

DESKTOP STUDY ON CURRENT ENGINEERING PRACTICES IMPLEMENTATION FOR CLIMATE RESILIENT IN MALAYSIA



National Water Research Institute of Malaysia (NAHRIM)

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CHAPTER 1

1. INTRODUCTION

1.1. BACKGROUND OF THE STUDY

Recently, a considerable literature has grown up around the theme of climate change effects on water resources. The global mean temperature is expected to increase by 4 °C in 2100, as reported by the Intergovernmental Panel on Climate Change (IPCC, 2014), and this may have serious problem on water resources and demand of the world. In general, there are both supply-side and demand-side pressures facing water resources. In the supply-side pressures, they include climate change by reducing the amount of water availability and environmental quality primarily water pollutant. In the demand-side pressures, they include population growth that leads to increase demands for domestic, industrial, and agriculture.

In the current context, Malaysia has been identified to be vulnerable to climate change. Within the climate change matrix, water resources are at the epicentre of projected climate change impacts. If there is no concrete action on water resources management, the potential impacts on these resources were likely to increase in magnitude, diversity, and severity (Kusangaya *et al.*, 2014). It is also evidenced that climate change impacts on water resources can be both, direct and indirect effects on several aspects including agriculture, health, ecosystems, and biodiversity as well as energy generation.

Climate change is commonly related to three aspects, which are increasing sea levels, storms and heavy rainfall events, and mean temperature. In this context, the mean temperature is predicted to increase by 0.25 °C per decade for the Peninsular Malaysia, 0.20 °C per decade for Sabah, and 0.14 °C per decade for Sarawak. A significant increase in annual rainfall (at 95% confidence level) and northeast monsoon rainfall (90% confidence level) was also found in the east coast of Peninsular Malaysia over the period of 1971–2010 (Mayowa *et al.*, 2015). Based on the tidal data from 1984 to 2013, the average sea level raise for 21 tide gauge stations in Malaysia was 3.67 ± 0.15 mm/year (Kamaruddin *et al.*, 2016). Moreover, the projected sea level along the coast of the Peninsular Malaysia and Sabah-Sarawak would increase by 0.517 m and 1.064 m, respectively in 2100 (Ercan *et al.*, 2013).

Strategy for adaptation on climate change effects on water resources in Malaysia considers both, structural and non-structural measures. For structural measures, the strategy

has been incorporated in the designing and implementation of flood control projects, dam construction, and groundwater monitoring. For the non-structural measures, several awareness campaigns have been implemented. They include the integrated water resource management and River Care Programme to promote sustainable water use and better water management which are crucial in adapting to climate change.

Aligning the aforementioned issues, it is timely to identify practices including policy, guidelines, strategy, and program implemented on climate resilient for water resources as well as their status in terms of implementation and achievement in Malaysia. This information is very crucial for society and policy makers in Malaysia. Therefore, this report reviews current status of engineering practices implemented for water resources in relation to climate change in Malaysia. It focuses on climate change effects on three sectors, which are water resources, water service industry, and water related disasters. In addition, the discussion for current engineering practices implementation on the water sectors has also been provided. In the water resources, climate change effects on river, sea, dam, and groundwater are discussed. Domestic and industrial water supply, irrigation, hydropower, and fisheries are the subjects discussed for water service industry. Water related disasters focuses on flood, drought, and water pollution. Moreover, current engineering practices implementation presents updated Intensity–Duration–Frequency (IDF) curves, alternative water resources, water demand management, efficient irrigation, interbasin water transfer, and reducing non-revenue water. This report ends up with the conclusion and recommendation for foreseeable future work.

1.2. OBJECTIVES OF THE STUDY

The objectives of this study are:

- (a) To collect, provide, and analyze data, information, and issues related to current engineering practices on climate resilient on water resources in Malaysia.
- (b) To provide analysis relating to climate change adaptation in water sectors in Malaysia based on current engineering practices.

1.3. IMPORTANCE OF THE STUDY

- (a) There is a need for a comprehensive understanding of current engineering practices on climate resilient on water resources in Malaysia.

- (b) Findings from this work are useful for better understanding of the impacts of climate change on water resources in Malaysia.
- (c) This study is crucial as an initial comprehensive report regarding to climate change adaptation on water resources in Malaysia.

CHAPTER 2

2. TERMS OF REFERENCE

2.1. INTRODUCTION

To achieve the objective of the study, this chapter outlines the terms of reference including the scope and deliverables. It is a desktop study to review and qualitatively analyze current engineering practices on climate resilient on water resources in Malaysia.

2.2. SCOPE OF THE STUDY

The scope of this study are as follows:

- (a) The service provider needs to identify all related fields in water sectors in Malaysia, which are directly affected by climate change and subsequently collects the related information and data for qualitative analysis. It can be categorized as follows:
- (b) Climate change impact on water resources or water bodies which include:
 - i. River: drought and flood risks caused by changing in rainfall pattern and extreme river flow, sedimentation, river flow capacity, navigation issues, and saltwater intrusion.
 - ii. Sea: sea level rise, flood in coastal area, water temperature rise, and acidification.
 - iii. Dam: water level variation, drought potential, eutrophication, and decrease in water quality.
 - iv. Groundwater: effect on groundwater discharge, saltwater intrusion into aquifer, and groundwater capacity.
- (c) Climate change impact on water services industry which includes:
 - i. Domestic and industrial water supply: water availability, water crisis, saltwater intrusion, and decrease in water quality during low flow.
 - ii. Irrigation: water infrastructure, crop yield, and agriculture activities.
 - iii. Hydropower: Effects of increase in rainfall and water flow on the operation and capability of hydropower system.
 - iv. Fisheries: Effects of increase in rainfall and saltwater intrusion on aquaculture industry and fish migration.

- (d) Climate change impact on water-related disasters which include:
- i. Flood: increase in rainfall potentially leads to flooding particularly in lowland area and causes many losses.
 - ii. Drought: Lengthening the drought period can cause water crisis.
 - iii. Water pollution
 - Increase in water temperature, rainfall intensity, and low flow period affects water quality. It also leads to algae growth and bacteria that have negative impact on water ecosystem, and human health that incur additional operation and maintenance cost of water supply system.
 - Dam pollution – increase in water temperature would lead to decrease in water quality by increasing thermal stabilization, decreasing dissolved oxygen, and increasing phosphorus content.
 - Pollution from soil erosion and sedimentation – increase in rainfall intensity causes increase in solubility.
 - Increase in water flow affects sewerage system capacity.
 - Increase in low flow can decrease dilution capacity.
- (e) The service provider needs to do primary and secondary information collection to achieve the objective of this study if the related information is not available.
- (f) The service provider needs to list and collect information relating to current engineering practices including policy, guidelines, strategy, and program implemented on climate resilient for water ecosystem as well as their status in terms of implementation and achievement.
- (g) The service provider needs to provide report for this study relating to the climate change adaptation in water ecosystem sector in Malaysia and to be printed with ISBN registration.

CHAPTER 3

3. WATER RESOURCES

3.1. INTRODUCTION

The main climate change consequences related to water resources are shifting in precipitation patterns and a likely increase in the frequency of flooding and droughts. Therefore, this chapter discusses climate change impacts on water resources including river, coastal/sea, dam, groundwater, and water ecosystem. The discussion for these resources is presented in terms of the expected impact, adaptation measures, and regulation.

3.2. RIVER

3.2.1. The Expected Impact

The common indicator used to assess the impact of climate change on freshwater resources such as rivers is by looking at changes of mean annual runoff. In Malaysia, impacts of climate change scenario on runoff of rivers have been investigated. For example, climate change effects on river runoff in Klang watershed (state of Selangor) were studied using a statistical downscaling model and the rainfall-runoff hydrological model (Kabiri *et al.*, 2012). The mean annual runoff of the river is predicted to decrease by 4 % for A2 scenario in 2020s and 2050s, and by 4.5% in 2080. Under B2 scenario, the corresponding runoff is expected to decrease by 2.1%, 2.7, and 3.3 %.

In another study, Tan *et al.* (2017) investigated the impact of climate change on annual streamflow and evapotranspiration in Kelantan River Basin. They employed thirty-six downscaled climate projections from five General Circulation Models (GCMs) under the different Representative Concentration Pathways (RCPs) scenarios simulated for the periods of 2015–2044 and 2045–2074. The simulation was then incorporated into the calibrated Soil and Water Assessment Tool (SWAT) model. The study found that the annual rainfall and maximum temperature at the river basin were projected to increase by 1.2–8.7% and 0.6–2.1 °C, respectively. This resulted in the increases in the annual streamflow between 14.6% and 27.2% and evapotranspiration between 0.3% and 2.7%.

To investigate the impacts of land-use and climate variability on hydrological components at the Johor River Basin, a study was carried out by Tan *et al.* (2015).

The SWAT model was calibrated and validated using measured monthly streamflow data. The trend analysis showed that there was an insignificant increase in trends for streamflow, whereas significant increase in trends for precipitation and temperature was observed. The combined (climate + land-use change (conversion of forest to oil palm plantation)) impact caused the annual streamflow and evaporation to increase by 4.4% and 1.2%, respectively. In general, their study found that climate change imposed a stronger impact than land-use change on the streamflow and evaporation.

The future projections of climate change effects on several rivers in Peninsular Malaysia were investigated by Shaaban *et al.* (2011). The investigation was simulated using hydroclimatic conditions during the historical period of 1984–1993 and future periods of 2025–2034 and 2041–2050. Their study found that the overall mean monthly streamflow is approximately the same during both the future period and the historical period for most of the watersheds of Peninsular Malaysia, except Kelantan and Pahang, which show significant increase in the overall mean monthly streamflow during the future period. It was also predicted that the high flow conditions would be magnified in the Kelantan, Terengganu, Pahang, and Perak River watersheds during the wet months, whereas low monthly flows can be significantly lower in the Selangor and Klang watersheds during dry months.

Most of the literatures on climate change impact on rivers are confined to quantitative aspect. The future total flow is expected to increase but the low flow, which is more critical for water supply is expected to decrease. This occurs because of the shift of rainfall pattern whereby the extreme wet and dry periods would be more obvious. Therefore, the most vulnerable parameters in relation to climate change on rivers are low flow which leads to a longer drought and high flow which leads more frequent flood.

3.2.2. Adaptation Measures

In order to ensure the sustainability of water resources in Malaysia which is mostly abstracted from river, the DID Malaysia has initiated a comprehensive assessment of water resources on a river basin approach. The program is called the National Water Balance Management System (NAWABS), which takes into account climate change impact (NC3, 2018). Under this program, the water balance for seven river basins, namely Kelantan, Melaka, Muda, Kedah, Bernam, Klang, and Similajau rivers is

developed. The program comprises nine key areas of water which are water accounting system, water availability system, water demand options system, water prioritisation and demand management options, water allocation system, water quality system, water storing and releasing during low flow and high flow, water resources index and dry spell index, and water auditing system. It also offers a quantitative approach for water savings efforts and flood management to improve reservoir storage and dam security concerns during extreme events arising from climate change.

An example of state level initiative has been carried out by Negeri Sembilan Water Resource Council which developed water resources inventory management system (NC3, 2018). This program aims to improve work performance, especially in recording and reporting on daily work then to improve record and license system, finance, and enforcement. Campaign “*Cintai Sungai Kita*” was initiated by the DID in 1993 which was then under the ministry of Agriculture Malaysia. The purposes of this campaign are to create awareness about the importance of rivers for life, promote conservation measure, and increase knowledge for effective river management. The campaign has been conducted for all states in Malaysia.

Besides the government, the initiative was also undertaken by several NGOs such as the River Care Program (RCP) by the Global Environment Centre (NC3, 2018). RCP aims to campaign the importance of rivers and their value for life. RCP focuses on the promoting the knowledge and society participation in river and water resources protection. It has been conducted in Kinta River, Pencala river, and Klang river. The achievements of this project were the establishment of five community groups in river monitoring and waste management.

In order to enhance the potential of river for water supply, the government through the ministry of Ministry of Energy Green Technology and Water (KeTTHA) now the ministry of water, land, and natural resources (KATS) has promoted the Off River Storage (ORS) (NC3, 2018). This is to resolve clean water scarcity during drought and at the same time minimize flood risks during wet season. Over a long-term, ORS could ensure adequate water supply in states experiencing water stress. This could relieve pressure to transfer water from different states.

3.2.3. Regulation

In order to ensure adequate and uninterrupted supply, Malaysia has taken serious action towards water management where the action for implementation has been in place in the 10th Malaysia Plan (RMK 10) and National Physical Plan (NPP). The implementation of the Integrated River Basin Management (IRBM) plan which includes integrated management of water resources, land resources, ecosystems and socio-economic needs would enable a more comprehensive approach towards reducing the vulnerability to climate change.

The launch of the National Water Resources Policy (NWRP) in 2012, which was formulated based on the outputs of the earlier 2011 National Water Resources Study (NWRS), is one of the key milestones towards a more sustainable and integrated management of water resources in the country. Under this policy, the National Climate Change Policy that was endorsed in 2009, has been taken into consideration. This was done in accordance with the directive of the National Water Resources Council (MSAN) for climate change to be taken into cognizance for the better management of the country's water resources.

3.3. COASTAL/SEA

3.3.1. The Expected Impact

Climate change also affects sea level in Malaysia. For instance, the sea level had increased at an average of 1.3 mm per year from 1986 to 2006 as measured at Tanjung Piai, Johor (Daud *et al.*, 2015). It potentially leads to tidal inundation, shoreline erosion, increased wave action, and saline intrusion, causing submergence of corals, loss of fisheries resources, plantation land, agricultural area, mangrove forests, and possible relocation of coastal infrastructure.

Alternative study on the effect of climate change on long term sea level in Malaysia was reported by (Kamaruddin *et al.*, 2016). Their study used tidal data obtained from gauge stations along the Malaysian coastlines from year 1984 to 2013 in order to analyze the rate and magnitude of sea level rise using robust fit regression. It was found that the sea level for Malaysian coast including Peninsular Malaysia, Sabah, and Sarawak had risen at the rate of 3.67 mm/yr. Table 3.1 lists the magnitude of sea level rises in Malaysia obtained from the study.

Table 3.1: Sea level rise at selected coastal in Malaysia (Kamaruddin et al., 2016)

LOCATION	TIME RANGE	MAGNITUDE SEA LEVEL RISE (mm)
Pulau Langkawi	1986 – 2013	14.60
Geting	1987 – 2013	13.50
Sandakan	1994 – 2013	12.00
Pulau Pinang	1985 – 2013	11.80
Kukup	1986 – 2013	11.60
Tanjung Sedili	1987 – 2013	11.40
Pulau Tioman	1986 – 2013	10.00
Bintulu	1993 – 2013	9.60
Tanjung Gelang	1984 – 2013	9.30
Lumut	1985 – 2013	9.20
Kota Kinabalu	1988 – 2013	8.80
Lahad Datu	1996 – 2013	8.50
Tanjung Keling	1985 – 2013	8.40
Tawau	1988 – 2013	8.40
Kudat	1996 – 2013	7.10
Labuan	1996 – 2013	7.00
Pelabuhan Kelang	1984 – 2013	6.50
Johor Bahru	1984 – 2013	6.30
Cendering	1985 – 2013	6.20

Another study to investigate sea level rise at various coastal regions in Malaysia simulated using the Atmosphere-Ocean coupled with General Circulation Model was conducted by Ercan *et al.* (2013). The simulation results show increases in the sea level around Peninsular Malaysia between 0.066 m and 0.141 m in 2040 and from 0.253 m to 0.517 m in 2100. In addition, the sea level around Sabah-Sarawak coastlines was predicted to increase between 0.115 m and 0.291 m in 2040 and from 0.432 m to 1.064 m in 2100. It was found that the highest sea level rise occurs at the north-east and north-west regions of Peninsular Malaysia and at north and east sectors of Sabah. Figure 3.1 shows the means of the sea level rise projections around Malaysia coastlines for 2040 and 2100. Without adequate mitigation measures, the future floods are expected to be bigger and more damaging.

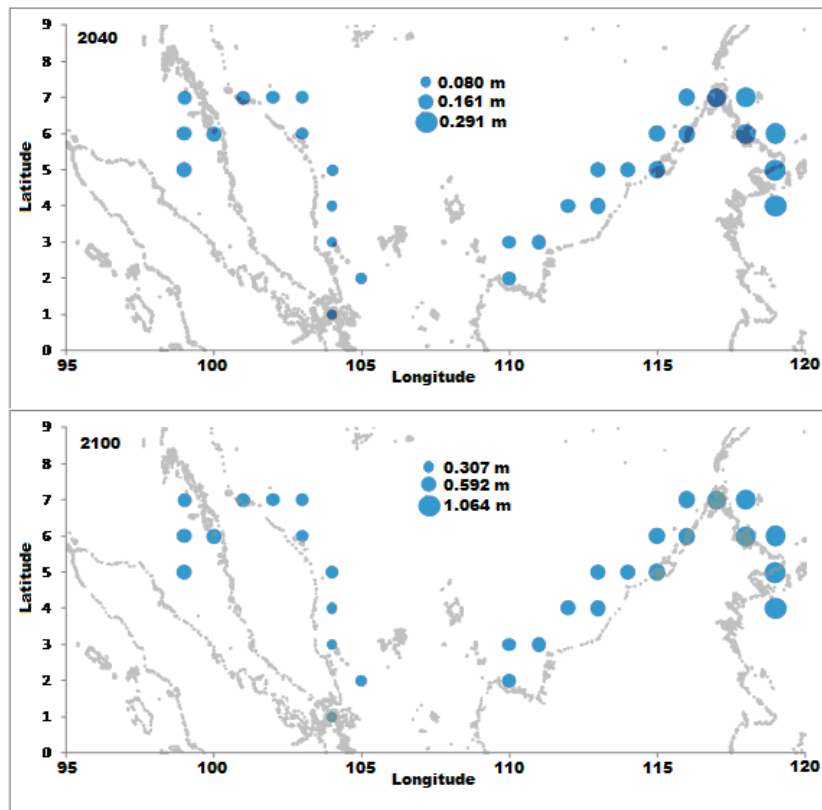


Figure 3.1: Mean of the sea level rise projections around Malaysia coastlines for 2040 and 2100 (Ercan et al., 2013)

Approximately, 31% of Peninsular Malaysia population lives along the coastal line, with total length of 8840 km. Currently, many beach resorts were developed without coastlines protection, while the rising of sea level would lead to more severe coastal erosion. According to the NC3 2018, there are 44 areas (55.4 km) of coastline under the critical erosion category; 309 areas (376.1 km) under the Significant Erosion category; 2,344 areas (916.5 km) under the Acceptable Erosion category as listed in Table 3.2. The expected increase in the sea level will further threaten the very existence of the coastline. By 2030, 37 out of 344 areas (excluding Labuan) were predicted to be under Critical Erosion and Significant Erosion category threatened by sea level rise (NC, 2018). Thus, sea level rise associated with climate change has huge impact on the socio economic and ecosystem.

Table 3.2: Coastal erosion category in Malaysia (NC3, 2018)

STATE	CATEGORY 1:		CATEGORY 2:		CATEGORY 3:	
	CRITICAL EROSION		SIGNIFICANT EROSION		ACCEPTABLE EROSION	
	NO. OF AREAS	LENGTH (km)	NO. OF AREAS	LENGTH (km)	NO. OF AREAS	LENGTH (km)
Johor	0	0.0	30	38.1	42	26,8
Kedah	4	1.9	28	13.6	90	11,3
Kelantan	2	2.0	2	2.5	43	15,3
Melaka	1	0.2	6	1.7	3	1,8
Negeri Sembilan	6	5.5	9	4.1	2	0,2
Pahang	2	1.5	14	16.9	58	43,4
Pulau Pinang	7	4.7	13	5.0	31	6,6
Perak	1	0.3	21	33.8	105	61,2
Perlis	0	0.0	0	0.0	2	0,1
Selangor	2	4.8	16	18.6	156	51,2
Trengganu	8	12.3	20	15.4	115	21,0
Sarawak	7	18.6	78	144.8	566	329,1
Sabah	3	3.0	63	79.1	1120	347,2
Labuan	1	0.6	9	2.5	11	1,3
TOTAL	44	55.4	309	376.1	2344	916,5

3.3.2. Adaptation Measures

According to NC3 2018 report, a total of 208 structural coastal protection projects had been implemented between 1985 and 2015 to protect over 212 km of coastline (NC3, 2018). A revised NCES study in 2016 has recommended a number of adaptation measures for critical erosion coastal areas around the country. In addition, DID has also conducted studies of Integrated Shoreline Management Plan (ISMP) to harmonize all the activities in the coastal area. In 2017, ISMP studies have been carried out for Pahang, Melaka, Negeri Sembilan, Pulau Pinang, Labuan, Miri in Sarawak, Sabah and Johor (NC3, 2018).

3.3.3. Regulation

In Malaysia, the development of a comprehensive and integrated coastal zone management policy has been initiated under the Seventh Malaysia Plan (7MP). Under the 7MP, legal provisions that govern the management of coastal resources are highlighted.

3.4. DAM

3.4.1. The Expected Impact

Dam operation would be much affected by climate change especially during extreme wet and dry seasons. During wet season, the increase frequency of extreme rainfall would result in large amount in runoff volume that could no longer be stored by the existing dam capacity. On the other hand, during dry period, which is expected to be longer in the future and higher evaporation would deplete the water storage at a much faster rate. The higher rainfall intensity coupled with more land opening would lead to higher slope erosion and sedimentation of the dam which could further reduce the dam capacity.

Studies on the climate change impact on dams in Malaysia have intensively been carried out. For instance, a study by NAHRIM at Bekok Dam based on 15 climate change scenarios found that the reservoir would experience several critical drawdown periods from 2010 to 2100 (Aziz, 2014). In another case study, climate change has also affected the capacity of Durian Tunggal dam in Malacca. The drought in 1991 has dried up the reservoir and resulted in prolonged water rationing in most parts of the state (Rahman, 2009).

Several dams in Peninsular Malaysia also experienced low storage level during dry period. During the El Niño episode between March 2015 and April 2016, the water storage had reached critical level for the Padang Saga Dam, Bukit Merah Dam, Timah Tasoh Dam, Labong Dam, Bukit Kwong Dam, Gemencheh Dam, Beris Dam, Muda Dam, and Pedu Dam. The water shortage was experienced for at least three consecutive months from January to August 2016 and in the case of the Labong Dam and the Bukit Kwong Dam, the shortage prolonged for eight consecutive months.

A study in 2014-2015 revealed that the Sungai Langat Dam, Sungai Selangor Dam, and Sungai Tinggi Dam experienced three or more consecutive months of storage levels below 50% capacity (NC3, 2018). Moreover, future dry spell projections predicted that these dams may experience significant dry spells with return period more than 10 years by 2040.

As the occurrence of low reservoir storage is expected to be more frequent in the future, it is timely to review the current practices in designing the dam capacity. The current storage capacity of three months may need to be lengthen. Similarly, the spillway capacity may need to be revised to cope with larger flood in the future. It is evident that that the climate change would have significant impact on the dam design and operation in dealing with uncertain runoff regime (quantity) specifically on flood and drought.

3.4.2. Adaptation Measures

In Malaysia, it is mandatory for each dam operator to develop Emergency Response Plan (ERP) especially to minimize flood risk and possible dam failure (Said *et al.*, 2016). The ERP should include warning system to be alerted to public when the water level reaches danger levels.

3.4.3. Regulation

Studies on the dam break and water balance in relation to climate change impact are needed to reduce the dams' vulnerability to flood events especially for the older dams. The preparation of a National Dam Safety Management Guidelines and a National Dam Safety Management Act are now being conducted by the Malaysian government. In addition, the establishment of a Dam Technical Centre as a knowledge and skills hub for dams is proposed under the Act.

3.5. GROUNDWATER

3.5.1. The Expected Impact

Currently, the exploration of groundwater resources are increasingly carried out because the current water supply is heavily abstracted from surface water. It is timely for Malaysia to explore its groundwater potential in order to avoid water crisis during prolong dry period.

Climate change may affect groundwater storage due to expected change in the rainfall regime. According to Mogaji *et al.* (2013), climate change effects in Peninsular Malaysia would lead to 1% reduction in potential recharge in 2020s. This is due to the expected decrease in precipitation and increase in evapotranspiration. Moreover, more comprehensive study is needed to assess the climate change impact on

groundwater on spatial basis as the rainfall and evapotranspiration varies over the space.

3.5.2. Adaptation Measures

Since 2011, the Department of Mineral and Geoscience (JMG) has put in place strategies to strengthen the exploration and development of the nation's groundwater through increasing research and providing monitoring services on groundwater quality (NC3, 2018). It also provides information on safe rate of extraction to state governments as guidelines in issuing groundwater extraction licences at the coastal areas to avoid saltwater intrusion. Moreover, modelling studies on five major basins in Malaysia, which focus on groundwater reserve determination and risk analysis of salt water intrusion have also been carried out.

3.5.3. Regulation

Except for Kelantan which depends 50% of the water supply from groundwater, the groundwater consumption for other states in Malaysia is still low. Most of the groundwater resources are used by individual users for industry and local water supply.

The Peraturan Pemajuan Telaga Dan Korekan 2013 (Development of Well and Excavation 2013) is enforced to ensure no excessive extraction. The policy is initiated to improve groundwater management. In addition, under the Eleventh Malaysia Plan, a study to determine the risk of saltwater intrusion zones at selected basins has also been conducted.

CHAPTER 4

4. WATER SERVICE INDUSTRY

4.1. INTRODUCTION

This chapter discusses climate change effects on domestic and industrial water supply, irrigation, hydropower, and fisheries. The effect of climate change on domestic and industrial water supply particularly on expected impacts, adaptation measures, and regulation is presented. It is then followed by elaboration and discussion on its effects on irrigation, hydropower, and fisheries.

4.2. DOMESTIC AND INDUSTRIAL WATER SUPPLY

4.2.1. The Expected Impact

In Malaysia, up to 97% of water demand is abstracted from surface water, which is generally from rivers. Clean and sufficient water supply have become a problem in water resource management during flood disaster. Flood can affect water quality associated with accelerated erosion, landslide, and bank erosion which finally lead to sedimentation in the downstream (See *et al.*, 2017). Other forms of non-point sources pollution may also be transported by overland flow due to overflow from treatment ponds and wash off from agricultural lands and other impervious surfaces (Shields *et al.*, 2008).

Besides flood, occasionally, Malaysia is experiencing severe drought especially during El Nino years (Salimun *et al.*, 2014). For example in the south Johor, the water level at Lebam and Layang, has reached critical low levels of 9.57 m and 19.19 m, which are far below the critical levels of 12.27 m and 23.5 m, respectively (NST, 2019). According to Chuah *et al.* (2018), the drought event in Johor and Singapore was the worst as reflected by the Palmer Drought Severity Index (PDSI) derived from rainfall data of more than sixty years.

The severe drought always leads to water rationing. For example, the shutting down water treatment plant at Kota Tinggi because of prolonged drought caused some residents collected water from swamps for household purposes (Khamis, 1997). The

residents also complained that they received uncleaned water (Tor, 2005). Moreover, some districts in Johor such as Kluang, Mersing, Kota Tinggi, Johor Bahru, Pasir Gudang, and Kulai Jaya experienced water rationing (Bernama, 2014). Table 4.1 lists examples of the drought impact on water supply in Johor.

Table 4.1: Drought impact on water supply in Johor

Impact	Drought event	Region
Caused water rationing where supply was limited to a few hours daily nearly all of Johor districts, including Batu Pahat, Kluang, Mersing, and Muar	1990	Batu Pahat, Kluang, Mersing, and Muar
Waterworks at Kota Tinggi ceased operations due to inadequate raw water supplies from rivers. Some residents collected water from swamps for domestic uses	1997	Kota Tinggi
Water rationing occurred in Kluang and Batu Pahat districts. Supply was only available every alternate day. Residents also complained for receiving untreated water	2005	Kluang and Batu Pahat
The prolonged drought has disrupted water supply in most parts of the state such as in Kluang, Mersing, Kota Tinggi, and Kulai Jaya districts with several months of scheduled water rationing	2014	Kluang, Mersing, Kota Tinggi, and Kulai Jaya
Water rationing occurred for resident in Johor Bahru and the industrial area of Pasir Gudang	2015	Pasir Gudang

The drought in 2014 has also affected many states. In Selangor, the water level in all reservoirs decreased by 50%. During that time, the state government of Negeri Sembilan has also declared water crisis (ABCNews, 2014). Moreover, water crisis results in water rationing and the supply was 10% lower than water demand (Shahabudin, 2015).

It was also observed that the decrease in monthly river flow and shifting of dry spells at river basins, such as Padas and Kinabatangan in Sabah, Limbang and Sadong in Sarawak, and Muda in Kedah can affect water availability in the regions. A study conducted by NAHRIM predicted that there would be water supply issues in the future, especially in areas with higher risk or vulnerability such as in the Muda watershed in

Kedah and small basins such as Linggi (NC3, 2018). In addition, several critical drought episodes were predicted to occur within 2010 to 2100 in Bekok Dam based on reservoir storage analysis using 15 climate change scenarios and projections.

Climate change could affect domestic and industrial water supply during both dry and wet periods. During drought, water availability from domestic water supply decreases, thus increases the water exploitation index. In addition, during flood, domestic water supply can be polluted. Therefore, it was proposed that the water exploitation index and water quality indicator are the two main vulnerability parameters.

4.2.2. Adaptation Measures

In Malaysia, there are 93 dams (until 2013) to serve various purposes such as water supply, irrigation, flood mitigation, hydroelectric power, sediment control, and recreation. Among these, 57 dams serve as water supply dams. The Malaysian government has been planning to construct additional of 40 water supply dams to meet water demand due to population increase and climate change issue. The construction is planned for Peninsular Malaysia (30 dams), Sabah (7 dams), and Sarawak (3 dams).

4.2.3. Regulation

To ensure water supply sustainability in Malaysia due to population increase and climate change issues, the government has initiated a water resources policy for the water sector in Malaysia under the Tenth Malaysia Plan (2011-2015). In addition, the National Water Resources Policy (NWRP) for Malaysia endorsed by the Cabinet in 2012, is aimed at ensuring that the demand for water by all user sectors is met in terms of quantity and quality. In the policy, it provides clear directions and strategies such as water resources security, water resources sustainability, partnership, and capacity building and awareness.

4.3. IRRIGATION

4.3.1. The Expected Impact

Climate change represents a challenge for agriculture, hence adapting irrigation system to climate change is a priority for the future. NAHRIM (2009) carried out study to identify vulnerabilities in three granary areas, which are the Muda Agriculture

Development Authority (MADA), Kemubu Agriculture Development Authority (KADA), and the Barat Laut Selangor granary areas by employing the RegHCM-PM model. Their study found that Barat Laut Selangor and KADA areas were projected to experience water deficit that potentially affects the sustainability of paddy planting in the area. However, for the MADA, the area was predicted to experience excess water up to 76%.

It is noted that the most important aspect of reservoir management is to ensure the appropriate quantities of water released to irrigation at the appropriate times. There are two elements for assessing vulnerable parameters related to the climate change effects on irrigation, which are the potential water supply capacity and the irrigation water requirements.

4.3.2. Adaptation Measures

There are structural and non-structural implemented as adaptation measures on climate change for irrigation. For instance, the development of flood mitigation projects has successfully protected the MADA granary areas from sea water intrusion (NC3, 2018). In addition, the implementation of flood mitigation along the Golok River and the development of Sungai Kelantan Integrated River Basin Development projects have successfully protected the KADA granary areas. Moreover, to overcome water stress problems in the granary areas, the irrigation management has been improved via efficient demand and supply management.

As a result, these implemented measures have improved the water resources and reduced dependency of water released from dams. Other implementation measures such as rescheduling of water released from dams, use of water pumps, cloud seeding, and the use of telemetry water monitoring systems were also carried out. Hence, MADA has capability to increase its usage of recycled drainage water from 6% to 8%. Similarly, KADA was able to manage its water deficit issues, which usually occurred during off-seasons.

Another adaptation was also carried out by introducing traditional single cropping rice varieties such as Biris and Rotan or Bario that have been planted by farmers to counter problems such as unlevelled field, lack of irrigation, floods, dry spells, and other soil constraints, which is implemented in Sarawak. Although these varieties often lack in

yield and they do not respond well to fertilizer application, they can adapt well to uncertain changes in the environment. For the improvement, a newly developed rice varieties such as Saratani ARC 2, which enables double cropping practices has been proposed to increase its yield.

For non-structural measures, development of Climate-Smart Rice Irrigation Management Information System (CSRIMIS) was proposed by Kamal (2017). The proposal provides better understanding of the government sectors for instituting water policy and implementing allocation measures for irrigation and water resources. Basically, it can support the knowledge-based decision making through intensive climate-related research and development, capacity building of adaptation, and mitigation measures. By implementing this system, it is possible to develop new strategies to adapt to climate change impacts.

4.3.3. Regulation

Appropriate regulation is necessary to support the aforementioned measures. For instance, in Sabah, a new major rice granary area and agriculture zoning have been undertaken based on the Sabah Second Agriculture Policy (SAP2). In the policy, the needs for improved irrigation area for both main and off seasons rice planting periods were encouraged.

4.4. HYDROPOWER

4.4.1. The Expected Impact

Since hydropower operation is highly dependent on water flow, it is crucial to understand the effect of climate change on the future operation. There are five main hydropower dams in Malaysia, namely, the Kenyir Sultan Mahmud Power Station with 400MW installed capacity, the Pergau Hydroelectric Power Station with 600MW installed capacity, the Temenggor Hydroelectric Power with 348MW installed capacity, Bakun dam with 2400MW installed capacity, and Murum dam with 944MW installed capacity. The total electricity generated from hydropowers in Malaysia is approximately 11% of the total supply.

The future dry spell investigation indicated that four hydropower plants in Malaysia may be affected by future dry spells (MESTECC, 2019). For instance, Kenyir dam in

Terengganu and Pergau dam in Kelantan had the highest possibility of limiting water resources to operate (NC3, 2018). However, due to their larger reservoir capacities, a preliminary analysis using long term model projection indicated that the dry spells may not affect the operations of the hydropower dams in Sarawak.

It is well known that the effect of climate change on hydropower is mostly influenced by the change of the river runoff. In areas with reduced and less predictable precipitation regimes, the hydropower production can be affected. In addition, high rainfall intensity can also cause erosion of the soil in reservoirs. Sediment that is transported into reservoir can reduce the reservoirs capacity. There are two main vulnerable parameters related to the climate change effects on hydropower, which are extreme rainfall and drought events.

4.4.2. Adaptation Measures

To improve hydropower production under uncertainty climate change, several non-structural measures have been developed. The development of dam failure concept was aimed to produce outflow hydrograph. Numerous simulation models of dam failures due to flow overtopping have also been developed (Sidek *et al.*, 2011). The concept was recommended to improve the community state of preparedness and resilience in reacting towards a disaster. Therefore, it can be used to improve disaster preparedness, reducing risk, and the formulation of disaster management policy and procedure.

In addition, the development of Emergency Response Plan (ERP) was also proposed (Said *et al.*, 2016). Once the dam safety threshold is exceeded, an alert can be triggered by issuing a 'Dam Safety Event' message. It can trigger a process where the dam and its surrounding are immediately inspected for the duration of the flood to detect signs of potential dam failure.

4.4.3. Regulation

Malaysia's energy policy is guided by three principle objectives stated in the National Energy Policy (1979). One of the objectives is aimed at ensuring adequate, secure, and cost-effective energy supply by developing and utilizing alternative sources of energy, both non-renewable and renewable, from within and outside the country (MESTECC, 2019).

The promotion of renewable energy (RE) is addressed by the National Renewable Energy Policy and Action Plan, approved by the Cabinet in 2010, with the vision of enhancing the utilisation of indigenous renewable energy resources to contribute towards national electricity supply security and sustainable socio-economic development. The adoption of RE technology is also supported by the National Green Technology Policy 2009. The Renewable Energy Act 2011 provided schemes to enhance the use of sustainable energy resources.

Furthermore, companies generating energy from renewable sources have a choice of applying for incentives, such as pioneer status with income tax exemption or investment tax allowance on qualifying capital expenditure incurred. Other incentives include import duty and sales tax exemption on equipment used to generate energy from renewable sources. The government through Sustainable Energy Development Authority of Malaysia (SEDA) has been promoting and implementing small hydropower in rural area in Malaysia.

4.5. FISHERIES

4.5.1. The Expected Impact

It was observed that changes in water properties, including temperature, salinity, pH, oxygen levels, and circulation, lead to shifts in the distribution of marine species (Rose, 2005). In addition, it was observed that increase in water temperature can lead to decrease in maximum body sizes of marine fishes (Cheung *et al.*, 2013). The changes in species composition due to climate change effects can affect global redistribution of maximum catch potential. Moreover, it was projected that the maximum catch potential in high latitudinal regions would increase whereas in the tropic regions would decrease (Cheung *et al.*, 2010).

In the context for Malaysia, effects of climate change on fish landings in Sabah, Malaysia, especially for the west and east coasts were investigated (Jafar-Sidik *et al.*, 2010). Their study found that local fish landing was highly sensitive to the effects of climate change as approved by correlation estimation between fish landings with climatic parameters. In addition, rainfall, temperature, wind, and the Southern Oscillation Index were highly correlated with the catch. Moreover, their study observed that during the north-east monsoon, fishermen record 20% drops in their catch.

A study on the climate change impact on fisheries community and their potential adapting strategies for small-scale fishermen in Malaysia was also carried out (Shaffril *et al.*, 2017). The study concluded that the climate change would reduce the fish catch, increase risk of catching activities, damage the fishing industry infrastructure in the coastal area, and affect the fish food chain. Moreover, the study proposed adaptation actions to reduce the climatic impacts on fisheries communities by several strategies, which are (i) reducing the risks associated with fishing routines, (ii) strengthening social relationships, (iii) managing fishermen's climate change knowledge, (iv) facilitating the community's learning of alternative skills, (v) involving fishermen in climate change adaptation planning, and (vi) enhancing fishermen's access to credit.

Sea surface temperature and sea level rise are expected to affect sensitive fish species through direct and indirect mechanisms. Direct effects include changes in reproduction, distribution, and population dynamics of fish stocks. Indirect effects include changes in productivity and composition of the ecosystems on which fish depend for food and shelter.

4.5.2. Adaptation Measures

At the present, one of the adaptation measures that has been developed is capacity building for fishermen to utilize the Fishing Site Identification System. The system is able to provide information on fishing ground location based on satellite imageries (sea surface temperature and chlorophyll). The system helps the fishermen to locate potential fishing ground within a short time, and hence reducing fuel costs while increasing the fish catch. This system is useful since climate change is expected to cause greater fish mobility due to rapid change in sea temperature.

4.5.3. Regulation

In order to enhance the fish resources, the Department of Fisheries Malaysia has implemented the conservation zone (0-1 n.m. from coastline) for the west coast of Peninsular Malaysia. The use of trawlers in Zone B has been banned on the west coast of Peninsular Malaysia. In addition, the implementation of high impact projects in the Aquaculture Industrial Zone has been carried out. Realizing the importance of sustainable aquaculture practices, the Malaysian government had launched the Malaysian Good Agricultural Practices (MyGAP) in 2013.

CHAPTER 5

5. WATER-RELATED DISASTERS

5.1. INTRODUCTION

In Malaysia, water related disasters are the most frequent and costly, particularly flood. It is estimated that annual loss associated with flood alone is approximately RM1 billion. The damage is expected to increase in the future because of climate change. This chapter provides an overview of the effects of climate change on water-related disasters focusing on flood, drought, and pollution.

5.2. FLOOD

5.2.1. The Expected Impact

Beside the influence of Northeast monsoon, climate change is expected to play equally important role in causing future floods. For example, Johor river basin is expected to experience higher rainfall and more frequent floods in the future (San Liew and Teo, 2013). The study found that the flood level was predicted to rise from 0.47 to 1.28 m for 200 year-ARI and 0.37 to 1.39 m for 270 year-ARI. In Johor, the most severe flood was recorded in Kota Tinggi in December 2006 and January 2007. The impact of the second wave was much higher compared to the first wave. Besides of higher total rainfall (416 mm) during the second wave compared to the first wave (366 mm), the hydrologic storage during the second wave has been filled up, thus most of the rainwater becomes direct runoff. In fact, this is a common phenomenon in many big flood events in the past.

Severe floods also experienced in Kelantan from December 2014 to January 2015 (Ismail and Haghroosta, 2014). The flood is caused by heavy rainfall, especially from 21th to 23th December 2014. The rainfall in that day was equivalent to two months normal rainfall. The rainfall reached 850 mm in 10 days (normal 100 mm). Heavy rainfall from December 21th to 23th 2014 led to unprecedented increase in the level of river water. The highest water level was recorded at Galas river was 46.47 m (danger level 38 m). It was estimated that about 3390 Kelantan residents had been evacuated.

Flood in Penang on November 2017 was the worst in history (Kong, 2017). The water increased up to 2.7 m. The drainage capacity in Penang does not work optimally because in the past the drainage was designed without consideration of climate change effects. There are 46 evacuation centres to evacuate 1731 families and around 5000 victims.

5.2.2. Adaptation Measures

In 2011, the DID has created Publicinfobanjir website, as an extension to Infobanjir website (DID, 2018b). The publicinfobanjir website focuses on flood warning dissemination to the public, which is much easier and simplified to understand. Important information such as details of evacuation centres, flood status, and current rainfall as well as water level data are displayed interactively on the website. The number of hydrological stations was increased to almost 500 stations. The improved Infobanjir website also displays the image of rivers in real time. Alternatively, National Flood Forecast and Warning Centre (PRABN) was also established under the DID Malaysia (DID, 2018a). It is aimed at providing accurate and reliable forecast and warning of impending floods for public safety and reducing the risks and property damage.

In terms of structural measures, Stormwater Management and Road Tunnel (SMART) was also developed for flood prevention strategy (DID, 2017). It is an innovative project of the Government to solve flooding problem in the City Centre of Kuala Lumpur and around the vicinity of Masjid Jamek caused by Klang River overflowing. SMART has the 3 km double-deck motorway within the 9.7 km tunnel which starts near the Kampung Pandan and ends at Kuala Lumpur-Seremban highway.

As an alternative measure, Rancangan Tebatan Banjir (RTB) was also established by the Minister of Water, Land and Natural Resources. This project was conducted in Golok river Kelantan in Februari 2018. This wall was built to prevent major flooding. In addition, DID implemented the telemetric water level and rainfall observations in the major river basins and has expanded to smaller rivers over the years. As of June 2016, a total of 355 river water level stations (online and offline) and 559 rainfall stations (online and offline) along the 98 river basins were established.

DID also operates a flood forecasting system for six major river basins in Malaysia. It has also implemented Very High Frequency (VHF) flood forecasting systems in some of the smaller river basins in the urban areas where flash floods occur frequently. In general, adaptation measures for flood management in Malaysia are listed in Table 5.1.

Table 5.1: Adaptation measures for flood management in Malaysia

ADAPTATION MEASURE	IMPLEMENTATION	STATUS	POTENTIAL APPLICATION
NON-STRUCTURAL MEASURE			
Launching of the Public 'Infobanjir' website as part of the flood forecast and warning system program	Provide alert on water levels to facilitate emergency response	The presence of the website is useful for communities to provide accurate information related to rainfall and water level in real time basis.	The website can be improved by providing a real time video and photos related to the current status of rainfall and water level
National Flood Forecast and Warning Centre (PRABN)	To provide accurate and reliable forecast and warning of impending floods for public safety and the reduction of risks and property damage	PRABN has successfully provided an accurate information related to an earlier forecast when a flood will occur and how big its impact would be based on data obtained from the radar	-
STRUCTURAL MEASURE			
Stormwater management and Road Tunnel	To alleviate flooding problem at the Kuala Lumpur city centre due to stormwater from the Klang-Ampang catchment	It has successfully reduced floods events in the city	The collected stormwater can be used as new alternative water supply for the city
Other flood mitigations projects under DID including flood control dams, flood diversion, and storage ponds of flood attenuation	To reduce flooding events that often occur in each catchment	They have been implemented to reduce floods for several regions	The collected stormwater can be used as new alternative water supply for the city

5.2.3. Regulation

Under the Tenth Malaysia Plan (2011-2015), 184 flood structural measures have been carried out. For the Eleventh Malaysia Plan (2016-2020), an additional 70 new flood mitigation projects will be implemented. An Urban Stormwater Management Manual (MSMA) has been implemented since 2001, and has been revised in 2012. This manual provides the design criteria for urban stormwater management.

MSMA has been a major requirement by the local authorities or municipal councils for the new urban development projects since 2001. In Addition, implementation of rainwater harvesting practice, which has been included in the Road, Drainage and Building Act 1974 Uniform Building By-Law (Amendment 2012), is mandatory and compulsory in Johor, Kelantan, Malacca, Perak, Perlis, Pahang, Negeri Sembilan, and Selangor to help reduce flood peak during heavy rain apart from supplementing as non-potable water. Moreover, the National Physical Plan-3 (NPP-3) contains 15 strategies and 44 actions including managing natural disaster risk areas and implementing integrated water cycle management (MESTECC, 2019).

5.3. DROUGHT

5.3.1. The Expected Impact

Evaluation of the effects of climate change on drought occurrence in Malaysia has been carried out. For example, the effects of climate change on drought in Pahang were examined using statistical downscaling procedure (Othman and Tukimat, 2018). Their study predicted that there was dry condition detected for the future in Pahang. In general, the percentage of dry period from 2018 to 2039 was predicted to increase about 2.5%. In addition, the percentage can increase in 2040 to 2069, which is 3.3%.

Selangor is one of state in Malaysia which has a large growing development. Drought issue in this state was identified in Langat River (Badd, 2018). The result showed that high rainfall in the future mainly on December and low rainfall in October. In the last 2 years, Selangor was through a worst drought issues. In 2016, recorded as many as 49.5 %, water supply issues were occurred in Selangor and increased 12.9 % in 2017. The water level in Kedah had decreased in last 30 years (31.02m to 30.37 m) (Suri *et al.*, 2014). The result was based on comparison of water level data for 1978-1980 with

2011-2013. Their study suggested that the climate change impact will be greater over the years. It will contribute to water crisis in the near future if the water level in Kedah is continuously decreased. Figure 5.1 shows the water level comparison in Kedah between 1978-1980 and 2011-2013. It was noted from the aforementioned works that low flow of rivers in Malaysia was predicted to decrease, thus potentially increases the drought risks.

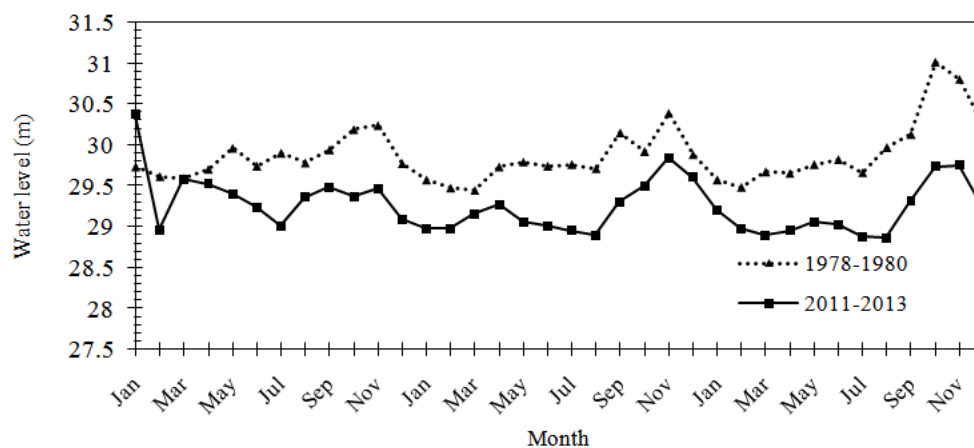


Figure 5.1: Water level comparison in Kedah between 1978-1980 and 2011-2013 (Suri *et al.*, 2014)

5.3.2. Adaptation Measures

As a non-structural measure, DID has launched 'InfoKemarau' to disseminate water resources status via online, to provide early warning on potential drought, and to provide technical advisory on drought status in Malaysia (see Table 5.2). DID is responsible for water resources management, and to disseminate drought information to various water related agencies and department for drought early warning system and preparedness through to this web site. This website provides the Standard Precipitation Index (SPI), which is a drought index based on precipitation. In addition, it also provides monthly report on drought status in Malaysia. However, there is no complete report provided in the website for all months in a year.

Table 5.2: Adaptation measures for drought management in Malaysia

ADAPTATION MEASURE	IMPLEMENTATION	STATUS	POTENTIAL APPLICATION
NON-STRUCTURAL MEASURE			
Launching of the Public 'InfoKemarau' website as part of the drought forecast and warning system program	Providing information on occurrences or projections of droughts	Providing drought status in Malaysia in real time. However, there is no complete report providing in the website for all months in a year. In addition, drought information for East Malaysia is lacking.	Can be used as a technical advisory on drought status over Malaysia
National Water Balance Management System (NAWABS)	It comprises water allocation system, water storing and releasing during low flow and high flow, water resources index and dry spell index		
STRUCTURAL MEASURE			
Cloud seeding	To produce rain	It has succeeded in producing rain in several areas	
Construction of dams	To ensure continuous water supply during dry spell seasons		The stored water in the dams can be used for potable and non-potables uses.

Some measures have been taken to ensure continuous water supply during dry spell seasons in the country. These include the construction of 57 water supply dams, bunded storages in Melaka, Off River Storage (ORS) at Sungai Labu in Selangor, and raw water transfers from Pahang to Selangor. Drought monitoring program was initiated by DID since 2001 to provide drought information and warning system. It was established following the 1998 drought which affected a large number of residents in the Klang Valley. Currently, there are 21 dam-level stations, 22 river water level stations at gauging site and 48 rainfall stations which provide information about the

real time situation on storage in dam and river flows as well as rainfall data. DID disseminates information on water resources status and provides early warning on potential drought via a web portal to assist relevant agencies and the public to make early preparation to face drought events.

5.3.3. Regulation

Drought disaster in Malaysia is managed according to the standard operating procedure (SOP) which was formulated by all the relevant agencies and was led by the National Security Council of the Prime Minister Ministry. The SOP provided guideline related to classification of drought, the responsible agencies to monitor drought, severity of drought, line of communication and roles, and responsibility of relevant agencies on drought event.

5.4. WATER POLLUTION

5.4.1. The Expected Impact

In Kelantan, severe flood experienced in 2014 affected water pollution especially in Kuala Krai River (Rafiuddin, 2016). Quality Index Water (QWI) and Biological Water Quality Index (BWQI) were measured as indicators for the river water quality. Their study found that the water quality in the Kuala Krai River decreased indicated by DO and BOD values. The low DO value affects deoxygenates to microbial population which affect the growth of aerobic aquatic microbial organisms. In addition, low BOD values can affect an unpleasant odor in river water. The average COD of the river shows fluctuating values, which influence dissolved oxygen. In the suspended solids parameter, the floods eroded the banks of the river by providing the highest value of 74.5 mg/L and the lowest value of 3 mg/L. The pH values for the river water changed caused by the flood. In terms of water quality index, their study found that river water in Kuala Krai River was slightly polluted (Rafiuddin, 2016).

In Johor, a study was conducted to measure the level of water pollution at Muar River affected by flood. The average of DO values during the first flood in November 2006 was 5.46 mg/L, and decreased to 5.24 mg/L in December 2006 and 5.03 mg/L in January 2007. It was possibly caused by water pollution from nutrient and organics during the floods. BOD values during floods was in slightly polluted category. In addition, COD values of the river water were in the class III category or Polluted. In

January 2007 the pH level was 3.2, which is in class IV category or dangerous to be used. The total Suspended Solids during floods was 84.2 and 130 mg/L in December 2006 to January 2007, which is in the class III category or polluted (Ching *et al.*, 2015). Before flooding, WQI value of Muar River in 2006-2007 was under class II category. However, during the flooding in December 2006 to January 2007, WQI value was present under the class III category or polluted (Ching *et al.*, 2015).

In Pahang, flood caused a lake water to be polluted (Shuhaimi-Othman *et al.*, 2007). The water in the Chini Lake during the flood on October 2004 contains ion such as sulphate and nutrient such as nitrate. During the flood, the data showed that lake water contains high ammonia nitrate in high concentration value. The turbidity levels of the water during the flood were over 30 NTU, which contains high suspended solids. Chemical oxygen demands values were low during the flood. Langat River basin in Selangor was also reported to be polluted by floods. The contaminated river water possibly came from floods experienced in that area (Chan, 2015). In general, water pollution was observed in several rivers in Malaysia. It is well established that floods contain mud that result in the river to be contaminated (Lee, 2015). It is noted that the climate change can alter water quality. Therefore, water quality index was proposed as a vulnerability parameter in the water resources due to climate change.

5.4.2. Adaptation Measures

The Malaysian government has implemented several structural measures to preserve water quality. For example, the implementation of River of Life (ROL) to transform the Klang River into a vibrant and livable water front with high economic value has been carried out. This transformation is divided into three main components (a) river cleaning, (b) river master planning and beautification, and (c) river development. In general, the goal program is to bring the river from its current Class III – Class V water quality (not suitable for body-contact) to Class IIb (suitable for body-contact recreational usage) by year 2020. Integrated Lake Basin Management (ILBM) was initiated over more decade since its inception in 2005. It was developed for lakes and reservoirs management. It was implemented for 3 periods, which are 2005-2010, 2011-2015, and 2016-2018 focusing on developing strategic plan for sustainable lake basin management, preparing action plans and governance instruments, and implementing the strategic plans. As a result, national lake water quality standard was

developed in 2015 and approved by the national water resource council for implementation in August 2017.

Structural measures to treat water by implementing public sewage treatment plants were also proposed. In Malaysia, 38% of public sewage treatment plants in the country are mechanical plants. These plants operate using mechanical equipment that accelerates sewage break down. More recent developments in sewage treatment have been to improve the reliability and efficiency of treatment systems to treat sewage to meet standards and reduce the land area occupied by treatment works through accelerating natural treatment rates under controlled conditions. However, despite these developments sewage treatment systems are still mainly concerned with the removal of suspended and floatable materials, the treatment of biodegradable organic, and in some cases the elimination of pathogenic organisms. In general, adaptation measures for water pollution management in Malaysia are listed in Table 5.3.

Table 5.3: Adaptation measures for water pollution management in Malaysia

ADAPTATION MEASURE	IMPLEMENTATION	STATUS	POTENTIAL APPLICATION
NON-STRUCTURAL MEASURE			
River of life program	To transform river into a vibrant and livable water front with high economic value		
Implementation of the total maximum daily loads (TMDLs) concept	to efficiently and effectively manage their respective rivers	Has been implemented to monitor water quality in several rivers	
Developing a Water Quality Index	As a basis for assessment of a watercourse in relation to the designation of classes of beneficial uses as stipulated in the National Water Quality Standards for Malaysia.		

ADAPTATION MEASURE	IMPLEMENTATION	STATUS	POTENTIAL APPLICATION
Integrated Lake Basin Management (ILBM)	To manage lakes and reservoirs	Has been implemented for 3 periods (2005-2010, 2011-2015, and 2016-2018)	It is potential to be implemented for other lakes and reservoirs over the country.
STRUCTURAL MEASURE			
Sewage treatment plant	To treat water released from industrial and houses effluent before release into water bodies.	Has been implemented over country and capable to treat waste water before releasing into water bodies.	The treatment process can be improved and the treated water can be used for non-potable uses

5.4.3. Regulation

The legal framework for the water and sanitation sector differs between peninsular Malaysia and Eastern Malaysia. While a water reform was enacted for peninsular Malaysia in 2006, the previous legal and institutional framework was maintained in Eastern Malaysia. Two main laws passed in 2006 form the legal framework of the water and sanitation sector in peninsular Malaysia. The Water Services Industry Act (WSIA) established a national Water Asset Management Company (WAMCO), called PAAB in Malaysian, and a water forum to give voice to hitherto under-represented stakeholders such as consumers.

The National Water Services Commission Act established a National Water Services Commission known under its Malay acronym as SPAN. The acts separated the functions of policy making (government), regulation (SPAN), asset ownership (PAAB) and service provision (state water companies) from each other. The laws were enacted after extensive public consultations over two years. SPAN now issues licenses for water operators, mainly state water companies. These licenses can theoretically be revoked if key performance indicators are not met or other standards are not respected. The standards are set and monitored by SPAN. In Eastern Malaysia water supply remains a responsibility of state governments and sanitation a responsibility of local governments.

Within the executive branch of the federal government, the Ministry of Energy, Green Technology and Water is in charge of setting water supply and sanitation policies. It is assisted by two technical agencies under its supervision: The water supply department (JBA) and the sewerage services department (JPP). The latter was established through the Sewerage Services Act of 1994 as a regulatory agency for the private sanitation company IWK. When IWK was taken over by the government in 2000, the sewerage services department became responsible for the development of infrastructure while IWK remained in charge of operation and maintenance as a publicly owned company.

There are regulations such as Environmental Quality (Sewage) Regulations 2009, Environmental Quality (Control of Pollution From Solid Waste Transfer Station and Landfill) Regulations 2009, and Environmental Quality (Industrial Effluent) Regulations 2009, which are effective on December 2009. In addition, the National Physical Plan-3 (NPP-3) contains 15 strategies and 44 actions including strengthening integrated and sustainable solid waste management (MESTECC, 2019).

CHAPTER 6

6. CURRENT ENGINEERING PRACTICES IMPLEMENTATION

6.1. INTRODUCTION

Adapting engineering practices to climate change can minimize their impact on infrastructures particularly in the area of water resources. Therefore, this chapter discusses current engineering practices implemented to water resources in relation to climate change in Malaysia.

6.2. UPDATED INTENSITY–DURATION–FREQUENCY (IDF) CURVES

6.2.1. Concept

The impact of climate change is already observed on several hydrological systems both on a regional and sub-regional scale. One of the anticipated impacts is an increase in the intensity and frequency of extreme rainfall which further increase the region's flood catastrophes, human casualties, and economic losses. Optimal mitigation measures can be undertaken based on stormwater systems and application of updated rainfall Intensity-Duration-Frequency (IDF) curves derived from long-term and good quality rainfall data.

IDF curves are essential for the safe design of hydraulic structures such as drainage systems, flood controlling dams, and reservoirs. Malaysia often experiences flash floods driven by extreme rainfall which has been projected to increase under climate change scenarios. Design storms derived based on historical data without considering uncertainty of climate change are no longer valid for the design of hydraulic infrastructure especially for predicted higher return periods.

It is expected that future changes in rainfall intensity because of climate change are expected to alter the level of protection of hydraulic infrastructure (see Figure 6.1). Increase in rainfall intensity will result in more frequent flooding. The consequence of this is the possible failure of hydraulic structure due to inadequate capacity to cope with the future extreme rainfall. Therefore, in storm design, engineers must adapt to climate change impact.

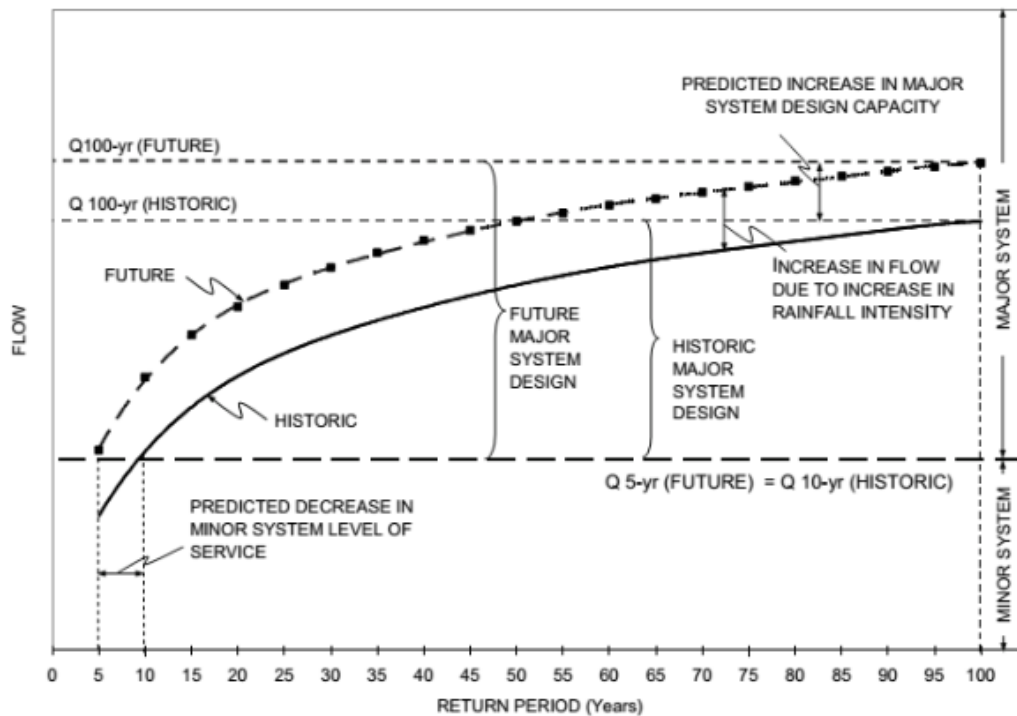


Figure 6.1: Expected changes in hydraulic design return periods under climate change (Arisz and Burrell, 2006)

6.2.2. Current Status and Implementation in Malaysia

The changing climate due to global warming has been found to alter rainfall patterns, making the current urban storm water management infrastructure vulnerable. To minimize losses due to extreme events, the designs for urban infrastructures need to be revised and updated, taking into account the effects of climate change. Hence, it is necessary to update the current IDF curves in practice with uncertainty levels in accordance with the climate change projections. An initiative has been performed to assess the effects of climate change on IDF curves in Malaysia.

The Water Resources Management and Hydrology Division of the DID Malaysia in cooperation with the National Hydraulic Research Institute (NAHRIM) has prepared and completed the Hydrological Procedure No. 1 in December 2010 and updated in 2015 (DID, 2015). In the procedure, climate change factors were provided to design IDF for returns periods of 2 to 200 years. Table 1 lists example of climate change factor (CCF) for SK Sg Lui for IDF curve at different return periods.

Table 6.1: Example of CCF for SK Sg Lui for IDF curve at different return periods (DID, 2015)

Return period (Year)	CCF (Median value)
2	1.10
5	1.23
10	1.29
20	1.33
25	1.34
50	1.37
100	1.41

The introduction of the updated IDF with climate change factor is a good step forward. However, more extension work is necessary to get wider acceptance among the practitioners especially when considering the implication of this IDF on the sizing and cost of hydraulic structure to cope with climate change impact.

6.3. ALTERNATIVE WATER RESOURCES

It is estimated that water consumption in Malaysia in 2010 is approximately 13,200 Million Liters per Day (MLD) and is expected to increase by 2020 to 16,500 MLD. The Malaysian government has promoted alternative water resources because the current water supply is heavily abstracted from river. It is timely for Malaysia to explore groundwater and rainwater harvesting in order to avoid water crisis during prolonged dry period due to uncertain rainfall pattern associated with climate change.

6.3.1. Groundwater and Rainwater Harvesting

In Malaysia, the estimated groundwater use is about 450 MLD, which is approximately 3.4 % of total water use. It is used for domestic, industry, and agriculture by 60, 35, and 5%, respectively. The government has promoted the exploration of groundwater. It is estimated that the groundwater storage in Malaysia is about 5,000 billion m³ with annual recharge of 64 billion m³.

Today, state of Kelantan explored groundwater for domestic and non-domestic uses by 40 % of the potable water supply. In 2009, Sime Darby Water Resources had launched a groundwater project in Batang Padang, Perak. Data from 136 tubewell drillings carried out for industrial water supply. In addition, it was reported that West

Coast of Peninsular Malaysia were found to have an average discharge rates of 343 m³/well/day (Sapari *et al.*, 2012).

Alternative water resources is by the promoting the use of rainwater. Malaysia is relatively rich in water resources particularly rainfall with an average annual rainfall of 2400 mm. Uneven distribution of rainfall over space and time due to uncertainty climate change has led to some areas suffering from dry spells, while others have been affected by major flooding. The aforementioned facts revealed that the use of rainwater for alternative water resources is crucial.

The severe drought in 1998 in some states in Malaysia has triggered the government to propose rainwater harvesting as an alternative resource. The Ministry of Housing and Local Government has promoted houses to install rainwater collector by issuing a guideline on installing a rainwater collection and utilization system in 1999. Following this, various initiatives in the form of policies and guidelines have been formulated by the federal and state government. This is to facilitate the implementation of rainwater harvesting for residential and government buildings.

To support the program, several projects have been carried out by the Malaysian government. In addition, a rainwater harvesting software called 'Tanki Nahrim' has been developed by NAHRIM to facilitate the analysis and designing of rainwater harvesting system. Currently, the implementation of rainwater harvesting in Malaysia is still limited to government buildings. It is therefore interesting to explore other potential buildings such as commercial buildings that usually have larger roof area. Moreover, since rainwater quality is almost free from major contaminant, only minimum treatment is needed for potable uses.

The above-mentioned facts that the exploration of groundwater and rainwater as alternative resources have been initiated. In view of increasing water demand and scarce surface water due to pollution, the government has to embark on the exploration of other alternative water supplies in order to cope with future demand and the impact of climate change.

6.4. WATER DEMAND MANAGEMENT

Based on water supply consumption from various states, the majority of Malaysians use more than the national average household consumption level of 210 litres per capita per day (l/c/d). The tendency for high consumption, logically, must be related to low tariff rate in the country. With tariffs being so low, consumers and users of water (including industrial users) hardly see the need or the importance of ensuring sustainability of water supply, including water conservation.

Consumption per capita promoted by World Health Organisation (WHO) is 165 l/c/d, which should be a long-term target for Malaysia. For short-term measure, SPAN has targeted 180 l/c/d by 2020. To achieve the target, the volume of water saved in 2020 would be in the order of 2337 mld for Peninsular Malaysia and 267 mld for Sarawak and 208 mld for Sabah.

6.5. EFFICIENT IRRIGATION

Continued increase in demand for water by non-agricultural uses, such as urban and industrial uses have put irrigation water demand under greater scrutiny and threatened food security. It is believed that climate change will increase water scarcity in the coming decades. Therefore, strategies that ensure sustainable use of the limited water resources are of absolute necessity. Such strategies should support not only the safety and health of the environment, but also ensuring sufficient agricultural production to feed the growing population

Several countries have implemented water saving irrigation (WSI) to mitigate the negative impact of climate change on water resources available to agriculture and overcome the constraint of water scarcity by reducing water consumption and increasing water productivity. For example, WSI has been highlighted as one of the Chinese basic national policies as well as an important practice for water resources in relation to climate change. It has been found that the existing WSI in China can save water of about 30 Bm³ per year, accounting for about 8% of the total agricultural water demand (Zou *et al.*, 2012). WSI can play a positive role in coping with climate change. The available studies indicated that WSI can reduce water demand and negative environmental impacts at farm level (Pereira *et al.*, 2002).

In china, WSI is classified as types of engineering water-saving technology (EWST), agricultural water-saving technology (AWST), biological and chemical water-saving technology (BCWST), and managerial water-saving technology (MWST). EWST is mainly accomplished through the construction of a variety of water-saving irrigation projects that reduce water consumption, including the delivery of water, the distribution of water, the irrigation of water, and other processes of water leakage and evaporation to improve the utilization of irrigation water. AWST is mainly accomplished through specific measures that control the field of water and optimizes the production structure while improving water-use efficiency. BCWST is a real-time and reasonable irrigation system that promotes crop growth with biological and chemical technology. It also involves the use of biotechnology for breeding and cultivating of crop varieties that are drought-resistant and water saving. MWST can achieve a reasonable allocation of irrigation water resources and an optimal scheduling of irrigation measures to reach a specific target, which is deriving the maximum benefit from limited water resources.

In Malaysia, the traditional irrigation such as ditch irrigation is widely implemented. Ditch Irrigation is a rather traditional method, where ditches are dug out and seedlings are planted in rows. The plantings are watered by placing canals or furrows in between the rows of plants. Siphon tubes are used to move the water from the main ditch to the canals. This traditional system of irrigation is popular for small scale paddy farmers but currently was improved by agency responsible to paddy sector such as MUDA, KEMUBU and Trans Perak. In these types of irrigation, major water sources were gathered from major rivers diversion scheme or regulated by reservoir at the upstream site.

It is noted that agriculture uses about 68% of total water consumption in Malaysia but irrigation efficiency is 50% at best in the larger irrigation schemes and less than 40% in the smaller ones. There is also no recycling of irrigated water. All of these factors are challenge to the sustainability of water resources. The use of WSI technology such as the implementation of drip irrigation or sprinkler irrigation is recommended as it has been successfully in many countries. Drip irrigation is water-saving system which supplies water by slowly dripping the water into the soil or the root of the plant while sprinkler irrigation supplies water by sprinkling the water around the crop.

6.6. INTERBASIN WATER TRANSFER

6.6.1. Concept

Inter-basin transfer is defined as the moving of water from a watershed with a surplus (donor basin) to a watershed suffering from a shortage (recipient basin). The water is transferred primarily to alleviate water scarcity in the recipient basin and travels long distances via complex pipeline and canal systems. Critical considerations include ensuring that the transfer does not disrupt any water-dependent activities or access in the donor basin and that it meets relevant environmental protection laws and regulations.

Implementation involves the building of pipes or canals to divert water from the donor to the recipient watershed. This requires technical expertise, for example, dredging and installation of pipes, as well as other diversion and storage structures.

6.6.2. Current Status and Implementation in Malaysia

In order to address the problem, an inter-state water transfer was envisaged (Ithnin *et al.*, 2014). Under this scheme, water from the neighbouring state of Pahang is stored in a dam called Kelau Dam on the Kelau river which is a tributary of the Semantan river. Water released from the dam then be drawn at intake points near Kampung Kuala Pertang on the banks of the Semantan river. The water is transferred to Kampung Kuala Pangsun in Hulu Langat, Selangor via 44.6 km tunnel before it is treated at water treatment plants in Selangor. This scheme is able to supply 1,890 mld of water to Selangor. Anticipating shortage situation, the water authority started inter-basin water transfer from Kelichi Dam to the Terip Dam (Ithnin and Sakke, 2013). Even with the inter-basin water transfer effort, the water supply system in the Seremban area is difficult to cope with the ever-growing demand. Seremban has problem in terms of water supply. It seems that among all the study states, Negeri Sembilan in the state that has the most uncomfortable future in terms of water resources.

The RM4mil raw water transfer project is funded by the state government and carried out by SAJ Holdings via a 15.3 km-long network of pipes from Sungai Papan to the Sungai Lebam dam. Raw water from Sungai Tiram is channelled via a 5km-long

network of pipes to the Sungai Layang dam. The Sungai Layang dam supplies water to 580,000 consumers, mostly industrial users, in Pasir Gudang and Masai, and several parts of Johor Baru. The Sungai Lebam dam in Kota Tinggi channels water to about 66,496 users in Mukim Tanjung Surat, Mukim Pantai Timur, Mukim Pengerang and parts of Kota Tinggi. Water levels at the Sungai Layang and Sungai Lebam dams remain critically low even after the transfer of additional raw water from Sungai Tiram and Sungai Papan respectively. The raw water transfer is only a temporary measure to boost water levels as it still depends on rainwater to fill the two dams. The Sungai Muar Raw Water Transfer project commenced on 15 March, 2004. This project involved the construction and supervision of all civil and structural engineering works and building services. The manufacture, supply and laying of the 17-kilometre DN1150mm mild steel concrete-lined pipeline for supplying water from the Muar River to the Talang Dam have also been successfully completed in 2005.

There are four major dams within the Muda River basin, consisting of the Muda Dam, Pedu Dam, Ahning Dam, and Beris Dam. The Muda Dam is on the mainstream of the Muda River about 130 km upstream from the river mouth. The dam catchment area is 98,400ha with volume of 160 million m³. The dam reservoir stores almost all of the basin runoff discharge and conveys it to the Pedu Dam via the 6.6km long Saiong tunnel. Pedu Dam with a catchment area is 17,100ha, has an active storage capacity of 1,073 million m³ in the upper reaches of the Kedah River. Water conveyed to the Pedu Dam is principally used for the Muda Irrigation scheme of about 97,000ha. Thus the Muda Dam is part of the Muda River basin in terms of topography, but hydrologically, it is also shared with the Kedah river basin. The water is used for irrigation of rice cultivation along the Kedah River under the Muda Agricultural Development Authority (MADA).

The Sungai Perak Water Transfer Scheme proposal was approved by Kementerian Tenaga, Teknologi Hijau dan Air (KeTTHA) on 30 June 2012 and endorsed by Suruhanjaya Perkhidmatan Air Negara (SPAN), and is now awaiting implementation approval from the Economic Planning Unit (Penang, 2015). The proposed Perak-Penang Raw Water Transfer will be carried out by pumping the raw water to a new tunnel to be constructed across the highlands dividing the Sg. Perak and Kerian basin. The raw water is then extracted from Sg. Kerian near the existing barrage in Penang

state for subsequent treatment at the proposed Kerian Water Treatment Plant to supply potable water for the Penang State. There is an urgent need to implement the inter-state water transfer scheme to provide for future water demand, reduce dependency on one source i.e., Sungai Muda.

6.7. REDUCING NON-REVENUE WATER

6.7.1. Concept

Non-revenue water (NRW) is water that has been produced and is lost before reaching users. Losses can be real losses (through leaks, sometimes also referred to as physical losses) or apparent losses (for example through theft or metering inaccuracies). The formula of NRW equal to system input volume - billed authorised consumption.

6.7.2. Current Status and Implementation in Malaysia

NRW is a water issue that has been threatening Malaysia's water security for recent years. In 2013, NRW in Malaysia was recorded at an average of 36.6%, with the states' NRW rates ranging from 18.2% to as high as 62.4%. One of the primary causes for this is mainly old pipes, especially the fragile and leaky asbestos cement (AC) pipes that are still widely available in the distribution system by 27% or 41,560 km. The Malaysian government is focusing on reducing NRW to 31% by the end of the 11th Malaysia Plan (11MP). In this regard, among the initiatives taken is to implement the National NRW Reduction Programme 2018/2020 involving an allocation of RM1.39 billion until 2020, where its main scope is to change and replace the pipes on a large scale.

It is noted that seven states (Melaka, Negeri Sembilan, Johor, Perlis, Pulau Pinang, Perak, and Selangor) of 11 state governments in the Peninsular Malaysia have already signed the water restructuring agreement with the federal government. Nevertheless, only five of these have migrated their water assets and loans, while Perlis and Selangor are still in the process of migration. By signing the water restructuring agreement, water assets previously owned by the state or the private sector will then be transferred to Pengurusan Asset Air Berhad (PAAB), which is a water asset management company fully owned by the Ministry of Finance Incorporated. To govern the water service sector, the federal government has formed

the Suruhanjaya Perkhidmatan Air Negara (SPAN) in 2007 to enforce the Water Service Industry Act (WSIA) 2006.

Today, SPAN plays a role in monitoring the Key Performance Indicators (KPIs) of all the licensed WSPs. The NRW rate is considered by SPAN as one of the most important KPIs and all licensed WSPs are required to achieve the targeted NRW rate in order to get their license renewed by SPAN. The federal government now plays an active role in monitoring the performance of WSPs in managing NRW through SPAN and PAAB. SPAN serves as the regulatory body that manages the performance of WSPs in water services including NRW management. PAAB serves as the water asset provider that reduces the NRW through water asset management such as sourcing funds for meter and pipe replacement programmes. In comparison, the WSP is responsible for conducting technical works related to NRW reduction. After implementing these initiatives, the Malaysian government has successfully reduced NRW from 36.2% in 2008 to 33.4% in 2017. In addition, the Malaysian government has targeted NRW of 25% by 2025 (see Figure 6.1).

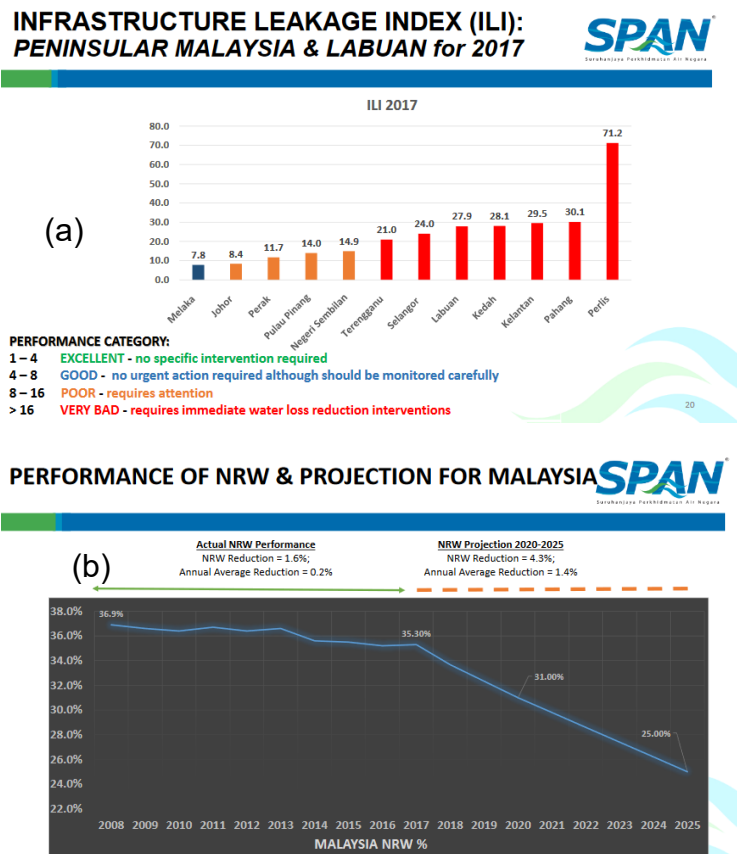


Figure 6.1: (a) Infrastructure leakage index (ILI) and (b) performance of NRW and projection for Peninsular Malaysia and Labuan (MWA, 2019)

CHAPTER 7

7. SUMMARY AND RECOMMENDATIONS

7.1. INTRODUCTION

This report highlights current status of engineering practices implemented for water resources in relation to climate change in Malaysia. Therefore, this conclusion chapter highlights the findings according to the research objective and suggests recommendation for future work.

7.2. Findings

Major findings related to the assessment of current engineering practices implementation for water resources under climate change in Malaysia are as follows:

(a) Water resources

- i. It has been identified that the most vulnerable parameter in relation to climate change effects on river is low flow which leads to a longer drought and high flow which leads more frequent flood.
- ii. Sea level rise associated with climate change is the main vulnerable parameter in relation to climate change effects on sea or coastal and has huge impact on the socio economic and ecosystem.
- iii. Climate change would have significant impact on the dam design and operation in dealing with uncertain runoff regime (quantity) specifically on flood and drought.
- iv. Climate change can affect groundwater quantity and quality.

(b) Water Service Industry

- i. Water exploitation index and water quality indicator are the two main vulnerability parameters in relation to climate change effects on domestic and industrial water supply.
- ii. There are two elements for assessing vulnerable parameters related with the climate change effects on irrigation, which are the potential water supply capacity and the irrigation water requirements.
- iii. There are two main vulnerable parameters related with the climate change effects on hydropower, which are extreme rainfall and drought events.

- iv. Sea surface temperature and sea level rise are expected to affect fisheries through a range of direct and indirect mechanisms.

(c) Water-Related Disasters

- i. The main vulnerable parameters in relation to climate change effects on flood are temperature rise, rainfall regimes, and high flow that lead to flood occurrence.
- ii. In relation to climate change on drought, low flow of rivers in Malaysia was predicted to decrease thus potentially increases the drought risks.
- iii. Water quality index is the main vulnerability parameter in relation to climate change water pollution.

(d) Current engineering practices implementation

- i. The Malaysian government under the DID in cooperation with NAHRIM has updated Intensity–Duration–Frequency (IDF) curves based on climate change scenario for water resource management guideline.
- ii. To ensuring the sustainability of water resources in the future due to population increase and climate change issues, the Malaysian government has promoted alternative water resources, namely, groundwater and rainwater harvesting. Policies to support the widespread use of these water resources have been established. Although rainwater harvesting in Malaysia has been promoted to residential and government buildings, its implementation to other potential buildings such as commercial buildings is interesting since commercial buildings usually have larger rooftop catchment area. For the groundwater exploration, only the Kelantan state explored groundwater for domestic and non-domestic uses by 40 % of the potable water supply. By having a high groundwater storage of 5,000 billion m³ with annual recharge of 64 billion m³, it is also potential to other states in Malaysia to explore the widespread use of groundwater as an alternative resource.
- iii. The Malaysian government through the National Water Services Commission (SPAN) has targeted to reduce the national average household water consumption level up to 180 l/c/d by 2020.
- iv. In Malaysia, agriculture uses about 68% of total water consumption but the irrigation efficiency is 50%. This is the result because agriculture in Malaysia still uses a traditional irrigation system such as ditch irrigation. The Malaysian

government must promote a modern irrigation system to achieve efficient irrigation such as the implementation of water saving irrigation (WSI) that has been adopted in many countries.

- v. The government has carried out interbasin water transfer to anticipating water shortage situation at related states. For example, interbasin water transfer from Pahang to Selangor via 44.6 km tunnel, inter-basin water transfer from Kelichi Dam to the Terip Dam, inter-basin water transfer from Papan river to the Lebam dam, inter-basin water transfer from from the Muar River to the Talang Dam, and inter-basin water transfer from Muda dam to Pedu Dam.
- vi. The Malaysian government has successfully reduced NRW from 36.2% in 2008 to 33.4% in 2017 and has targeted NRW of 25% by 2025.

7.3. Recommendation

Recommendations for future works are presented in the following tables. Tables 7.1-7.4 summarize general gaps and improvement plan on water resources.

Table 7.1: General gaps and improvement plan on water resources

AREA	VULNERABLE PARAMETER	GAPS	IMPROVEMENT PLAN
River	Low flow	Although extensive works on climate change effects on rivers have been carried out, most studies are focused only on the effects on river flows such as high and low flows. Hence, there is a need of study on the climate change impacts on sediment and nutrient yields in rivers	Need to do a comprehensive study on the climate change impacts on sediment and nutrient yields in rivers
Sea/costal	Sea level rise	Insufficient coastal hydrodynamic simulation that incorporates sea level rise impacts for vulnerable coastal regions in Malaysia	Develop high resolution coastal inundation maps based on coastal hydrodynamic simulation that incorporates sea level rise for 20-year time intervals up to 2100, and carry out detailed coastal erosion and sedimentation studies to plan comprehensive adaptation measures
Dam	Runoff regime	Insufficient priority and detailed analysis of impacts of dry spell on dams and reservoirs	Conduct studies on the impact of climate change on dams for electricity generation and water supply.
Groundwater	Quantity and quality	Lack of monitoring and simulation studies covering all the groundwater storage affected by salt water intrusion and prolonged drought	Conduct comprehensive monitoring and studies on the impact of climate change on groundwater quantity and quality

Table 7.2: General gaps and improvement plan on water service industry

AREA	VULNERABLE PARAMETER	GAPS	IMPROVEMENT PLAN
Domestic and industrial water supply	Water exploitation index and water quality	Lack of the design of safe yield for water supply based on projected occurrences of dry spell under climate change	Develop an updated the design of safe yield for water supply under climate change scenario
Irrigation	Water supply capacity and the irrigation water requirements	Insufficient detailed analysis of impacts of climate changes on irrigation water demand and supply, and quantify impacts on cropping patterns	Need to develop projections of irrigation demand and yields
Hydropower	Extreme rainfall and drought events	Current assessment has not been able to provide an in-depth assessment of the impact of dry spells, sea level rise, and extreme flood on hydropower plant operation and electricity generation	Additional detailed and comprehensive assessments need to be carried out in particular for the large hydropower dams
Fisheries	Sea surface temperature and sea level rise	Lack of comprehensive understanding of the impacts and threats of climate change to seafood security	Conduct analysis on the impact of climate change on aquaculture species, biosecurity of aquaculture species, and biodiversity

Table 7.3: General gaps and improvement plan on water-related disasters

AREA	VULNERABLE PARAMETER	GAPS	IMPROVEMENT PLAN
Flood	Temperature rise, rainfall regimes, and high flow	Lack of projected flood maps covering all the	
flood prone basins	Establish comprehensive flood maps covering all flood prone basins in Malaysia		
Drought	Low flow	Analysis of projected dry spells for vulnerability assessments need to be based on seasonal rather than annual scale, and with high spatial resolution	Develop seasonal projected dry spell maps that are suitable for vulnerability assessments at the sub basin and local scales

Table 7.4: General gaps and recommendation action on engineering practices

AREA	TOPICS	GAPS	RECOMMENDATION ACTION
Water Resources	Encourage to alternative water supply: groundwater and rainwater harvesting	Lack of enforcement and economic studies to implement groundwater and rainwater harvesting	Establish comprehensive studies on the use of groundwater and rainwater harvesting in term of economic analyses
	Interbasin water transfer	Lack of study on the environmental and economic impacts within the donor basin	Assessing the potential impacts associated with proposed transfers in terms of environmental damage or the loss of economic opportunity within the donor basin
Water Service Industry	Reduction of the national average household water consumption level	Lack of enforcement and structural-non-structural strategies to achieve the national long-term target	Develop the national long-term target and strategies for reduction of household water consumption level
	Promoting modern irrigation system	Lack of study on the impact of modern irrigation systems use on water resources and agriculture yields	Establish comprehensive studies on the implementation of modern irrigation systems in agriculture
	Reduction of non-revenue water	Lack of a comprehensive studies on the implementation of existing strategies to reduce NRW	Develop a comprehensive study on the implementation of existing strategies to reduce NRW
Water-Related Disasters	Intensity–Duration–Frequency (IDF) curves	Lack of study to examine acceptance among the practitioners especially when considering the implication of this IDF on the sizing and cost	More extension work is necessary to get wider acceptance among the practitioners especially when considering the implication of this IDF on the sizing and cost

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