TOOL FOR WATER RESOURCES MANAGEMENT

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ABSTRACT –

To overcome water scarcity during drought and threats from future climate changes, a comprehensive water resources management system, the National Water Balance Management System (NAWABS) is being developed by Malaysia Drainage and Irrigation Department. The NAWABS system provides a platform for sharing engineering skills on managing the river system, evaluating alternative developments and operational management schemes. With its in-built Decision Support Management System (DMSS), it could support decision-management for river basins and inter-state planning for developing water resources in a cooperative manner, sharing socio-economic benefits, and promoting efficient water utilisation. By customising the NAWABS's DMSS to support the operational objectives for a specific river basin, it will enable the river basin manager to better manage and balance supply and demands through an improved assessment of the future low conditions and the ability to assess the risk of various operational strategies.

A NAWABS DMSS is being developing for the Perak river basin to evaluate the potential of supplying raw water for the water demand consumption as well as supplying raw water for interbasin transfer to the adjacent water shortage state Penang. Perak is one of the water resources abundance state in Malaysia. Analysis show that the Perak river has sufficient raw water in the Perak river for supplying the raw water to meet the projected demand of 2,228 MLD for Perak's own consumption and interbasin transfer of 1,000 MLD to the adjacent Penang state up to year 2050 under a drought probability level of 1 in 50 years. However, it is vital of selecting a river intake location with minimum 7,700 km^2 to ensure the reliability level is achieved. Preliminarily results show that the rainfall in Perak state will be experiencing climate changes form the historical data and the future satellite data. Therefore, further studies are required to enhance the NAWABS Perak for assessing existing water balance and water resources distribution for short- and long-term scenarios, as well as an operational system for real time decision management, water accounting and water availability.

Keywords: Water resources management, NAWABS development, Decision Management Support System, water basin manager, water security.

1.0 INTRODUCTION

Water balance from the hydrological cycle perspective is defined as the amount of water entering and leaving a control system during a specific time period. It also accounts for major hydrological inputs, outputs and delayed components over specific spatial and temporal scale. The development of water balance model has been established for many river basins of various catchment sizes in the world and some of the example includes Nile Basin in Egypt (3,254,555 km^2), Tarim River in China (557,000 km^2), 11 River Bains in Nepal (147,181 km^2) and Murrumbidgee Basin in Australia (84,000 km^2) (Michael B. Butts et al., 2016; Yang Yu et al. 2015; GON, 2018 and Department of Primary Industries Water, 2015). The main reason for the development of a water balance modelling which typically includes a modelling tool is to provide a comprehensive solution to water resources management issues such as providing updated information on water availability, water demand, and options for water transfer, water storing and allocation and integration of surface water and groundwater.

In Malaysia, like elsewhere, water is considered as the core of sustainable development and a critical element for its socio-economic development. Water is a finite resource and renewable only if well managed. The implementation of an integrated water resources management via NAWABS is particularly important for key river basins involving interbasin sharing or transferring of water resources, among the states in Malaysia. One of the major Key river basins, viz., the Perak river has an abundance of water for its own consumption. It is the second longest river in Peninsular Malaysia. The Penang State is a water thirsty state with densely populated and industrialized urbanized areas in a limited land. The Perak river is considered as the potential sources of raw water to the adjacent state Penang state. However, the risk of its water resources of the Perak river diminish

over times is high in emergent due to development pressures, water mismanagement as a result of non-integrated development and climate change. Over years, the water resources situation in Perak river has been gradually changed "from one of relative abundance to one of relative scarcity", especially during the drought seasons. Furthermore, the two bordering states Perak and Penang are seeking the implementation of the Sungai Perak Raw Water Transfer Scheme (SPRWTS) as the most logical, rational and economical option for achieving water supply security in Penang and North Perak until Year 2050.

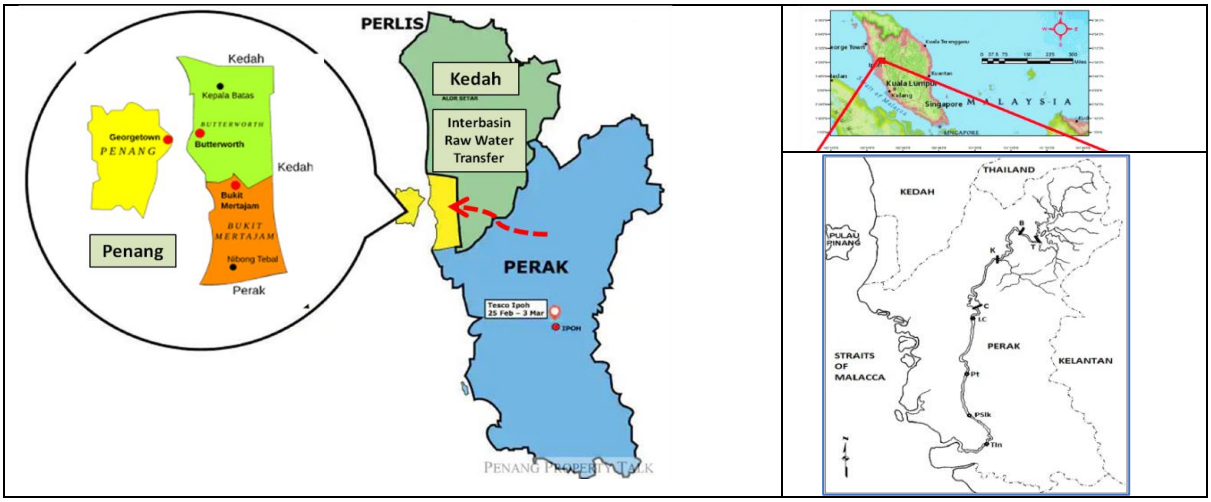


Figure 1. Location of Penang and Perak State with Perak River with proposed Interbasin Transfer of Raw water scheme

The interbasin transfer (see Figure 1) of raw water from Sungai Perak to Penang is considered as the best option for Penang now due to the following reasons:

(1) A readily available raw water resource that is presently underutilized.
(2) A raw water resource covering two bordering states: Perak and Penang.
(3) An inter-state raw water transfer project with the financial fund from Federal Government of Malaysia
(4) Construction cost for a conventional water treatment plant to treat raw water transferred from Sungai Perak are significantly lower than the costs of setting up a desalination plant or other types of the same capacity.
(5) Operating cost for a conventional river water treatment system is more cost efficient than recycling or desalinating water. Note that a large-scale desalination and reverse osmosis (or ultra-filtration) processes will be more energy-intensive and cost-intensive.
(6) Other types of options such as water recycling and rainwater harvesting require additional specialized infrastructure, including separate pipeline networks for channelling the raw water and/or distributing the processed water.

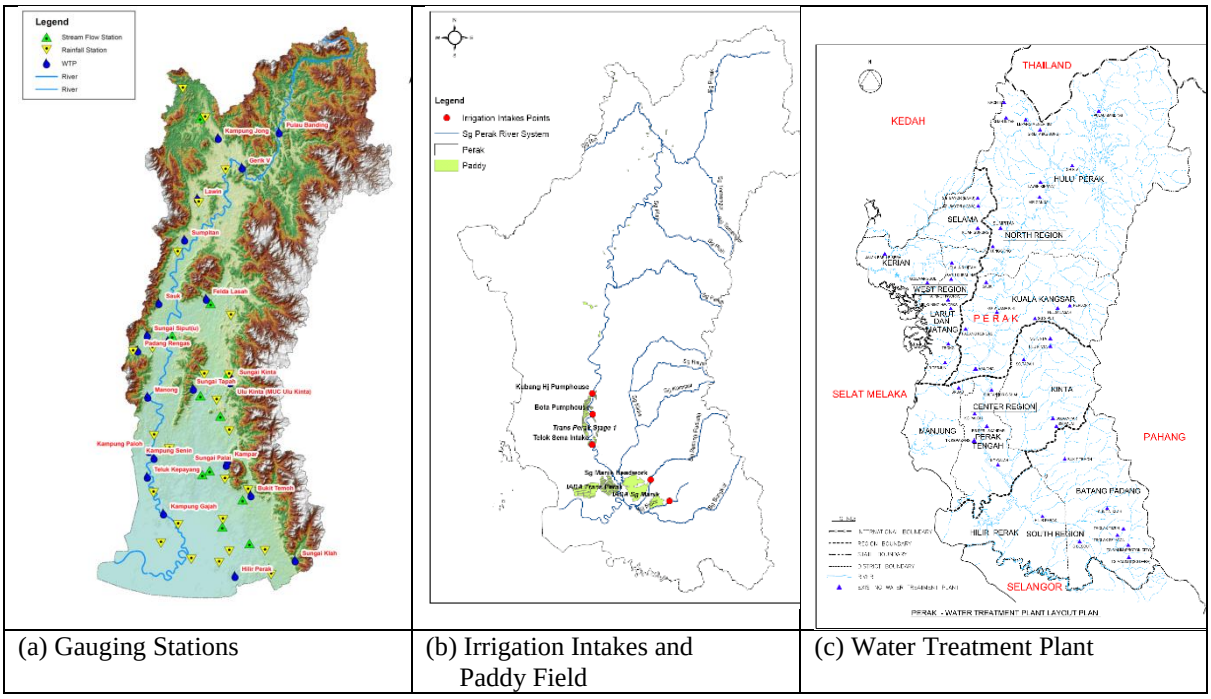
One of the key elements in ensuring a sustainable water resources for the Perak river system is to provide a comprehensive management instrument which provides multiple functions including a systematic accounting for water resources, real time on-line information on water availability, an assessment tool to evaluate operation options for efficient water allocation and a forecasting to assist in the decision management process. Therefore, Jabatan Pengairan dan Saliran Malaysia is implementing a water balance study and to develop of a Water Balance Management Modelling (NAWABS) for Perak River which includes a Decision Management Support System (DMSS).

2.0 BACKGROUND AND THE STUDY AREA

The Perak river basin has a catchment area of about 14,908 km^2, which covers about 70% of Perak state. It originates from the mountainous Perak-Kelantan-Thailand border of the Belum Forest Reserve in the north. The river flows southward from Perak River Hydro Scheme to Telok Intan and subsequently turns west to discharge into the Straits of Melaka at Bagan Datuk. The major tributaries are Pelus river, Kinta river, Batang Padang

river and Bidor river. The upper reaches of the basin where the Perak River Hydro Scheme is located is covered by forest land. Figure 2 shows the gauging stations, irrigation intakes and paddy field; and water treatment plant within the Perak river basin. (DID, 2011)

Figure 2 shows the existing hydroelectric plants constructed in a cascading sequence. The hydropower dams do not consume raw water after power generation. However, these dams are required to regulate and release water to the downstream water intakes during droughts. Therefore, the water resources operation is required to take the interests of all stake-holders into consideration. Priority on the water allocation for the relevant stake-holders should be set during extreme droughts.



(a) Gauging Stations | (b) Irrigation Intakes and Paddy Field | (c) Water Treatment Plant

Figure 2. Perak River Catchment with Major Hydraulic Structures

3.0 NATIONAL WATER BALANCE SYSTEM (NAWABS)

Figures 3 and 4 show the framework and components of NAWABS's Decision Management Support System (DMSS), respectively. Once it is customised specifically to support the operational objectives, the operational NAWABS DMSS will enable the river basin managers to better balance supply and demands, through an improved assessment of the future climate conditions and the ability to assess the risk of various operational strategies. The modelling tools are developed using DHI's proprietary programs such as MIKE OPERATION, NAM, MIKE HYDRO BASIN, MIKE 11 and MIKE SHE. The NAWABS DMSS has been designed to assess the existing water balance and future scenarios, as well as an operational system for real time decision management. Real time inputs are rainfall, river levels and flows, pumped extractions and structure rule operations. Short-term forecasts are generated based on available weather forecast data from the Malaysian Meteorological Department, while longer-term assessments, including uncertainty, will be based on ensemble climate forecasts from NOAA's NCEP CFSv2 (Saha et al. 2010 and Saha et al. 2014). The system is built upon a comprehensive Decision Support System (DSS) framework based on DHI's MIKE OPERATION in which hydrologic and water resources model are used to perform analysis and modelling for decision management and planning. NAWABS DMSS provides data management and model-based forecasting results for operational control of river systems, water collection systems, water distribution systems, and tools for acquiring and combining online data sources in preparation for real-time modelling. (AM Ishak et al, 2017; M. R. Husain et al, 2017; NM Ghazali et al, 2019)

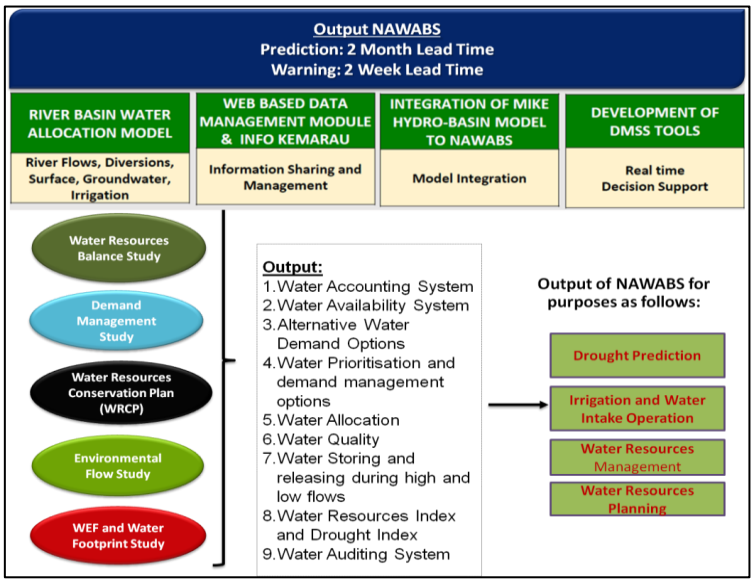


Figure 3. Framework of NAWABS Decision Management System

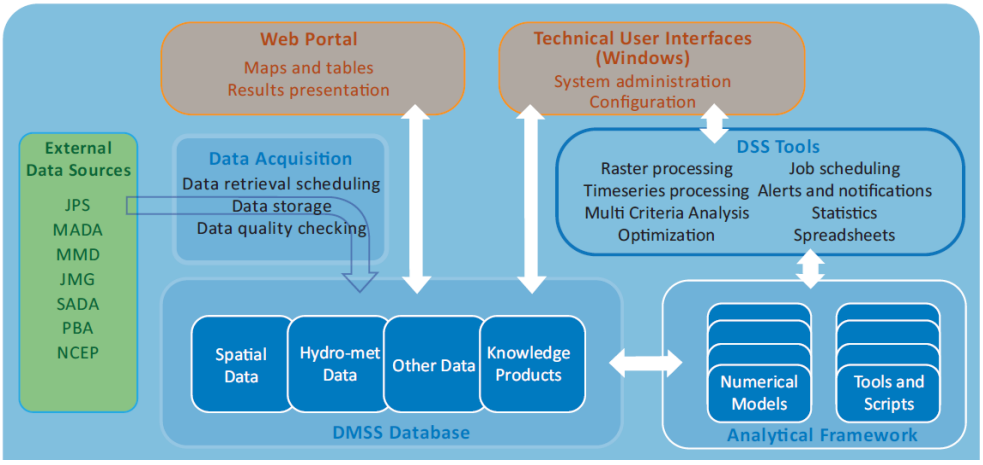


Figure 4. NAWABS DMSS Components

4.0 WATER DEMAND IN PERAK AND PENANG

Penang:
The water supply services in Penang is managed by a state government linked company, Penang Water Supply Corporation (Perbadanan Bekalan Air Pulau Pinang; abbreviation PBA). The water demand of Penang state is estimated to continue escalating in tandem with population growth as well as increasing economic activities. In terms of billed water consumption, PBAPP (PBA 2019) recorded an average increase of 1.64%, from 826.3 million litres per day (MLD) in 2017 to 840 MLD in 2018 (LAP, 2016). The water demand is projected to reach 1,483 MLD by 2030 and 1,696 MLD by 2050. Due to its inherent geographic limitations and the issue of limited water resources, PBAPP will not be able to produce sufficient treated water to meet Penang's future demand. Therefore, the interbasin raw water transfer from Perak River is necessary to avoid water scarcity and shortage in Penang.

Perak
The water supply services in Perak is managed by a state government institution, Perak Water Board (Lembaga Air Perak; abbreviation LAP). The water demands (high projection category) of Perak state are estimated to 1,385 MLD by year 2030, 1,683 MLD by year 2030 and 2,228 MLD by year 2050. It is expected that there

should not be water shortage if the catchment conditions are well maintained in Perak state. Figure 5 shows the projected water demand for Perak state, data plotted from the study DID, 2011 and published figure from the LAP corporate profile 2016 is scaled for comparison purposes.

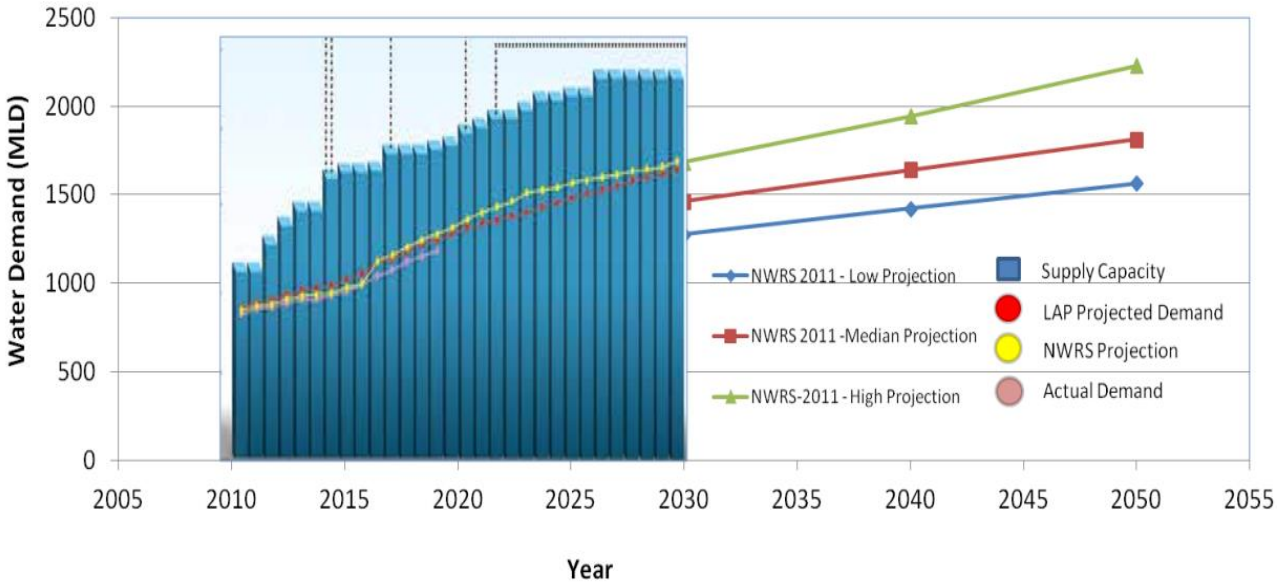


Figure 5. Water Supply and Demand in Perak State (Data plotted from NWRS, 2011 and figure excerpted from Corporate Profile of LAP (2016).

5.0 ISSUE and THE RATIONALE OF THE STUDY

It has been proposed that the proposed Sungai Perak Raw Water Transfer Scheme (SPRWTS) as a solution that delivers 1,000 MLD of raw water to Penang in 4 phases until 2050. With its high volume of potential yield, the SPRWTS will ensure water supply security for Penang and North Perak until Year 2050. The NAWABS for the Perak river basin will be developed to manage the water resources for all development needs. The study results will then be use for the management and long-term sustainability of water resources in the Perak river basin.

Key considerations that justify the development of the NAWABS Perak to manage water resources for the future include: -

(i) Multiple stakeholders which have different priorities;
   a) River basin managers – need short term operational and long-term seasonal planning tools to balance demand with supply management. The modelling system shall be capable of advising users the abstraction value from the river and groundwater (from model auto-optimization).
   b) Water users – need access to up to date information on river flows and levels to better manage their own operations
   c) Policy makers – need to understand the long-term risks to supply to enable them to make informed economy investment decisions based on cost benefit analysis from the study.

(ii) Long-term water resources planning and Climate Change Assessment
   a) Water resources capacity planning and drought management tools during extreme droughts
   b) Effects of climate changes by using projected climate change

(iii) Project Viability and Decision Management Support System (DMSS)
   a) New project feasibility evaluation for water availability assessment
   b) Option evaluation based on results derived from DMSS

However, the water availability for the proposed scheme and the Perak river system is assessed using the studies proposed under NAWABS projects. The development of Water Balance Modelling System under NAWABS is to fulfil the key objective of SPRWTS as follows: -

i. to conduct a water balance study and other relevant study for the Perak basin;
ii. to plan a water balance model together with a option of Decision Making;

The water availability for the interbasin transfer of raw water will be assessed to provide rules of water allocation, priority and options for decision makers during extreme drought and future climate conditions.

6.0 WATER AVAILABILITY

6.1 Hydrological Data Analysis and Modelling

JPS is the main agency in Malaysia operating a network of hydrological stations and maintaining the national hydrological database. The JPS hydrological stations can be categorised into two types, National Network and Non-National Network. Currently, there are 97 rainfall stations under JPS National Network in operation in Perak. (DID, 2011)

Due to the data consistency and availability, only 36 rainfall stations are used in the analysis. Figure 6 shows the hydrological model set-up using NAM model and the locations of treatment plants in the Perak river basin. Figure 7 show the double mass curve of rainfall runoff relationship for consistency checking. A ratio of 0.54 between rainfall and runoff has is reasonable for a typical catchment in Malaysia. With the NAM model set-up, typical simulation results at selected locations are shown are shown in Figure 8.

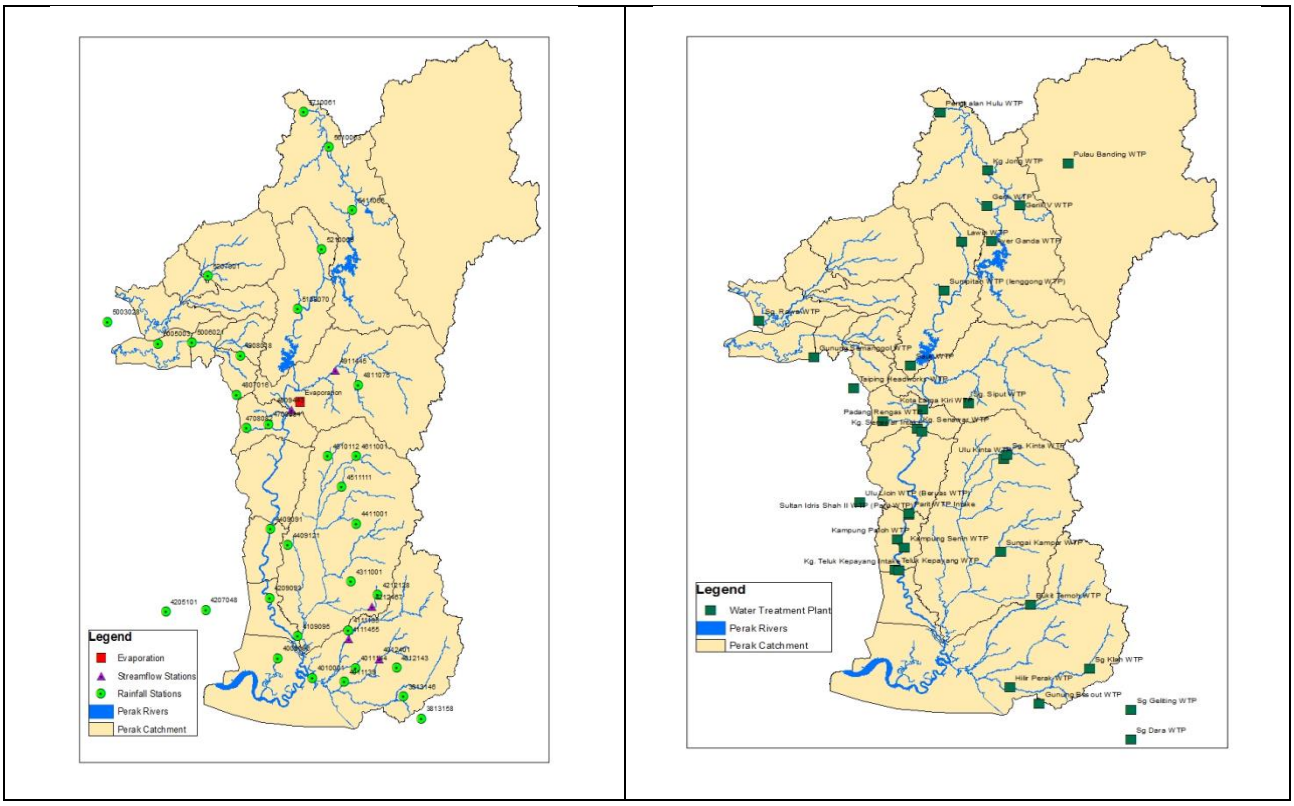
6.2 Water Availability Assessment

Based on the data available, and a preliminarily assessment on the water availability for the self-consumption of Perak river basin and the potential of interbasin transfer. The assessment was carried out based on the synthetic drought hydrographs derived from the year 2011 for a probability level of 1: 50-year occurrence. The water demand for the Perak state is assumed to comply with the categorized "High Projection" in the study of DID, 2011. The estimated water demand for Perak state is estimated to 2,228 MLD up to year 2050. The analysis and assessment have determined the minimum catchment areas required in order to confirm the water availability. Three scenarios have been considered: (a) Interbasin with 1,000 MLD, (b) Perak state water demand projection up to year 2050, and Perak state water demand and interbasin transfer of 1,000 MLD up to year 2050. Table 1 shows stream flow gauging stations of which drought hydrographs with a 1 in 50 years of return periods are developed for yield assessment in DID, 2011.

From the results of Figure 9, intake location with sufficient catchment area for the abstraction location in the Perak river basin is 7,770 km^2. will have sufficient raw water demand for Perak and Penang. However, a detailed investigation will have to be carried out in a more in-depth to determine the environmental flow requirements. With a larger catchment area, the stream will be sufficient to provide internal state water demand consumption and interbasin transfer of 1,000 MLD, under the critical drought with a return period of 1 in 50 years. However, detailed study on the water resources to determine other requirements such as environmental flow and navigational requirements at the downstream river is needed.

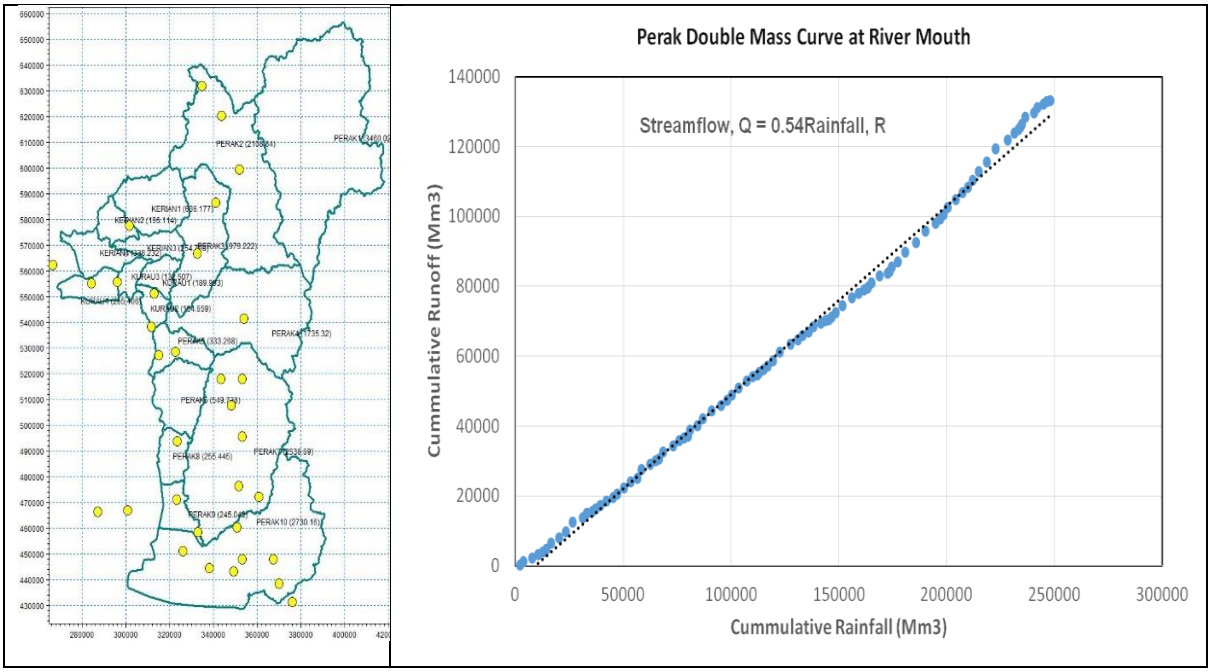
Table 1. Stream Flow Gauging Station In Peak River Basin

No.	Station No.	Name	Catchment Area (km^2)
1	4212467	Sg Chenderiang at Bt 32 Jln Tapah	119
2	4012401	Sg Bidor at Bidor Malayan Tin Bhd	210
3	4111455	Sg Batang Padang at Tg Keramat	445
4	4911445	Sg Pelus at Kg Lintang	1,090
5	4809443	Sg Perak at Jamb Iskandar	7,770



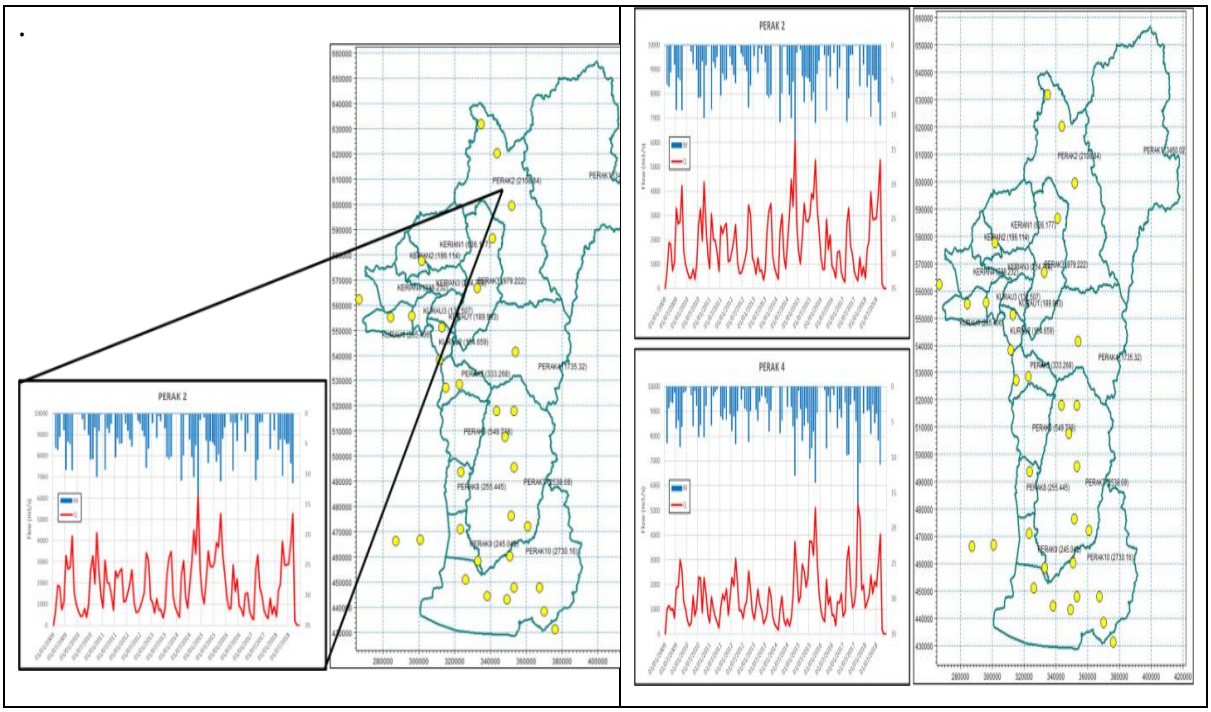
(a) Hydrological Stations in NAM Model (b) Water Treatment Plant in Perak Catchment

Figure 6. Hydrological Rainfall Station in NAM Hydrological Model and Water Treatment Plant in Perak River Catchment



(a) Hydrological Stations in NAM Model (b) Water Treatment Plant in Perak Catchment

Figure 7. Hydrological Rainfall Stations in NAM Hydrological Model Set-up and Hydrological Data Consistency Analysis – Double Mass Curve at Perak River Mouth



(c) Hydrological Stations in NAM Model (d) Water Treatment Plant in Perak Catchment

Figure 8. Typical Simulated Stream Flow of NAM Model

Figure 9. Water Availability of Perak River of 1: 50-year Drought Hydrographs with (a) Water Demand Typical Simulated Stream Flow of NAM Model

6.3 NAWABS and Climate Change

The water resources for a river basin will be diminished due to future land use and climate changes. The land use and climate changes can be mitigated via the implementation of NAWABS. The land use changes can be prevented via the gazetted catchment conservation. However, the future climate will make the water availability

uncertain. Therefore, a comprehensive modelling tools and decision management support system in the NAWABS will help to ensure the following targets are achieved:

(a) WATER ACCOUNTING

I. The analysis and modelling shall account for all water entry and exit/loss within the river basin and key sub-basins and shall be updated on a daily basis;

II. The accounting process shall be updated on a weekly/monthly basis and aggregated on a yearly basis.

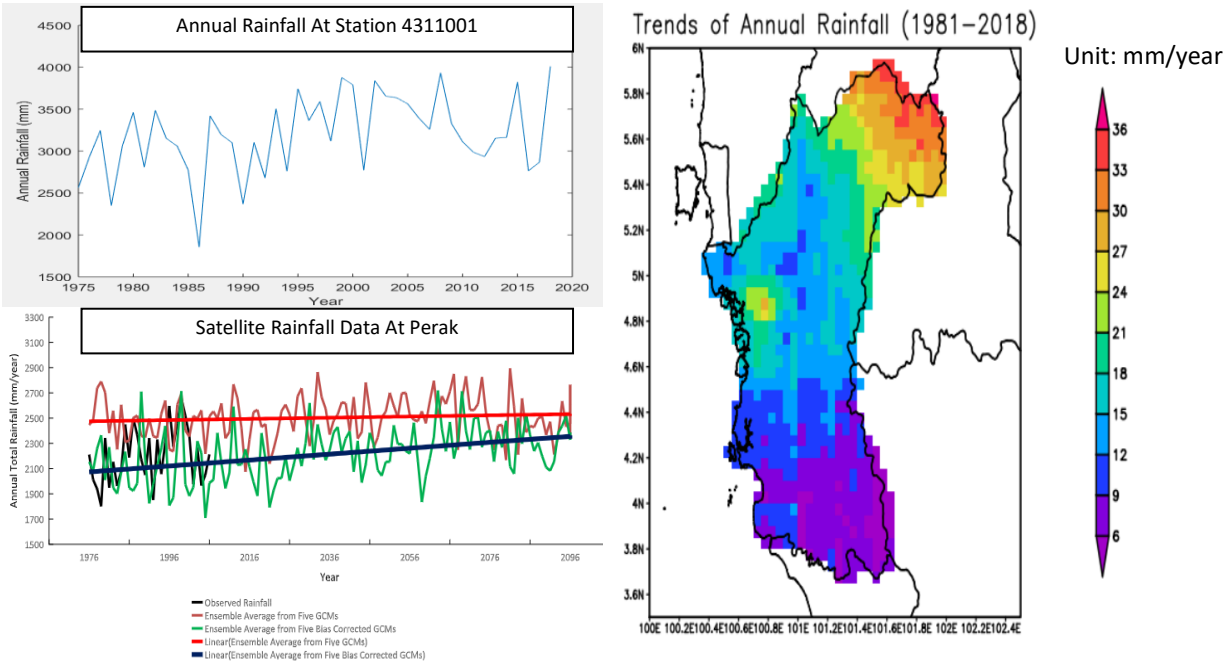
(b) Water Availability

i. The analysis and modelling shall account for water availability both in terms of volume and river stage (m) at all key demand points and be designed to incorporate and take into account future demand points;

(c) Water Allocation

i. The analysis and modelling shall assist the water resources manager to determine how water shall be allocated depending on demand and priorities.

Figure 10 shows the projected changes in annual rainfall in the station 4311001, Pejabat Daerah Kampar, extracted from one of the most complete historical data. The results show that there is an upward trend of annual rainfall, and suggesting that an increasing trend of rainfall over the past 4 decades. The average changing rate is approximately 130mm/decade. The annual rainfall trend is consistent pattern between station and satellite data. The change rate is about 150 mm / decade since 1980s. Also, the spatially satellite data shows a larger change over the northern inland part of the state, minimal at the southern part of the state.



(a) Current and Future Climate Change (b) Spatial Trend of Changes in Rainfall (mm)

Figure 10. Annual Rainfall Changes in Point and Spatial Historical Station and Satellite Data.

7.0 Conclusions

A comprehensive water resources management system, the National Water Balance Management System (NAWABS) is developed by Malaysia Drainage and Irrigation Department to support the water resources sustainability for the key river basins. Using the DMSS and Modelling tools, the NAWABS will provide decision makers with an improved understanding of the overall water availability within the target river basin and allow for the formulation of improved plans and policies for water resource developments and allocations.

The operational system will enable the river basin managers to manage the water supply and demands, and assess the future low conditions and the risk of various operational strategies.

The NAWABS DMSS for the Perak river basin can be used to evaluate the potential of supplying raw water for the water demand consumption as well as supplying raw water for interbasin transfer to the adjacent water shortage state Penang. For water resources sharing system, it could be used to assess the existing water balance and water distribution, short- and long-term scenarios, as well as an operational system for real time decision management, water accounting and water availability.

The Perak NAWABS system will support decision-management and inter-state planning for developing water resources in a cooperative manner, sharing socio-economic benefits, and promoting efficient water utilisation between the two bordering Perak and Penang states. Based on the analysis, there is sufficient raw water for supplying the water demand requirements of 3,228 MLD inclusive of Perak's own consumption and Penang interbasin transfer of raw water of 1,000 MLD up to the year of 2050, under a drought probability of level of 1 in 50 year. Historical gauging and satellite data have shown significant gradual changes in rainfall. To manage and mitigate the negative impact of future climate changes on the water availability, further studies are required to improve the NAWABS Perak.

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