WATER RESOURCES MANAGEMENT STRATEGY: REVIEW ON THE IMPACTS OF SARAWAK RIVER BARRAGE ON THE WATER QUALITY

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LIST OF ABBREVIATIONS

BOD          Biochemical Oxygen Demand
COD          Chemical Oxygen Demand
DO           Dissolved Oxygen
NH$_3$-N     Ammonical Nitrogen
NTU          Nephelometric Turbidity Unit
TDS          Total Dissolved Solids

EIA          Environmental Impact Assessment
EMP          Environmental Management Plan
EQA          Environmental Quality Act
INWQS        Interim National Water Quality Standards
MSL          Mean Sea Level
SSRS         Sungai Sarawak Regulation Scheme
UNEP         United Nations Environmental Programme

ANOVA        Analysis of Variance
$H_0$        Null Hypothesis
$H_a$        Alternative Hypothesis
SPSS         Statistical Program for Social Science

CTTC         Centre for Technology Transfer and Consultancy
DOA          Department of Agriculture
DOE          Department of Environment
DID          Department of Irrigation and Drainage
JKR          Jabatan Kerja Raya (Public Works Department)
KBM          Kuching Water Board
NREB         Natural Resources and Environmental Board
SRB          Sarawak Rivers Board
ABSTRACT

The Sungai Sarawak Regulation Scheme (SSRS) is the first of its kind in South East Asia and could be one of the very few “three in one” infrastructure-combining barrage, lock and bridge. This scheme aimed to improve and maintain the water quality to the quality standard acceptable as a reservoir for water supply for Kuching City and its surrounding areas besides improving the aesthetic value of the river. The effectiveness of SSRS as a tool for water resource management in Kuching area was evaluated by comparing the water quality data of the pre-barrage era against the post-barrage era. The data were tested first for normality by using One-Sample Kolmogorov Smirnov test followed by a descriptive statistics, ANOVA (analysis of variance), Paired Samples T-Test and Trend Analysis. This study concluded that the installation of the barrage across Sarawak River has brought about significant improvement to the dissolved oxygen (DO) levels, biochemical oxygen demand (BOD) levels, salinity, turbidity and the bacteria counts, to the section of the river upstream of the barrage. Other water quality parameters such as chemical oxygen demand (COD) and ammoniacal nitrogen (NH₃-N) were deteriorated after the installation.
Skim Pengawalaturan Sungai Sarawak (SPSS) merupakan satu-satunya yang seumpama di rantau Asia Tenggara yang merangkumi struktur tiga dalam satu; tambak, kekunci dan 'penghalang'. Skim ini diwujudkan bertujuan untuk mempertingkatkan dan mengekalkan tahap kualiti air mengikut piawaian yang ditetapkan disamping mengekalkan nilai estetika kawasan sekitar sungai. Keberkesanan SPSS sebagai salah satu medium pengurusan sumber air di sekitar kawasan Kuching telah dinilai berdasarkan perbandingan kualiti air era sebelum dan selepas pemasangan tambak Sungai Sarawak. Pada mulanya, ujian kenormalan menggunakan 'One-Sample Kolmogorov Smirnov' dijalankan, diikuti analisa statistik secara deskriptif, Ujian ANOVA (Analisis Varians), Ujian T-Berpasangan dan Analisis Tren/Masa. Hasil kajian ini membuktikan bahawa, pemasangan tambak merentasi Sungai Sarawak secara signifikan telah mempertingkatkan mutu paras oksigen terlarut (DO), BOD, kemasinan (salinity), kekeruhan (turbidity) dan kiraan bakteria terutamanya di bahagian hilir Sungai Sarawak. Parameter kualiti air yang lain, seperti COD dan ammonia nitrogen telah menurun selepas pemasangan tambak tersebut.
CHAPTER 1
INTRODUCTION

1.1 Preamble

Sarawak River has two major tributaries, namely Sungai Sarawak Kiri and Sungai Sarawak Kanan, which originate from the mountains near the Kalimantan border. Both streams meet near Batu Kitang approximately 55 kilometres upstream of the river mouth. From the confluence, the mainstream Sarawak River flows north and through Kuching City. Further downstream near Pending area, the river splits into two, forming a distributary called Sungai Santubong. The Bako causeway has now closed this watercourse, which carries about half the flow. Sarawak River is joined by Sungai Kuap and Sungai Loba Batu Belat before flowing north east into the South China Sea.

This river has served as one of the most important medium of transportation as well as a source of water supply for drinking, domestic and industrial uses. It also plays an important recreational role and contributes to the unique scenic beauty of the city. Within this catchments area is where the State capital city, Kuching, is located, with its’ rapid growth of human population and land-use development. The exponential development activities along its’ riverbanks have led to the increasing of source and non-source pollution to the river. Sarawak River has been a recipient of waste and effluent discharges from both grey and black water of domestic, commercial and industrial activities. Thus, the water quality was reported to gradually decreased due to rapid economic development and increase in population, particularly in the river alongside Kuching City.
Many issues relating to water quality resulted directly or indirectly to changes especially in the physical changes. The construction of structures such as barriers, barrages or weirs, which are designed to modify or totally prevent the progression of the tide up an estuary or inlet, may indirectly deteriorate the water quality. Burt and Rees (2001) pointed out that both upstream and downstream water quality may be affected by the introduction of a tidal control structure. They also stated that tidal flushing will be altered and the pattern of salinity variation will be changed as a result of changes to tidal propagation upstream of the barrage.

On 27th August 1998, the Sarawak River Barrage, Lock and Bridge were officially opened under the Sungai Sarawak Regulation Scheme (SSRS). The SSRS was planned to assist in facilitating the development strategies for Kuching City and its environment. It is also the first step towards future efforts to rehabilitate the coastal beaches and provide an attractive site with clear shore waters. This scheme also aimed to improve and maintain the water quality to the quality standard acceptable as a reservoir for water supply for Kuching City and its surrounding areas besides improving the aesthetic value of the river. All of these efforts were formulated to enhance best practices management in water resources especially for Sarawak River Catchment (Figure 1.1).

The objectives of the Scheme were:

i. to provide transport links between the City of Kuching and Sejingkat area, thus facilitating infrastructural and industrial growth in Kuching region

ii. to regulate the river water level upstream of the barrage

iii. to mitigate fluvial and tidal flooding in the City of Kuching

iv. to secure Kuching’s water supply

v. to reduce the transport of muddy sediments to the foreshores of Santubong and Damai
Based on the Environmental Impact Assessment (EIA) report (VOL 1) for the SSRS project, (Jabatan Kerja Raya, 1994), the implications and effects of the Scheme were evaluated and the study concluded that the most feasible Scheme to achieve the objectives would comprise of the following:

i. The Santubong causeway at Jalan Bako
ii. The Sarawak causeway at Jalan Keruing
iii. The barrage and ship lock gate at the cut in the isthmus
iv. Bridge over barrage and the Pending-Sejingkat link road
v. Diversion channel with gated barrage structure in the isthmus between Sejingkat and Pending
vi. Land reclamation and road infrastructure in isthmus

1.2 Problem Statement

An alteration of any river/floodplain including channel modifications such as barrage’s construction will either lead to direct or indirect impacts on the biotic environment such as the loss of existing vegetation and its dependent habitats and fauna, as well as abiotic factors such as riverbank erosion, nutrient transfer, saline intrusions, sedimentation and water resources in terms of deterioration of water quality, flooding, drainage and run off. The impact of the installation of the Barrage on the river environments need to be verified against the potential impacts suggested in the EIA reports.

1.3 Significance of the Study

The Sarawak River Catchment is one of the fastest growing regions in the State of Sarawak. With the state capital of Kuching, located in the catchments and the Country’s vision of forging ahead towards industrialisation, the pace of development is expected to
accelerate even further. Added to that, with the SSRS, whereby the barrage has cut off tidal flushing of the river, it is necessary that such study be carried out to determine the effectiveness of the barrage performance in terms of water resources practices and its impact on water quality.

1.4 Objectives of study

The general objective of this study was to review the impact of the Sarawak River Barrage on water quality, which was planned under the SSRS. The study evaluated the effectiveness of SSRS as a tool for water resource management in Kuching area.

The specific objectives of this study were:

i. to study the current operation and management practices (for barrage) from the perspective of water resources management;

ii. to compare and analyse the water quality data for the selected station of Sarawak River (near the barrage area) for pre-barrage operation and post-barrage operation; and

iii. to determine if there have been improvements in selected water quality parameters over time (trend analysis).
Figure 1.1: Sarawak River Catchment
(Source: KTA (Swk) Sdn. Bhd. In association with CMPS, UNIMAS and DHI; May 1995)
CHAPTER 2
LITERATURE REVIEW

2.1 Water Resource Management

Water is one of the most vital resources on earth. Despite its chemical simplicity (H₂O), water's properties make it absolutely essential for all life form. Our planet is very rich in water, which covers over 70% of the planet's surface. Unfortunately, most of this (97.4%) is saltwater which is not usable by land life. Only 2.6% of earth's water is made up of fresh water to satisfy most of our needs. About $\frac{3}{4}$ (three-quarter) of freshwater occurs as ice and is inaccessible. Ninety percent of this ice occurs in Antarctica. Only about 0.6% of earth's water is fresh water in the readily available liquid state. The vast majority of this occurs as groundwater. Only a very tiny fraction (less than 0.014%) of earth's water occurs as freshwater lakes and rivers that we usually associate with water (McKinney & Schoch, 2003).

An adequate supply of affordable water of suitable quality makes major contribution to economic and social development. More than a billion people, mostly the poor, still have no access to clean water. Almost 1.7 billion people are without adequate sanitation. Many parts of the world are constantly struggling with drought and floods; in addition, many countries face problems of fast-growing populations, rapid urbanization, rising costs of supplying water and pollution of inland (fresh) water. All of these problems have increased the urgency of formulating policies and associated strategies that will ultimately lead to effective measures to manage water as a social and economic resource with emphasis on its conservation (Moigne et al., 1994).
Water resource management can be looked at from two different viewpoints: non-structural and structural. The non-structural sections may involve the water resource strategy, policies, guidelines, law and legislations and other rules and regulations that enacted on paper. Structural sections may include designing, engineering works and implementation, which involved operational and monitoring level. This may involved the engineers who were taught to design the various works for water resource management from the structural and functional viewpoints. The implementation level seek the involvement and cooperation from all kind of parties including the government agencies, private sectors, educational, scientist, sociologist, public and individual.

In the non-structural viewpoint, one of the most important agenda that should be looked into is the water resource strategy. A water resources management strategy is a set of medium to long-term action programs to support the achievement of development goals and to implement water-related policies. Development goals might concern, for example, aspects of water supply security, population growth, flood mitigation, rural and urban development, and the role of public and private sectors. Water-related policies might include government decisions about the preservation and protection of ecosystems, water quality monitoring programs and water rights (World Bank, 1994).

According to Rast and Thornton (1999), the water regulations should cover land use rights related to water management, watershed development, environmental quality and pollution control standards, dam safety standards, service standards for water supply, and financial and management standards.

Susan S. Seacrest, President of The Groundwater Foundation, Nebraska, (Cech, 2005), explains that watershed approach to water management has become a template for
integrated natural resources stewardship, and this approach is being adapted on almost 
every level: local, state and federal. She added that the growth at grassroots watershed 
level may also be part of our need to “act locally, think globally”.

The United Nations Environmental Programme (UNEP) has developed a new holistic 
approach of freshwater resources management. Its comprehensive water resources 
planning approach to the management of both water quantity and water quality in 
international river and lake basins were formalized by UNEP as the environmentally sound 
management of inland waters (EMINWA) process. Through EMINWA, the inventory and 
analysis of freshwater resources, water needs and water management in this international 
water system extend also to the national rivers and that form an integral part of the 
international water systems.

2.2 Sarawak River: Water Resource and Management Plan

Water is one of the major development assets in Sarawak, mainly derived from 23 major 
river basins in the State. Sarawak River, which is approximately 120 km long and 
navigable up to 34 km consist of two principal tributaries namely Sungai Sarawak Kanan 
(with catchment area of 691 km$^2$) and Sungai Sarawak Kiri (with catchment area of 524 
km$^2$). The catchment areas of Sarawak River is estimated to be 1,423.6 km$^2$ (with SSRS) 
comprising multipurpose land use pattern including urban areas, agricultural areas, fishery 
and aquaculture areas, mining areas, rural areas and the barrage.

In Sarawak, water resource harvesting and utilisation is reliant on the ability of its 
catchment areas. Murtedza Mohamed and Ali Memon (1999) estimated that the total 
water resource to be about 460 billion m$^3$ of which 41% returns to the atmosphere through 
evapotranspiration process, 52.3% occurs as surface run-off and 6.5% infiltrate into
ground water. Almost 95% of the water supplies for Kuching region are obtain from Sungai Sarawak Kiri through Kuching Water Boards pumping station at Batu Kitang.

Based on paper presented by Sawal (2003), the current State annual aggregate treated water demand for domestic and industrial sectors is estimated at 180 million m$^3$, serving about 70% of the State population. The City of Kuching alone needs more than 240 megalitres of treated water daily.

According to the Annual Report 2003 produced by Kuching Water Board, a total of 105,732 megalitres of fully treated water was produced representing a 2.8% increase over 2002 production. The average daily consumption rose from 282 megalitres in 2002 to 290 megalitres in 2003, an increase of 2.8%.

Within the context of the State of Sarawak, the government has given serious outlook towards the management of water resources. For example, Sungai Sarawak Kiri has been gazetted as a water catchments area to protect this important water resource. A lot of study has been done pertaining to the above matter.

A research done by Murtedza Mohamed and Ali Memon (1999), recommended that the State’s strategy for sustainable water management should have a statutory based to accomplish the following tasks:

1) formulate State policies and plans for integrated water management on a catchments basis. Each plan could include a single catchments or more than one catchments. The scope of these plans should relate to water allocation; water quality; catchments land management; and flood hazard mitigation;
2) develop regional river basin plans for allocating water and protecting water quality. Such plans should be based, amongst other things, on specific policies on land use regulation, water quality standards, water allocation and pricing, minimum flows and allocation priorities between different users during low flows;

3) implement river plans and carry out enforcement. It is preferable that the task of enforcement is decentralised as much as possible;

4) monitor and evaluate the effectiveness of the plans; and

5) encourage participation of user groups (e.g. water supply companies and the local community groups in urban and rural areas) in the planning and implementation process.

As stated in the EIA report for the SSRS, it was recommended to have an Environmental Management Plan (EMP) that covers not only the scheme itself but the management of the whole river and its catchments, including management of land use, wastewater discharges, water supply, resources and aesthetics. The Sarawak State Government has commissioned KTA (Sarawak) Sdn Bhd to do a Study of the Sarawak River Catchments, upstream of the barrage, focusing on environmental control and river management under post-barrage conditions. The primary delivery of the Study was a River Management Plan (Volume 2). It was a first step towards ensuring that the quality and amenity of Sarawak River is maintained at an acceptable level.

The Sungai Sarawak Environmental Control and River Management Study have outlined the objectives of the study as follows (NREB, 1996):

1) to maintain and enhance the water quality of Sarawak River, particularly in the post-barrage conditions;
2) to maintain the hydrological integrity of the river and provide for effective 
drainage and flood mitigation;
3) to conserve the ecological resources of the catchments, and in particular, riparian 
ecosystem, birds and wildlife, and mangrove forest;
4) to balance the needs of all forms of development (including industrial, urban and 
agricultural development) with the requirements of conservation of the catchments 
natural resources;
5) to assist and ensure that all relevant parties implement the principles of sustainable 
development by establishing stronger links with developers, government agencies, 
and the local communities; and
6) to enhance the aesthetics of the river corridor.

The Study draws together the findings and recommendations of the following (NREB, 
1996):

1) Volume 2: The River Management Plan

Describe the River; its current status in respect of particularly 
environmental land use conservation, water quality, vegetation, 
wildlife, aquatic resources, socio-economic status, public health and 
sedimentation.

2) Volume 3: Flood Mitigation Study and Report
3) Volume 4: Floating Waste management Study and Report
4) Volume 5: Urban Drainage Study and Report
5) Volume 6: Sewerage Study and Report
6) Volume 7: Institutional and Organisational Aspects and Public Health Program
2.3 Early Water Quality Issues in the Sarawak River

There are four main key issues identified in the Executive Management Plan (EMP) (NREB, 1996) mainly the water quality, land use, flood management and floating waste issue.

Based on the study above, the water quality issues generally highlight the major problems on high heavy metal, poor dissolved oxygen and wastewater pollution from pig ranching. The heavy metal readings were reported high in the upstream of Sungai Sarawak Kanan which could be attributed to waste from mines or the one processing plant at Bau. While the mine has undertaken studies and believes that there is little threat to the river from this point source there is no enforcement or monitoring programme in place to ensure sustainability of the water supply in this area and the downstream communities generally.

The general water quality modelling works predicts severe deterioration in quality as identified by poor dissolved oxygen levels in the river upstream of the barrage during dry periods. The wastewaters from piggeries are causing high bacteria levels in the river upstream of Kuching. In order to reduce the pollution levels of the discharges, regulations need to be implemented on site treatment.

2.4 Sungai Sarawak Regulation Scheme

According to Goh (2004), the original concept of a scheme to regulate the flow in Sarawak River has been attributed to the Sarawak Chief Minister in the early 1980’s. He also mentioned that, the first serious action towards implementation was made in 1990 within KTA (Sarawak) Sdn. Bhd. and the Sarawak Government on the proposed concept adopting the present configuration. This was followed up in May 1991 when consulting engineers, Rendel Palmer and Tritton (RPT) of the U.K, in association with KTA
(Sarawak) Sdn. Bhd. and H.R Wallingford was commissioned to undertake a feasibility study of the proposed Sarawak River Regulation Scheme (SSRS). The final report of this study, which incorporated comments from the steering committee appointed to oversee the study, was submitted in December 1991.

Based on EIA report (Vol 1) (JKR, 1994), the Scheme has been developed as an initial objective to reduce the sedimentation nearby coastal beaches of Pasir Pandak, Pasir Panjang and the Santubong Peninsula. Other than that, SSRS was also formulated to achieve the following objectives:

i) to improve transport links between the City of Kuching and the Sejingkat area
ii) to mitigate fluvial and tidal flooding in the City of Kuching
iii) to regulate the river water level upstream of the barrage
iv) to secure Kuching's water supply
v) to enhance the beauty of waterfront through the City

The construction of the SSRS near Kuching has been developed through a three phase time frame (Figure 2.1). The project comprises the following components:

Phase 1 : The Construction of the Bako Causeway, a rock fill dam across the Loba Santubong on the Bako Road.

Phase 2 : The Construction of the main Barrage Facility comprising:

(i) A tidal exclusion barrage of five radial gates controlling the Sarawak River,
(ii) A 125m long by 25m wide ship lock, and