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Proposal of Water Allocation Plans for Mandalay Area in Myanmar

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Abstract

This study aims to investigate the current water demand and supply situation of domestic, industrial, irrigation and hydropower sector around Mandalay area in 2014 as reference year and proposes allocation plans based on the changes of water demand and supply due to the growth of water demand and completion of future water supply projects for 2015 to 2030. The Water Evaluation and Planning (WEAP) model is used to assess present and future water allocation for all sectors of study area in terms of unmet demand and demand site coverage. In this study, Mandalay city, Mandalay industrial zone I and II, Sedawgyi and Sedawlay irrigated areas and Sedawgyi hydropower plant are considered as demand site and Sedawgyi dam, Ayeyarwaddy river, Dotehtawaddy river and groundwater along the Ayeyarwaddy river are considered as supply sources. Based on the year 2014 water supply and demand condition, reference scenario is simulated. According to the results of reference scenario, there is unmet demand at Mandalay city and industrial zones but irrigation and hydropower sectors are met with required demand. And then, two options of the future scenarios are simulated with and without consideration of proposed government projects as the proposal allocation plans for the future trend of water supply sources and demand sites.

Keywords: water allocation plan; Water Evaluation and Planning (WEAP) model; reference scenario; future scenario, unmet demand;Mandalay area.

1. Introduction

Water of a desired availability and quality is often scared to satisfy the demand for different uses, decisions and plans have to be made on how it will be shared between different locations and competing users.

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This is the practice of water allocation. In simple term, it is the mechanism for determining who can take water, how much they can take, from which location and for what purposes [4].Nowadays, water shortage is one of the real challenges facing many countries in the world. In Myanmar, the process of population growth, urbanization and industrialization occur at an ever increasing phase at every year. These processes show that demands are increasing for water use in the sector of domestic water supply, industry, agriculture and hydropower generation. Thus, the water allocation plan and water resources development projects are undertaken to address these requirements. And water allocation plans need to balance the water supplies with demands, particularly to manage the natural water availability to avoid frequent or unexpected water shortfalls. According to report from Asian Development Bank, total water withdrawal from available water resources in Myanmar are around 89% for agriculture, 10% is for municipalities and 1% is for industries. Approximately 91% of the total water withdrawal comes from surface water and 9% from groundwater. Groundwater is mostly used for domestic purpose [3].

As the difference between water resources and demand is ever increasing, the government is facing with the increasingly difficult task of allocating the available water resources among the competing demands. In the face of growing competition, the water allocation has evolved to be a complex process. Simulation and optimization modeling techniques can help to analyze this complicated process and to develop sustainable water allocation solutions. Over the years, a number of computer-based tools that employ simulation and optimization techniques have been developed. Among them, Water Evaluation and Planning (WEAP) model developed by Stockholm Environment Institute, has been used worldwide in order to perform allocation, scenario analyses and reporting data tool for water resources management [5].

2. Background and Problem Statements

2.1. Background of Study Area

Mandalay city is located in the central region of Myanmar at 21° 58' N 96° 04' E. It is also the second largest city and the last royal capital of Myanmar. It is located 445 miles north of Yangon and bordered by the Ayeyarwaddy river at the west. The city has an estimated population of 1.3 million and is the capital of Mandalay Region. Mandalay is the main commercial, educational, health and economic hub of Upper Myanmar and have been considered as the centre of Buddhism in Myanmar. In Mandalay city municipal area, five downtown townships are included, Aung Myae Tharsan, Chan Aye Tharsan, Mahar Aung Myae and Pyi Gyi Tagon townships. Presently, piped water supply is being provided to Aung Myae Tharsan, Chan Aye Tharsan, Maha Aung Myae, Chan Mya Tharzi and a small part of Pyi Gyi Tagon township. As a whole, overall population accessed to piped water supply in Mandalay city is 72% of total city population.

Mandalay industrial zone is located in Pyi Gyi Tagon township in Mandalay city and near the Dotehtawaddy river. According to the data of the Supervision Committee of Mandalay industrial Zone, 1259 enterprises are fully operated and employed about 11000 workers. Its main products are consumer goods, foods, textile and machinery products.

Around Mandalay area, most of the water supply is controlled by the Sedawgyi Multipurpose Dam and used for irrigation, hydropower and domestic purposes. Almost of irrigated areas are downstream of the Sedawgyi Dam. The Sedawgyi dam is constructed across the flow of Chaungmagyi river and is divided into three separated river and canals. These are Yenatha Canal, Mandalay Main Canal and the Chaungmagyi River which continues to flow towards the Ayeyarwaddy River. The Yenatha Canal is the man-made canal that flows into the northern irrigation network distributaries. And the Mandalay Main Canal is also a man-made canal which flows southward to Mandalay and is used as water supply canal for both irrigation and domestic use of Mandalay city. Sedawgyi dam water supply covers all irrigated areas of Mandalay city, Mattaya, Patheingyi and Amarapura townships. In selected area, Sedawlay weir is located across Nadaung Kya Chaung in Patheingyi township. This weir can supply for Patheingyi and Amarapura irrigated areas with canals.

Sedawgyi hydropower plant is an integral part of the irrigation and domestic supply utilizing the surface water of the Chaungmagyi River by construction of a storage dam and related facilities. The design capacity of the hydropower station is 12.5 MW x 2 Units of Kaplan turbines. Yearly targeted power generation fluctuates around 134 GWh. This fluctuation of generation was caused by irrigation demand side requirements since irrigation supply is main purpose of the reservoir. The outflow from hydropower plant is used for irrigation and domestic purposes by Mandalay main canal and Yenatha canal. The location map of study area is shown in Figure 1.

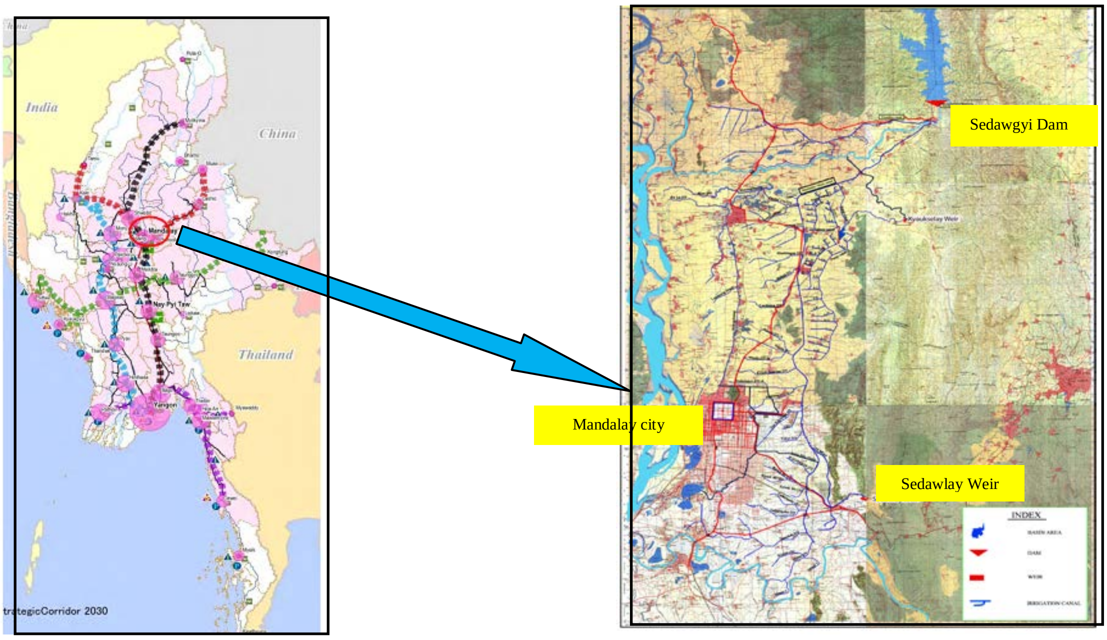

Figure 1: Location Map of Study Area

2.2. Problem Statements

In Mandalay city's water supply system, piped water supply system is available only during particular times of the day in the different townships and intermittently supply in almost zones. In general, citywide infrastructure networks and municipal services do not reach at adequate level for a large proportion of the urban population.

Consumers have adapted to inadequate provision by improvising self-supply, usually involving private tube wells. During the hot season, residences face with water shortage because pumping stations are unable to operate. Areas that are far from pumping stations face with difficulties all year round. The self supply from private wells and tube wells donated by Japan International Cooperation Agency (JICA) and Korea International Cooperation agency (KOICA) due to water shortage during the hot season in some parts of Mandalay city is shown in Figure 2.

Figure 2: Private wells and donated Tube well in Some Parts of Suburb in Mandalay City

In Mandalay industrial zones, there is no public water distribution system and, enterprises have to rely on their own tube wells. But groundwater may be contaminated especially by brewery factories because of lack of waste water treatment system in industrial zone.

In Sedawgi dam, problems have risen that during the rainy season, the water level is too high in the reservoir and the spill gates have to be opened shown in Figure 3. This leads to large flow going downstream of the dam into the irrigation network and causes flooding of irrigated fields. A lot of water is wasted in such a way and it is unused for agriculture. So, this leads to a low overall efficiency of water usage of dam.

Figure 3: Overflowing from Spill Gates and Flooding of Paddy Fields during the Rainy Season in Sedawgyi Dam

3. Materials and Methods

3.1. Water Evaluation and Planning (WEAP) Model

The WEAP model is an integrated water resources management tools to enable evaluation of planning and management issues associated with water resources development. The WEAP model can be applied to planning and allocation at multiple scales, from community to catchment and can address a wide range of issues including sectoral demand analyses, water allocation, streamflow simulation, reservoir operation, ecosystem requirements, water quality and project cost-benefit analyses.

WEAP uses scenarios as a way to evaluate different water allocation plan, given water demand and associated priorities. To simulate water allocation, the elements that comprise the water demand-supply system and their spatial relationship are characterized.

The system is represented in terms of its various water sources, withdrawl, transmission, reservoir, and wastewater treatment facilities, and water demands. The data structure and level of detail can be customized according to the requirement of analysis and limited data.

3.2. WEAP Modelling Process and Data Requirements

(a) Initiation of WEAP Model

To allow simulation of water allocation for study area, time step boundary is firstly set up. Year 2014 is used as reference year which is the basic definition of the water supply as it currently exists including specification of supply and demand data for the first year of study on a monthly basis.

Last year of scenario is 2030 and time steps per year is 12 based on calendar month. The study period may start from January, 2014 and end at December, 2030. And then, local map are georeferenced and converted to raster layer with ArcGIS software and inputted in WEAP as background map.

(b) Domestic Sector

The various parameters which are fed to WEAP model are annual activity level, annual water use rate, monthly variation and consumption for demand nodes, storage capacity, initial storage, maximum withdrawal and natural recharge for groundwater nodes and physical and operation data for reservoir nodes, etc. All the data is compiled and brought in the format acceptable to model.

The WEAP model for Mandalay city was then constructed which operates on the basic principle of water balance for every node and link in the system subject to demand priorities and supply preferences. The WEAP model for Mandalay city which consists of sixteen demand nodes by the red circles, nine groundwater nodes by the green squares and one reservoir node by green triangle is shown in Figure 4.

Demand site nodes were connected with the supply nodes by green line transmission links.

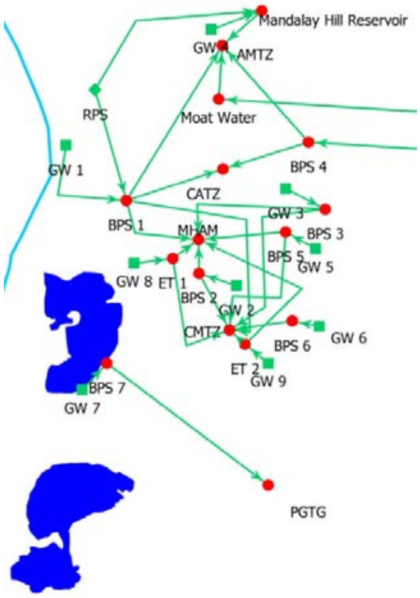

Figure 4: WEAP Model for Mandalay City

(c) Industrial Sector

For industrial demand, the research manual of optimum water use for different types of industry classified with Standard Industrial Classification (SIC) code developed by the Environmental Agency is used as calculation manual. Example calculation of industrial demand for product of oil is shown in Table 1 as an example calculation. According to calculated results, total yearly water use of Mandalay industrial zone including product processing and employee use is 12576.286 MG. Specified monthly demand method is used in WEAP model for industrial demand node. So, the total yearly value is divided into monthly variation weighted by the day in each month to input month by month value in WEAP model.

Table 1: Example Calculation of Industrial Demand for Oil Enterprises

Question	Answer
Which type of product is to be produced?	Oil
What is the yearly manufacturing capacity of the plant, in terms of volume?	1835.82 ton/year
Which type of industry group and SIC code are included this product?	Edible oil, 203
How much specific rate of water consumption for this product in manual?	2.6 m^3/ton
How much water is needed to produce this product?	4773.13 m^3/year (1.2609 MG/year)
How many employee are working in these enterprises?	343 workers
How much is specific rate of water consumption for sanitation of employee and site cleaning in manual?	0.05 m^3/day (4.187 x 10^{-3} MG/year)
How much water is used for sanitation of employee and site cleaning in these enterprises?	1.4362 MG/year
How much water is needed in these enterprises yearly?	2.6971 MG/year

In this study, CROPWAT 8.0 model is used to calculate crop water requirement and net irrigation requirement to input irrigation demand node. CROPWAT is a decision support system for planning and management of irrigation. All calculation procedures used in CROPWAT are based on two FAO publications of the Irrigation and Drainage series No. 33 and 56.

In order to run properly, CROPWAT 8.0 model needs some input data, namely, climatic and rainfall data, crop characteristics. After all data have been correctly intputted, the monthly results, such as reference evapotranspiration (ET_0), effective rainfall, actual crop evapotranspiration (ET_c) and net irrigation water requirement are ouputted.

The summary of total net Irrigation water requirement for Sedawgyi and Sedawlay irrigated are shown in Table 2. Then, WEAP model for different irrigated areas around Mandalay were constructed.

The WEAP model for study area shown in Figure 5 consists of seven demand nodes, one reservoir node and one weir node in which supply and demand nodes were connected by green transmission links.

Table 2: Net Irrigation Water Requirements for Sedawgyi and Sedawlay Irrigated Areas (MG/month)

Month	Sedawgyi Irrigated Areas				Sedawlay Irrigated Areas	
	Amarapura (IR1 AMAPA)	Mandalay (IR1 MDY)	Mattaya (IR1 MTY)	Patheingyi (IR1 PTG)	Amarapura (IR2 AMAPA)	Patheingyi (IR2 PTG)
Jan	30.72	0.00	2079.1	308.50	0.00	12.57
Feb	47.33	0.27	1927.00	255.62	0.00	7.89
Mar	540.87	4.09	2954.11	1221.53	0.62	9.24
April	1373.00	9.45	5569.80	2945.11	2.25	33.72
May	486.93	3.71	1907.90	1124.55	0.52	7.74
June	307.91	2.86	938.24	734.89	1.55	0.00
July	56.46	0.00	471.79	119.27	19.83	9.27
Aug	4.52	0.00	37.743	9.54	1.35	0.74
Sept	0.00	0.00	0.00	0.00	0.00	0.00
Oct	80.15	0.00	192.23	176.34	2.2	1.48
Nov	353.73	0.00	1081.30	838.97	5.35	6.68
Dec	186.69	0.00	1373.30	571.96	0.00	8.31

(e) Hydropower Sector

In this study, Sedawgyi hydropower plant is considered as hydropower allocation sector. To prioritize reservoir releases to generate hydropower, there are two methods for specifying hydropower energy demands in WEAP: as individual energy demands for each reservoir, or as an aggregate energy demand at the system level.

In this study, the method of aggregate energy demand at the system level are chosen because the outflow from hydropower plant is used for irrigation and domestic purpose by Mandalay main canal and Yenatha canal. The inputted parameters in WEAP are system hydropower priority, monthly system energy demand and selection of reservoir.

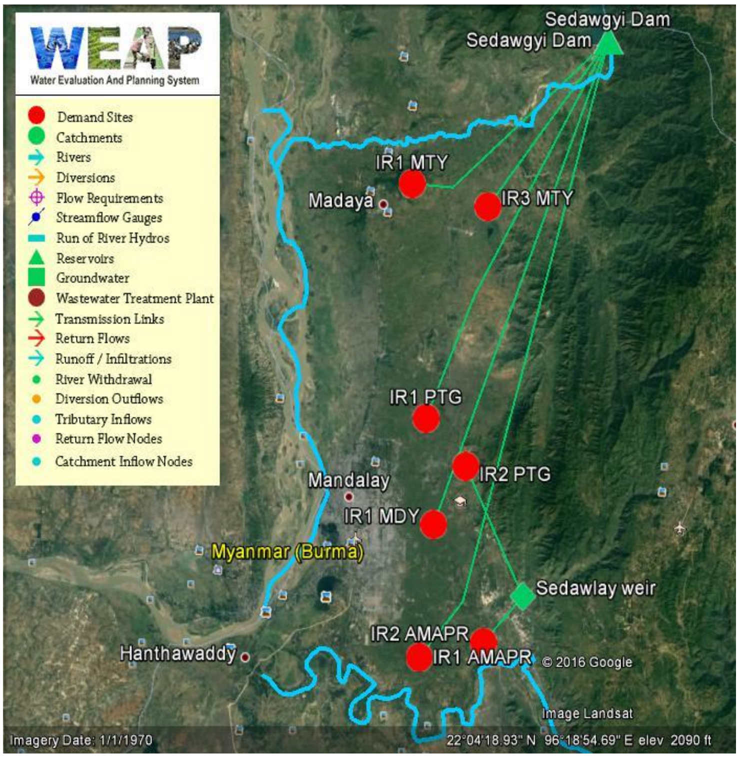

Figure 5: WEAP Model for Sedawgyi and Sedawlay Irrigated Areas

4. Results and Discussions

The flow chart of scenarios for proposal of water allocation plan for study area is shown in Figure

This scenario represents the current system condition with water supplies and demand sites for four sectors around Mandalay. It is based on Year 2014 condition for which the current account data are established. The unmet demand and demand sites coverage of all allocation sectors for scenario 1 are shown in Figure 7. According to model result, Aung Myae Tharsan and Chan Aye Tharsan townships were fully met with the required demand in domestic sector.

4.1. Results of Reference Scenario (Scenario 1)

Other remaining three townships, Chan Mya Tharzi, Maha Aung Myae and Pyi Gyi Tagon townships were facing water shortage all year round. Among these three townships, Pyi Gyi Tagon township has the highest unmet demand.

In Mandalay industrial zone, demand site coverage is 0% because of no public supply system. Under irrigation sector, all irrigated areas are met with required demand and demand site coverage is 100%. For Sedawgyi hydropower plant, there is no unmet demand to produce targeted energy and demand site coverage is 100%. Therefore, there are unmet demand at domestic and industrial sector in reference scenario.

The overall unmet demand is 1410.58 MG/month and demand site coverage is 80% for all water allocation sector at reference scenario.

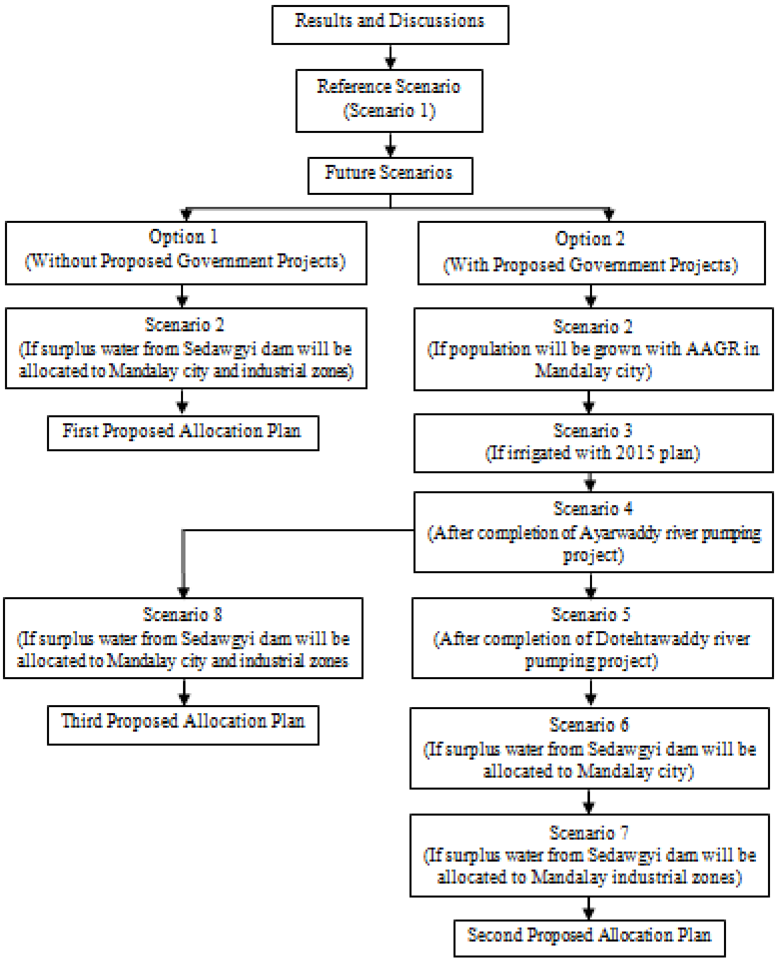

Figure 6: Flow Chart of Scenarios to Propose Water Allocation Plans

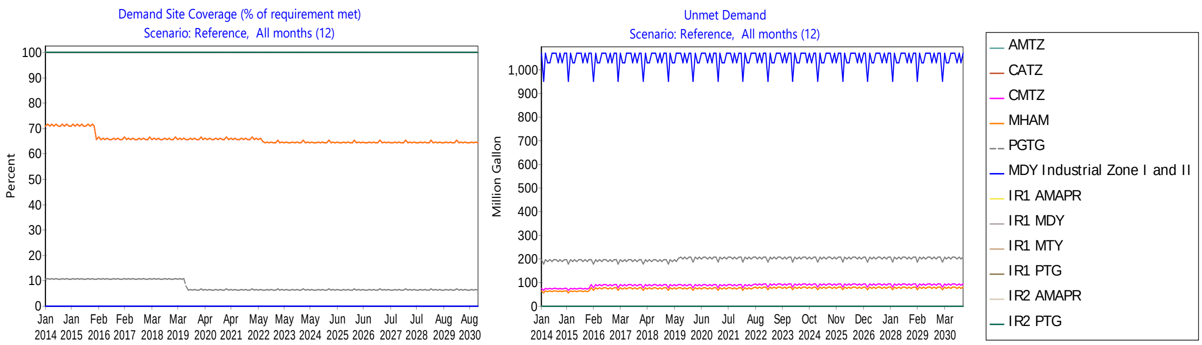

Figure 7: Unmet Demand and Demand Site Coverage of Scenario 1 (Reference Scenario)

4.2. Results of Future Scenario

Two options are considered for future scenario in this study. Option 1 is considered as the proposal allocation plan not including government proposed projects and Option 2 as including government proposed projects.

4.2.1. Option 1

Option 1 includes one future scenario. This scenario represents the situation in which surplus water from Sedawgyi dam will be allocated to Mandalay city and Mandalay industrial zones.

(a) Result of Scenario 2

This scenario is considered as the changes of water supply situation if surplus water from Sedawgyi dam will be allocated to required demand of Mandalay city and industrial zone at reference year. Due to model results, all demand sites are met with required demand and demand site coverage is 100% at current condition if demand will not be changed as reference year. The unmet demand and demand site coverage of scenario 2 for option 1 are shown in Figure 8. Due to the fully met of required demand, this scenario is considered as first proposed allocation plan.

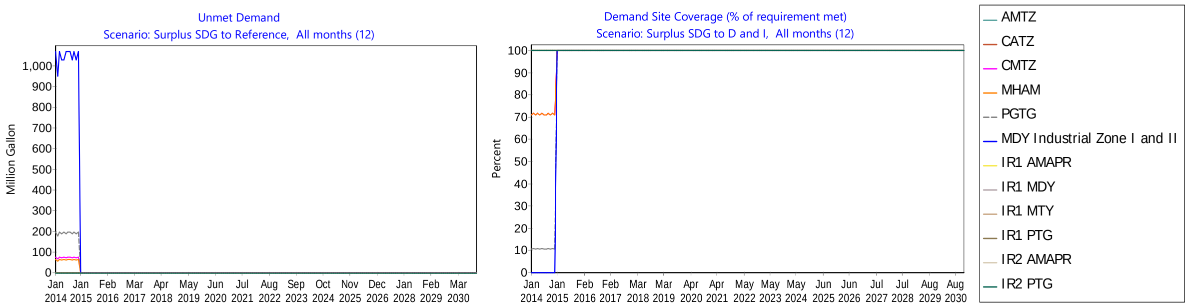

Figure 8: Unmet demand and demand site coverage of scenario 1

4.2.2. Option 2

Eight main scenarios are considered in option 2, if population will be grown with AAGR, if irrigation plan will be changed at 2015, if Ayarwaddy river pumping project will be completed, if Ayarwaddy and Dotehtawaddy river pumping project will be completed, if surplus water from Sedawgyi dam will be allocated to required demand.

(a) Results of Scenario 2

Today, population growth is the main threatening reason for the water crisis, water planners are needed to analyse how population growth will affect on water supply and demand situation. This scenario represents the impact of increasing population with average annual growth rate (AAGR).

According to the report of Urban Planning Departement of Mandalay City Development Committee (MCDC), average annual growth rate for Mandalay City may be 1.68 % during 2014 to 2030. If population of Mandalay city will grow with AAGR with no additional supply, the monthly unmet demand will be 135.34 MG for Chan Mya Tharzi township, 111.05 MG for Mahar Aung Myae township and 236.92 MG for Pyi Gyi Tagon township at 2030. But Aung Myae Tharzan and Chan Aye Tharzan townships are met with required demand and have no unmet demand even if population will grow with AAGR. Another sectors are the same as reference scenario and this scenario is considered form demand side of domestic sector. Under scenario 2, the overall unmet demand will be increased to 1554.97 MG/month and demand site coverage will be declined to 78 %. The unmet demand and demand site coverage for scenario 2 of option 2 are shown in Figure 9.

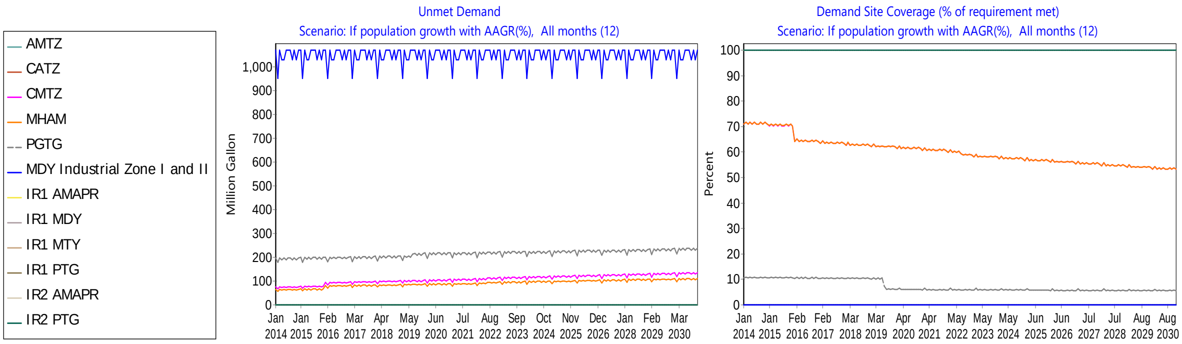

Figure 9: Unmet Demand and Demand Site Coverage of Scenario 2

(b) Results of Scenario 3

Scenario 3 refers the condition of changing crop pattern of irrigated areas at 2015. This scenario is considered from demand side of irrigation sector. In 2015 plan, even irrigated areas were increased to double, there will be still no unmet demand and demand site coverage is 100% for Sedawgyi and Sedawlay irrigated areas. Based on this scenario, surplus water from Sedawgyi dam can be allocated for domestic and industrial demand of Mandalay City. In this scenario, other sectors are the same as scenario 2 and the unmet demand and demand site coverage of scenario 3 are shown in Figure 10.

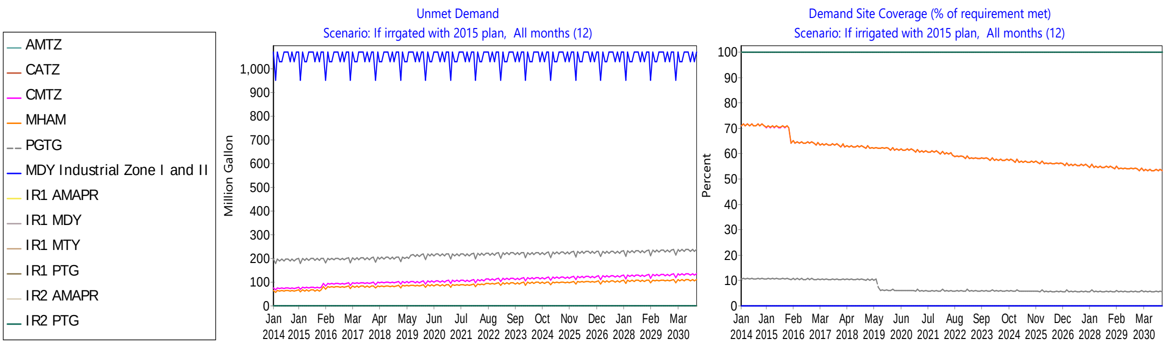

Figure 10: Unmet Demand and Demand Site Coverage of Scenario 3

(c) Results of Scenario 4

The Scenario 4 represents combination condition of Scenaio 2, 3 and the water supply and demand situation of Mandalay city after completion of Ayerwaddy river pumping project. According to MCDC master plan, it is mentioned that new Ayeyarwaddy river pumping project is under construction and will be completed at 2020. This project can supply 10 MGD for Mandalay city. This scenario is considered from supply side for domestic sector. Due to model results, the overall unmet demand will be decreased to 1317.12 MG/month and demand site coverage will be increased to 85% for all water allocation sectors. So, new project creation may be required to balance the remaining unmet demand. Other sectors have no changes in this scenario and not affected to other sector. The unmet demand and demand site coverage of scenario 4 are shown in Figure 11.

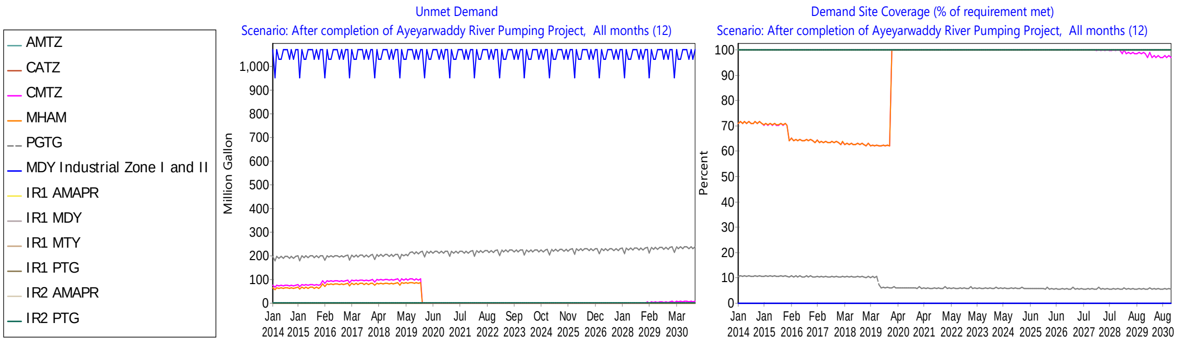

Figure 11: Unmet Demand and Demand Site Coverage of Scenario 4

(d) Results of Scenario 5

The Scenario 5 represents combination condition of Scenario 4 and the completeed condition of Dotehtawaddy river pumping project. From MCDC proposed plan, Dotehtawddy river pumping project is proposed to construct and will be completed at year 2025 and 3 MGD can be supplied to Pyi Gyi Tagon township of Mandalay city. This Scenario is considered from supply side of domestic sector. The model results showed that the overall unmet demand will be decreased to 1224.13 MG/month and demand site coverage will be increased to 88% at all water supply system. But, these two river pumping project could not fullfilled the unmet demand and new project is required to create. In this scenario, other sectors have no changes except domestic sector. The unmet demand and demand site coverage of scenario 5 are shown in Figure 12.

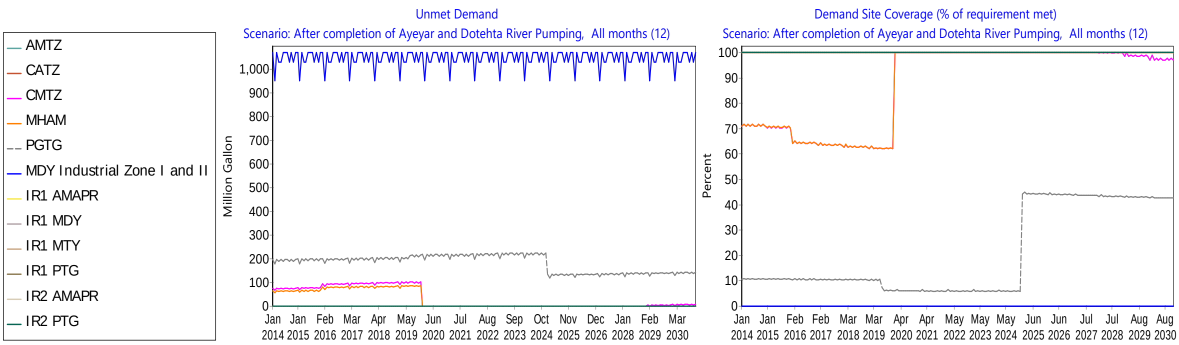

Figure 12: Unmet Demand and Demand Site Coverage of Scenario 5

(e) Results of Scenario 6

The scenario 6 considers the combination of scenario 5 and the condition of filling required demand of Pyi Gyi Tagon and Chan Mya Tharzi townships from surplus water of Sedawgyi dam. According to model results, the supply delivered are balanced with unmet demand and demand site coverage is 100% for Mandalay city. So if this scenario will be completed, Mandalay city will have no unmet demand and all townships have no water shortage all year round from the year 2025. But it is remained to supply Mandalay industrial zone. Under this scenario, the overall unmet demand will be decreased to 1071.66 MG/month and demand site coverage will be increased to 92% for all water allocation sectors. The unmet demand and demand site coverage of scenario 6 are shown in Figure 13.

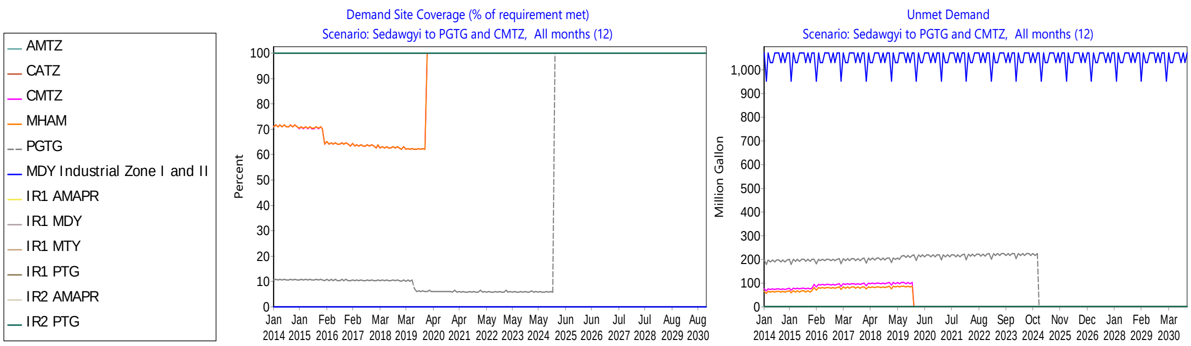

Figure 13: Unmet Demand and Demand Site Coverage of Scenario 6

(f) Results of Scenario 7

The Scenario 7 represents the condition of Scenario 6 plus allocation of surplus water from Sedawgyi dam to required demand of Mandalay industrial zone. The model results revealed that all demand sites are met with required demand and demand site coverage is 100 % for all allocation sectors at 2030. So, this scenario can solve water shortage problem of all sectors. The unmet demand and demand site coverage of scenario 7 are shown in Figure 14.

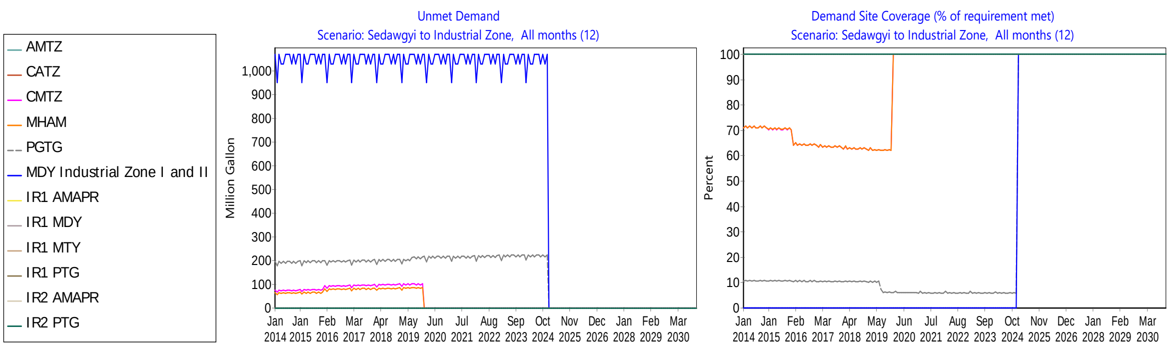

Figure 14: Unmet Demand and Demand Site Coverage of Scenario 7

(g) Results of Scenario 8

This Scenario is considered to check whether Dotehtawaddy river pumping project may be required or not. The Scenario 8 represents the combination condition of Scenario 4 and allocation of surplus water from Sedawgyi dam to required demand of Mandalay industrial zones. According to model results, the demand site coverage is 100% and there is no unmet demand for all water allocation sectors from year 2020 even if not included Dotehtawaddy rive pumping project. So, this scenario shows that the proposed Dotehtawaddy river pumping project may not be required. The unmet demand and demand site coverage of scenario 8 are shown in Figure 15.

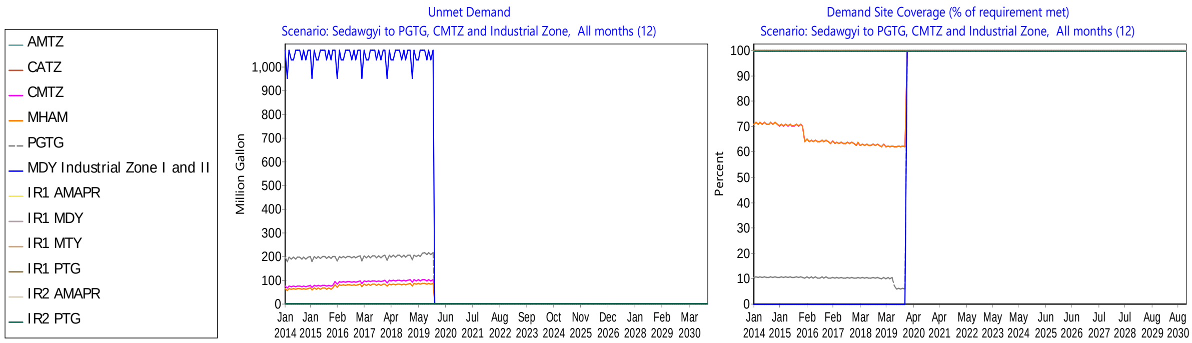

Figure 15: Unmet Demand and Demand Site Coverage of Scenario 8

5. Conclusion

The purpose of the study is to propose water allocation plans with Water Evaluation and Planning (WEAP) model for the simulation of water demand and supply system for domestic, industrial, irrigation and hydropower sector of Mandalay area to balance the growing of water demand. In this study, cost and benefit analysis are not undertaken due to time limitation and insufficient data. Allocation is just considered to meet the required demand of all water allocation sectors. Based on results of two options, three allocation plans can be proposed. Under option 1, new Sedawgyi water supply network for the required demand of Mandalay city and industrial zones is implemented as first proposed allocation plan. Under option 2, Ayarwaddy river pumping and Sedawgyi network project is represented as second proposed allocation plan and Ayarwaddy river pumping, Dotehtawaddy river pumping and Sedawgyi network as third proposed allocation plan. All allocation plans can meet with the required demand of all water allocation sectors.

But, the first proposed plan requires one new project, second plan requires three new projects and third plan requires two new projects. In all proposed plans, surplus water allocation from Sedawagyi dam project is included. So, this new project is vitally need to balance the unmet demand of all sectors. Moreover, due to the allocation of surplus water from Sedawgyi dam, overflowing of spilled water to crop fields problem can be prevented and the water usage efficiency of the Sedawgyi dam would be increased. But Sedawgyi dam is located at within a few miles away from the Mandalay and this means that the more construction cost will be needed for such long raw water conveyance main pipe line or canal. Otherwise, the current used canal of Mandalay main canal can be reconstructed to convey the additional amount water demand.

Among three proposed plans, the second plan should not be selected because this plan requires three new projects. Moreover, Dotehtawaddy river water should not be used directly for public supply because of contamination of water with disposal of industrial wastes from Mandalay industrial zones. So, waste water treatment plants are needed to construct and more construction, operation and maintenance cost are required. The Ayeyarwaddy river is situated within a little miles from the center of city. So, compared with Dotehtawaddy river, Ayeyarwaddy rive is close to Mandalay city and construction cost of water conveyance pipe line can be reduced. As the main purpose of water allocation is balancing supply and demand, and promoting the efficient use of water, the first proposed allocation plan should be selected for domestic, industrial, irrigation and hydropower sector of Mandalay area. Moreover, WEAP model is a very useful integrated water resources management tool to predict water shortage and changes in consumption for current and future in local scale.

6. Recommendations

The followings are recommended for further study:

1. Cost analysis should be advanced in this model to analyse cost and benefits of the system to select the best water allocation plan and to get the water price for water pricing policy.
2. Water quality study of Ayeyarwaddy river, ground water and Sedawgyi dam should be integrated with this model to analyse the water quality of the system and to develop the management plan.
3. Scenarios analysis results from this study should be used in discussion among water planners, decision makers, stakeholders and local authorities relating with management plan for the improvement of integrated water resources management system around Mandalay area.

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