A Review of Water Demand Framework for River Basin in Southeast Asia

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Abstract. Water demands are the most referred indicators for water distribution system operators to regulate production and storage of potable water. Many regional in Southeast Asia are greatly dependent on freshwater resources, which most of the time comes from large rivers basin, with starting point in high mountains and the flowing water which distribute into many parts in particular region for daily activities. Hence, understanding the projection of water demand by the reservoir that are formed by constructing dams across rivers need to be done which can contribute to water demand framework for river basin. Evaluation on consideration and estimation between water withdrawal and water availability can provide the quantity of water loss. This paper presents a review of water demand projection for different reservoir in river basin across Southeast Asia.

1. Introduction

Water is essential for human in daily activities and vital for comforting quality of life on this planet especially countries in Southeast Asia. In Southeast Asia, it consists of eleven countries of impressive economic growth with full of variety in culture, religion and history which includes Brunei, Burma (Myanmar), Cambodia, Timor-Leste, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand and Vietnam. From part of the world, Southeast Asia also one of the most energetic areas with full of potential in economically which largely accounts for its growing international importance with expansion of cities expected to carry on at high pace in the advancing years.

Based on GUPTA, 2001, in the water sector, there are three different categories of activities. [14] Two of these categories have to do with construction of hydraulic infrastructure and with operating and maintaining that infrastructure. [14] The third and last category is water resources management and its quite different from the other two. It is involving and requiring an integrated address to water with enclose preparation and policy of regional and national management and development proposition. [14] So as to enhance the water withdrawal and water management in terms of space and time, it requires a stabilized water framework for the whole water sector. Institutional computes and by correlating the establishment of hydraulic works also one of the comprises the implementation of these plans.
The fast-expanding metropolis in Southeast Asia have to concurrently recognize different levels of water challenges for example high demand for sanitation and availability to clean drinking water and planning for increased flooding, at lower income levels as correlated to the incident of several cities around the global North. There several requirements to meet the need for water resources management. Based on GUPTA, 2001, one of them is the significance of the economic enhancement of water being used for now and in the future such as by managing the allocating water to many various sector. [14] So it is again back to back with the projection of water allocating to certain economic sector. The legal framework and government water policies for each country in Southeast Asia should have to re-examine in terms of water availability and distribution to all development areas and disciplines to have better water demand management. This work will evaluate on water distribution and water availability which can generate more understanding the projection on water demand by the hydropower in a future and also embark on a systematic approach to water resources management and efficient water used.

2. Water Availability in Southeast Asia

Based on study of Agriculture Organization of the United Nation, the hydrology in Southeast Asia is influenced by the typical tropical monsoon atmospheric condition, which persuade of huge distinctions of river flows. [4] In general, the earth is generally well provided with water resources for total region constituting to 16 percent of the earth’s area which gets 22 percent and produces 25 percent of its rainfall and water resources respectively. Nevertheless, based on AQUASTAT Main Database, the earth is the place to the world’s population with 53 percent in it, the total of water resources per inhabitant is 2 970 m3/year, which is less than half the world’s average of 6 236 m3/year in 2009. [3]

Distinctively, more than 70 percent of Southeast Asia is water, and the monsoon rains are a regular feature of the region, and yet few have attempted to focus on water as an essential element which not just a setting but for understanding Southeast Asian society. Study from Andaya, 2018 stated that the evaluated availability of water resources on average within the region is very considerable compared to the world and Asian averages [1]. However, there is a large variation between countries in average annual surface water availability per capita.

2.1. Estimated Availability of Water Resources

Different countries have different total renewable water resources and rainfall distribution. As we all know, Southeast Asia’s region, the average water availability of water resources in this region is quite significant when compared with countries in Southeast Asia as shown in Table 1. However, there is a large variation between countries in average annual precipitation/rainfall in volume, with Indonesia having the highest amount of 5170 (109 m3/year) in 2017, as estimated based on the AQUASTAT Main Database by Food and Agriculture Organization of the United Nations (FAO, 2017). [3]

| Country   | Average annual precipitation/rainfall in volume (10^9 m^3/year) | Total renewable water resources (10^9 m^3/year) | Total renewable water resources per capita (m^3/inhab/year) |
|-----------|---------------------------------------------------------------|-----------------------------------------------|-----------------------------------------------------------|
| Brunei    | 15.71                                                         | 8.5                                           | 19827                                                     |
| Cambodia  | 344.7                                                         | 476.1                                         | 29747                                                     |
| Indonesia | 5170                                                         | 2019                                         | 7648                                                      |
| Laos      | 434.3                                                         | 333.5                                         | 48629                                                     |
| Malaysia  | 949.7                                                         | 580                                           | 18341                                                     |
| Myanmar   | 1415                                                         | 1168                                         | 21885                                                     |
| Philippines | 704.4                                                      | 479                                           | 4565                                                      |
| Singapore | 1.795                                                        | 0.6                                           | 105.1                                                     |
| Thailand  | 832.3                                                         | 438.6                                         | 6353                                                      |
| Timor-Leste | 22.3                                                      | 8.215                                         | 6339                                                      |
| Vietnam   | 603.2                                                         | 884.1                                         | 9254                                                      |
Indonesia might have the highest amount of annual precipitation in a year but Indonesia is the among of lowest total renewable water resources per capita, with 7648 (m³/inhab/year) followed by Myanmar and Malaysia with 21885 (m³/inhab/year) and 18341 (m³/inhab/year) respectively which it is already surpassed with the limit water resources. The demand for water resources has escalated hastily in current years and the basin often having dreadful shortages of water in Southeast Asia.

2.2. The dam capacity in Southeast Asia

It is exhilarating to recognize that Southeast Asia gradually becomes a new economic development point of the planet. Based on Sani and Rindam, 2011, the rapid growth of population has led to an increase in water demand, not only in terms of public water supply but also other activities like industrial activities. [22] The rapid urbanization process taking place in every corner of the country has increased demand for clean water due to rising living standards and quality of life. [22] According to Tang et al., 2019, there are four largest countries in Southeast Asia which are Myanmar, Thailand, Indonesia and Malaysia that have high source demand for economic development and also for water demand management. [24]

Table 2 The overview of hydropower or dam’s capacity in four major countries in Southeast Asia. (FAO, 2017)

| Countries     | Total dam capacity (km³) | Dam capacity per capita (m³/inhab) |
|---------------|--------------------------|-----------------------------------|
| Indonesia     | 23.02                    | 87.2                              |
| Malaysia      | 22.45                    | 709.9                             |
| Myanmar       | 15.46                    | 314.4                             |
| Thailand      | 68.28                    | 1006                              |

By analysing the hydropower resources in four countries in Table 2, the hydropower development of Thailand is strongly policy-oriented and have the highest amount of total dam capacity with 68.28 km³. Based on study of Tang et al., 2019, The Chao Phraya River has a basin area more than 170,000 km² which recognize as the largest river in Thailand and very vital water resources for that country. [24] Thailand can be divided into 25 major river basins based on geographical characteristics. Based on Aroonrat and Wongwises, 2015, the total average annual precipitation/rainfall in Thailand is about 832.3 (10⁹ m³/year) and 75% of this amount about 600,000 million m³ is lost through evaporation, evapotranspiration, and infiltration. [2] Therefore, only 25% of total annual rainfall which is about 200,000 million m³ remains in the streams and rivers. [2]

Thailand gave a very good example on water demand challenges which they had higher demand with lower water storage capacity because water demand has already surpassed water storage capacity. According to AQUASTAT Country Profile-Malaysia, 2011, it is not just happening in Thailand but also the other countries for example in Malaysia with total dam capacity is an estimated 22.45 km³ besides the groundwater flow about 50 km³ (78%) which back to the rivers and is therefore not pondered an additional resource (overlap). [9] Not only lost through evaporation, evapotranspiration, and infiltration but also supply through various activities irrigation and drainage for agriculture, industrial and municipal sector which still exceeded the water resources capacity. Therefore, to meet the demand in these regions, more water storage facilities should be constructed.

Based on study of Tang et al., 2019, as time goes by, the proper use and proper management of water resources in different country in Southeast Asia is necessary and should be upgraded. Association of Southeast Asian Nations (ASEAN) has shown its full potential in the financial and economic development especially Thailand, the Philippines, Singapore, Malaysia, and Indonesia. In order to develop and improve the quality of people’s life, the hydropower in these four countries need a better and significant applicable policy encouragement and upfront investment. [24]
3. Water Withdrawal in Southeast Asia

Study from Andaya, 2018, reservoirs or dams are used for many purposes for our daily activities which is for irrigation, to conserve water during dry season, drain the land during the wet season and also for religious purposes. [1] There are three sectors that Southeast Asian countries require high demand of water consumption due to the climate in Southeast Asia can be categorized as tropical which most of the time tends to be humid and hot in several part of the year. Moreover, countries in Southeast Asia are experiencing a fast-paced of globalization era and also major focus in the world in many aspects.

Based on the AQUASTAT Main Database by Food and Agriculture Organization of the United Nations (FAO, 2017), the three sectors that being recorded for water withdrawal assessment which was agricultural sector includes for irrigation, livestock and aquaculture purposes, industrial sector and municipal sector which it is more often computed as the total water discharged by the public dissemination network. [3]

Table 3 Water withdrawal by different country in Southeast Asia from various sectors.

| Countries    | Agricultural water withdrawal (10^9 m^3/year) | Industrial water withdrawal (10^9 m^3/year) | Municipal water withdrawal (10^9 m^3/year) | Total water withdrawal (10^9 m^3/year) |
|--------------|---------------------------------------------|--------------------------------------------|------------------------------------------|---------------------------------------|
| Cambodia     | 2.053                                       | 0.033                                      | 0.098                                    | 2.184                                 |
| Indonesia    | 189.7                                       | 9.135                                      | 23.8                                     | 222.6                                 |
| Laos         | 7.02                                        | 0.17                                       | 0.13                                     | 7.32                                  |
| Malaysia     | 4.52                                        | 4.788                                      | 3.902                                    | 13.21                                 |
| Myanmar      | 29.57                                       | 0.4984                                     | 3.323                                    | 33.23                                 |
| Philippines  | 67.97                                       | 15.85                                      | 8.929                                    | 92.75                                 |
| Thailand     | 51.79                                       | 2.777                                      | 2.739                                    | 57.31                                 |
| Timor-Leste  | 1.071                                       | 0.002                                      | 0.099                                    | 1.172                                 |
| Vietnam      | 77.75                                       | 3.074                                      | 1.206                                    | 82.03                                 |

By analysing the water withdrawal for different country, Indonesia has the highest amount of water withdrawal with 222.6 (10^9 m^3/year) which due to Indonesia has wide area with 190,457,000 ha. Water withdrawal for agriculture accounted for 189.7 (10^9 m^3/year), or 85 percent, municipalities and industries accounted for 23.8 (10^9 m^3/year) (11 percent) and 9.135 (10^9 m^3/year) (4 percent) respectively (Table 2). Agricultural water demand in Indonesia has slightly increased over time for example in 2000, Indonesia recorded 82 percent and recently about 85 percent for almost 20 years later since based on AQUASTAT Country Profile-Indonesia, 2011, that country has been importing rice to control the pressure or to conserve a national buffer stock if there is a rice scarcity for the most part during the dry season which also includes Vietnam, Philippines, Thailand and Myanmar which is operated by the Bureau of Logistic (BULOG) for market operation. [12]

In contrary, Malaysia has quite equivalent amount of water distribution or water withdrawal for these three different sector which 4.52 (10^9 m^3/year) (34 percent) for agriculture, 3.902 (10^9 m^3/year) (30 percent) for municipalities and 4.788 (10^9 m^3/year) (36 percent) for industries (Table 3) with total water withdrawal was an estimated 13.21 (10^9 m^3/year) and categorized as among the lowest total water withdrawal. The authority for water resources planning and development is responsible by various government agencies and they have a proper and decent system to apply but Malaysia also have to look back their water withdrawal which every year it increased gradually. For example, for the past 20 years, in 1996, the total water withdrawal only about 5.488 (10^9 m^3/year). Mainly, irrigation and domestic uses is extracted from surface water and is always available throughout the year. Generally, according to AQUASTAT Country Profile-Malaysia, 2011, the groundwater is exploited by rural people to enlarge their piped water supply and is bounded to some patches of the coastal region. [9]
Based on West, 2019, as for the need of Sustainable Development Goal 6.3 (SDG6) by 2020 which includes mountains, forests, wetlands, rivers, aquifers and lakes where these areas will be restore and protect water-related ecosystems to meet the of Clean Water and Sanitation under SDG6 and by 2030, countries need to improve water quality by reducing pollution, eliminating dumping and minimising release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse internationally in context of Millennium Development Goal (MDG) Indicator 7.5 [25], summation, calculation and assessment has been recorded in Southeast Asian countries of total freshwater withdrawn in a given year, expressed in percentage of the total renewable water resources (TRWR) in Table 4. Malaysia is one of the country that has significant and decent data that take only few percent to increase for freshwater withdrawal in percentage of total renewable water resources within 20 years which is in 1997, the freshwater withdrawn are about 0.9455% meanwhile in 2017, it is about 1.156%. This is important regarding on access to improve and provide drinking-water source to household connection, borehole, etc.

Table 4 Freshwater withdrawal based on Millennium Development Goal (MDG) Indicator 7.5 in Southeast Asian Countries.

| Countries     | Freshwater withdrawal as % of total renewable water resources (%) |
|---------------|---------------------------------------------------------------|
| Cambodia      | 0.4587                                                        |
| Indonesia     | 11.03                                                         |
| Laos          | 1.047                                                         |
| Malaysia      | 1.156                                                         |
| Myanmar       | 2.845                                                         |
| Philippines   | 19.36                                                         |
| Thailand      | 13.07                                                         |
| Timor-Leste   | 14.27                                                         |
| Vietnam       | 9.259                                                         |

As for Philippines, the freshwater withdrawn in percentage of total renewable water resources are quite drastic to increase within 10 years which is in 2007 are about 17.01% meanwhile in 2017, it is about 19.36%. The percentage rose up quite gradually within several years. According to AQUASTAT Country Profile-Philippines, 2011, it is because of the Philippines use the surface water development in their country for irrigation part which in the structure of dams and reservoirs meanwhile for the groundwater development focus on through pumping from deep and shallow aquifers. [10] As we can notice here this is the reason why less groundwater is used for irrigation and the groundwater discharge is being restrained for municipal and also drinking purposes owing to its essentials for much better quality.

According to AQUASTAT Country Profile-Philippines, 2011, the effort and framework of the National Economic Development Agency (NEDA) and NWRB, together with various sector stakeholders, such as national government agencies, water service providers and non-governmental organizations was designed The Philippine Water Supply Sector Roadmap. It is designed to help the country meet the sector’s challenges in term of developmental of water management for the longest term and moreover aims to help the country in achieving the MDG goals. [10]

By looking at the data for Timor-Leste in Table 4, the freshwater withdrawal in percentage of total renewable water resources are quite demanding which is 14.27%. Although the country is not big enough like the total population was estimated almost 1.1 million, the freshwater withdrawal is quite outrageous. Based on Table 5, Timor-Leste is among the highest percentage of Water Stress (SDG 6.4.2) in Southeast Asia which is 28.27% together with Indonesia and Philippines in the top list of Water Stress which is 29.68% and 28.36% respectively.
Table 5 Water Stress in Southeast Asian Country

| Countries     | SDG 6.4.2. Water Stress (%) |
|---------------|-----------------------------|
| Cambodia      | 1.037                       |
| Indonesia     | 29.68                       |
| Laos          | 2.277                       |
| Malaysia      | 3.439                       |
| Myanmar       | 5.799                       |
| Philippines   | 28.36                       |
| Thailand      | 23.02                       |
| Timor-Leste   | 28.27                       |
| Vietnam       | 18.13                       |

In Timor-Leste, the climate or weather are quite different which can be characterized by extreme conditions for that country. According to AQUASTAT Country Profile-Timor-Leste, 2011, around almost eight months of the year, there is little or no rain in the north of the island area. The island has a monsoon climate which are normal for the Asian countries with tropics. The primary of wet season which winds prevail for the year to most parts of the island happen from December to March and from northwest to southwest. As is usual event in many tropical locations, Timor-Leste having extremely heavy rainfall occasionally with relatively short time intervals. [13]

4. Water Management in Southeast Asia

Based on GWPTEC, 2011, there are so many issues regarding to water problems like water shortages, water pollution and flooding which leads in producing regularly water policy implementation in Southeast Asia. Issues or challenges that connected with water management will undeniably become the utmost importance across Southeast Asia for about in the next 20 to 50 years which due to high populations and consequent demanding for water resources. To some extent in context of economic growth, many Southeast Asian countries are in favourable location that water resources availability should not be a major limiting factor. [15]

4.1 Structure of organization and management

Based on AQUASTAT Country Profile-Brunei, the Departments of Water Services and of Public Works and the Ministry of Development are in charge for monitoring treated water at treatment plants, storage points and end-points. Meanwhile, the Department of Health Services implement audits the quality of water at the treatment plant and end-points. In context of environment and health for the treatment of its drinking water, Brunei has magnificent facilities for it. There are two other facilities that operate privately which are Brunei Shell Petroleum (BSP) and Brunei Shell’s Liquefied Natural Gas (LNG). And in Brunei also there are bottled water factories which using much better technology to manufacture purified water. [8] Moreover, at the moment, the Department of Agriculture is working on upgrading system performance in the department. This includes reevaluating agricultural policies, marketing system, supportive programmes, legislation and other circumstances that affect the progress of this new inventiveness so that it can be better set out the needs of the agricultural sector which includes the water sector. [8]

In Cambodia, Ministry of Water Resources and Meteorology (MOWRAM) which was established in 1999 act as an important water sector agency, exercises in general responsibility for water management and conservation including Integrated Water Resources Management (IWRM) together with the Department of Water Resources Management and Conservation. MOWRAM works in concurrence with key agencies to jointly manage and govern the optimal and sustainable consumption of water resources. Nevertheless, the primary role of MOWRAM is to preserve the hydrological cycle which includes surface and underground flow and storage and water quality for daily consumption. At
the end of the year of 2005 under the Basin Development Plan (BDP), the framework and principles of integrated water resources management (IWRM) was acquire by Mekong River Commission (MRC).

In Vietnam, for about hundreds of years, water resources management regularly committed on freshwater conservation for agricultural production. In line with the data of FAOSTAT, Vietnam is one of the world's main agricultural water users with around 77.75 billion m3 per year and, importantly, water stress reached a medium-to high level in 2007 (Ritchie and Roser, 2020). Based on Nguyen et al., 2020, in recent years, Vietnam shows that there has been little or no data on water stress yet. [20] Meanwhile, nine ministries in Thailand take into action for water resources development which about more than 30 agencies are involved. Furthermore, according to GUPTA, 2001, about seven national commissions are take part in the water resources area but somehow this leads having obstacles which leads to incomprehensible and sometimes even baffling in decisions making. [14]

Based on AQUASTAT Country Profile-Malaysia, for the government in Malaysia recently have been decided to upgrade the strategic target of rice self-sufficiency to 100 percent. Moreover, it has important connection for water allocation to agriculture sector. Simultaneously, the Division of Irrigation and Agricultural Drainage (BPSP) of the MoA has received notable budgets to support this new policy and consequently has a chance to address issues which associated to managing demand or enhancing efficiency by upgrading the systems. Organic pollution of water has a negative impact in environmental issues and has catastrophically affected aquatic living organisms in several urban and industrial sector. Since 98 percent of the total water resources used originates from rivers, river water quality and pollution control need to take proactive action immediately. [9]

4.2 Challenges in Water Management
Study on AQUASTAT Country Profile-Indonesia, problems on water resources management, both qualitative and quantitative, are increasingly significant on Java and on other islands, including Papua, Sulawesi, Sumatra, Kalimantan, however with many kinds of problems and hence different solutions have to take account. Issues in Java are described by overpopulation, as well as water and other natural resources are being degraded. Different islands are mainly portrayed by natural resources and water degradation because of voluminous deforestation and new plantations and inappropriate open mining practices. [12]

As for Thailand, Bangkok faces issues of both too an extreme and too little water. Based on AQUASTAT Country Profile-Thailand, flooding happens quite often in the wet season attributable to low average elevation, high tides and insufficient drainage. The Metropolitan Waterworks Authority is unable to supply or provide water to meet all household and industrial demand. Subsequently, in the edge of Bangkok, private and industrial deliberation of groundwater surpasses the safe yield of the aquifer. This speed up the pace of land subsidence (5-10 cm/year), which in turn worsens the issue of flooding. Indeed, subsidence has caused some parts of the drainage systems to be below the normal water level and has thus, in this way rendered them incapable. [11]

Thailand is forecasted to have adequate water of better condition for all consumers by 2025 as a result of its efficient organization, a legal system and management that ensures the sustainable use and equitable of its water resources with association of all stakeholders and determinant to the quality of life. Establishment of water management institutions both at national and river basin level with nurturing legislation. The national organization is in charge for constructing national policies, coordinating and monitoring activities to satisfy the policies. The river basin organizations are in charge for constructing water management plans through a participatory resemble. Moreover, Thailand also underline equitable and suitable water distribution for all water use sectors and fulfil basic water necessities in domestic and agriculture uses, to be achieved by establishing sustainable and efficient individual river basin water use
priorities under clear water distribution basis, integrating beneficiary cost-sharing based on the level of services used and the ability to reimburse. [11]

Besides, based on AQUASTAT Country Profile-Philippines, policy implementation, conflict resolution and institutional arrangements for water supply and water availability are multi-level and the implementation mechanisms are adequately fragmented and complicated. A few number of private coalitions and organizations are take part in advocacy responsibility. Water demand in Manila city alone in 1995 surpassed the available groundwater availability. All the major cities will be having water issues in the 2025 projection if water supply depends fully on groundwater only. The need to enlarge other water sources will be hard for supporting the development of these localities. [10]

5. Conclusion
The objective of this paper is to find and introduce the idea of evaluation on estimation between water availability and water withdrawal which can contribute countries to provide and improve certain water resources management includes water framework and water policies. To sum up some of the issues and challenges, it would appear that the major challenges are collection of high quality data, diminishing the impact of extreme events on water resources, sustaining and enhancing water quality, upgrading governance systems and earning financing for the development of new water infrastructure.

Many countries in Southeast Asia are alert of the need for a better water resources management which there needs all different kind of support at all degrees to secure that this happens. Segmentation of the management of water between several authorities within Southeast Asian countries needs to be evaluated to determine if there are much better institutional arrangements can be established. Moreover, it is significant that surface water and groundwater are managed by the same agency or authority given their usual interrelation.

The planning for a dam project should take top-priority with all the alternatives to meet energy and water needs including upgrading the quality and productivity of generation and current consumption, considerations of the whole spectrum of types of energy and the option of no dam development where more sustainable alternatives are accessible. Preference should be given to improving or enhancing efficiency of selection of options and current existing infrastructures with the least environmental and social footprints. Planning and management should also take into account within the large scale of the river basin to meet the needs of affected people including downstream and upstream stakeholders.

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