 13B, 14B	2B1, 11B, 11B1, 11B2,
Water Resources Region 6	1B, 1B1, 2B, 2B1, 2B2, 2B3, 3B, 4B, 5B, 6B, 6B1, 6B3, 8B2, 14B	8B, 8B1	1B, 2B, 2B1, 2B2, 3B, 5B, 6B2, 6B3, 10B, 13B, 14B	2B1, 11B, 11B1, 11B2,
Bureau of Groundwater Resources Office Region 9	1B, 1B1, 2B, 2B1, 2B2, 2B3, 3B, 4B, 5B, 6B, 6B1, 6B3, 9B, 14B	8B, 8B1,	1B, 2B, 2B1, 2B2, 3B, 5B, 6B2, 6B3, 10B, 13B, 14B	2B1
Protected Areas Regional Office 2 (Sriracha)	1B, 2B3, 3B, 4B, 12B		3B	

Objective Agencies	Policy	technology	Public participation	Water conflict
State Enterprise				
Industrial Estate Authority of Thailand	1B, 1B1, 2B, 2B1, 2B2, 2B3, 3B, 4B, 5B, 6B, 6B1, 6B3, 14B	8B, 8B1	1B, 2B, 2B1, 2B2, 3B, 5B, 6B2, 6B3, 10B, 13B, 14B	2B1, 11B, 11B1, 11B2,
The Provincial Waterworks Authority Paknam Prasae Branch	1B, 1B1, 2B, 2B1, 2B2, 2B3, 3B, 4B, 5B, 6B, 6B1, 6B3, 14B	8B, 8B1,	1B, 2B, 2B1, 2B2, 3B, 5B, 6B2, 6B3, 10B, 13B, 14B	2B1
The Provincial Waterworks Authority Pattaya Branch	1B, 1B1, 2B, 2B1, 2B2, 2B3, 3B, 4B, 5B, 6B, 6B1, 6B3, 14B	8B, 8B1,	1B, 2B, 2B1, 2B2, 3B, 5B, 6B2, 6B3, 10B, 13B, 14B	2B1
Private Sectors				
The Federation of Thai Industries	1E, 1E1, 2E, 2E1, 3E4, 5E2, 7E, 8E, 10E	3E3, 3E4	1E, 2E, 2E1, 2E2, 3E, 3E1, 3E2, 3E4, 4E, 5E, 5E1, 5E2, 6E, 6E1, 6E2, 7E, 8E, 10E	9E
Rayong Chamber of Commerce	1E, 1E1, 2E, 2E1, 5E2, 10E		1E, 2E, 2E1, 2E2, 4E, 5E, 5E1, 5E2, 10E	
Eastern Water Resources Development and Management Public Company Limited	1E, 1E1, 2E, 2E1, 3E4, 5E2, 7E, 8E, 10E	3E3, 3E4	1E, 2E, 2E1, 2E2, 3E, 3E1, 3E2, 3E4, 4E, 5E, 5E1, 5E2, 6E, 6E1, 7E, 8E, 10E	9E
Other Agencies				
Joint Management Committee	1C, 1C1, 2C, 2C1, 2C2, 6C, 7C, 7C1, 7C2, 7C3, 8C, 13C	8C, 10C, 10C1	1C, 2C, 2C1, 2C2, 3C, 4C, 5C, 6C, 7C1, 7C4, 9C, 11C3 12C, 12C1, 12C2, 12C3, 13C	2C1, 11C, 11C1, 11C2, 11C3, 12C2

Objective Agencies	Policy	technology	Public participation	Water conflict
Wang Tanod Sub-basin Working Group	1D, 2D, 2D1		1D, 2D, 2D1, 3D, 4D, 4D1, 4D2, 4D3	4D2, 4D3
Irrigation Water User Groups of the Prasae Reservoir	1F, 2F, 2F1, 2F2, 3F, 4F, 4F3, 5F2, 11F	4F1, 4F2, 4F3,	1F, 2F, 2F1, 2F2, 3F, 4F3, 5F, 5F1, 5F2, 5F3, 6F, 6F1, 6F2, 6F3, 6F4, 8F, 8F1, 8F2, 9F, 9F1, 9F2, 10F, 10F1, 11F	6F2, 6F4, 7F, 7F1, 7F2