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NATIONAL OVERVIEW "THE STATUS OF EUTROPHICATION OF LAKES IN MALAYSIA"

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ABSTRACT

This paper highlights the findings of a desktop study on the status of eutrophication of lakes in Malaysia. It aims to take stock of the current status of the lakes in the country and the threats to ecosystems. This baseline study, together with its recommendations for remedial measures and environmental strategies, form the foundation for better planning, research and management of lakes in Malaysia. The research needs on lakes in Malaysia were also identified by benchmarking with the level of lake research in the US and Japan.

Keywords: Eutrophication, lakes, reservoir, restoration

INTRODUCTION

Lake Eutrophication is a global phenomenon happening all over the world. It also ranks as one of the most widespread environmental problems which impacted human and ecosystem health. Rapid development within lake catchments has had significant effects on the quality of water in lakes. Global climate change with extreme weather conditions are known to have considerable impact on the water quality and water quantity in inland water bodies. This paper attempts to highlight the findings from a desktop study on the status of lakes eutrophication in Malaysia. The study was initiated by the National Hydraulic Research Institute of Malaysia (NAHRIM) with the assistance of the Institute of Environmental and Water Resources Management (IPASA), UTM. The objective of the study is to take stock of the current status of the lakes around the country and the threat encountered by them, both from the standpoint of water quantity and water quality.

The main objective of the study is to review on the current status of lake (including reservoirs) eutrophication in Malaysia and to recommend appropriate remedial measures and environmental management strategies for the restoration and conservation of the identified lakes in Malaysia. Other important objectives are to identify the lake management knowledge gaps and human resources requirements. These include recommendations for a national lake research agenda that can be pursued to seek short and long term solutions within the Malaysian context, and the development of capabilities and capacities to comprehensively deal with the issues in the short and long term.

INVENTORY OF LAKES IN MALAYSIA

The inventory of lakes was developed based on various definitions of lakes and reservoirs including the definition by UNEP (2000), which defines lakes as 'natural, standing, freshwater or saline water body found on the Earth's continental land masses'. Reservoirs are defined as 'water bodies of different shapes and sizes that have been constructed by humans by damming a river'. Under the RAMSAR convention, lakes are also considered as part of wetlands. The latter is defined as 'areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static of flowing, fresh, brackish or salty, including areas of marine water the depth of which at low tide does not exceed six metres'. Wetlands are, thus, transitional habitats between dry land and deep water. They include marshes, swamps, peatlands (including bogs and fens), flood meadows, lakes and ponds, rivers and streams, estuaries and other coastal waters (including salt marshes, mangroves and even coral reefs)'.

Based on information gathered from the Malaysian Water Industry Guide 2003 (MWA, 2003) and from the National Water Resources Study 2000 - 2050 (EPU, 2000) and form various data from the Department of Environment (DOE), 90 lakes were identified in this study. Their distribution by states is as shown in Table 1.

Lakes in Malaysia served as important sources of water with 61% of the 90 lakes studied being used for water supply and irrigation purposes while the rests are utilised for hydropower, flood control and recreational purposes. More than 20% of the lakes were identified to have multi-purpose functions. The most number of lakes were located in Selangor, while Johor has the most number of man-made lakes.

Table 1. Distribution of Lakes in the various states in Malaysia by State

1.	Perak	2	9
2.	Selangor	5	10
3.	Pahang	2	8
4.	Kelantan	-	3
5.	Johor	-	13
6.	Kedah	1	6
7.	Labuan	-	3
8.	Melaka	-	4
9.	Negeri Sembilan	-	5
10.	Pulau Pinang	-	4
11.	Perlis	2	-
12.	Sabah	1	5
13.	Sarawak	2	2
14.	Terengganu	1	1
15.	W.P. Putrajaya	1	-

STATUS OF LAKES

Past Studies

At least about 85 reports and publications on lakes and reservoirs in Malaysia documented by Malaysian researchers at different public and private institutions were reviewed in this study. The studies on lakes and reservoirs in Malaysia can be classified into seven categories (Figure 1).

Past studies on only 30 lakes and reservoirs were carried out in different parts of the country. The distribution of the lakes and reservoirs reported in the literature are given in Annex 1. Tasik Kenyir, Layang Reservoir, Putrajaya Lake and Semenyih Reservoir were the most extensively studied lakes. Approximately 33% of the publications pertained to fish and aquatic fauna, followed by water quality (31%), modelling (11%), aquatic flora (10%), economic development, management and tourism (8% each), and dam and regulated river and lake information system (3% each).

The majority of the past studies on fish and aquatic fauna are related to the suitability of the lakes and reservoirs for fisheries development and fisheries management. Analyses of fish species, community and diversity, and survey of fish infection in lakes were also reported. Lakes that were involved in these studies include Tasik Kenyir, Tasik Dayang Bunting, Tasik Timah Tasoh, Semenyih, Chenderoh, Temenggor, Bukit Merah, Subang, Durian Tunggal and Kenering reservoirs.

Other studies cover water quality (13 studies), pollution sources identification (4 studies) and water quality improvement techniques (8 studies). Water quality analysis have been documented on Layang reservoir, Timah Tasoh reservoir, Tasik Kenyir, and Putrajaya Lake as well as small lakes such as the Zoo Negara Lake, oxbow lakes and abandoned tin mining lakes. Studies to identify pollution sources included analyses of high manganese and iron contents in Layang reservoir and studies on arsenic level in Tasik Biru. There were also studies on the application of techniques for improving lake water quality,

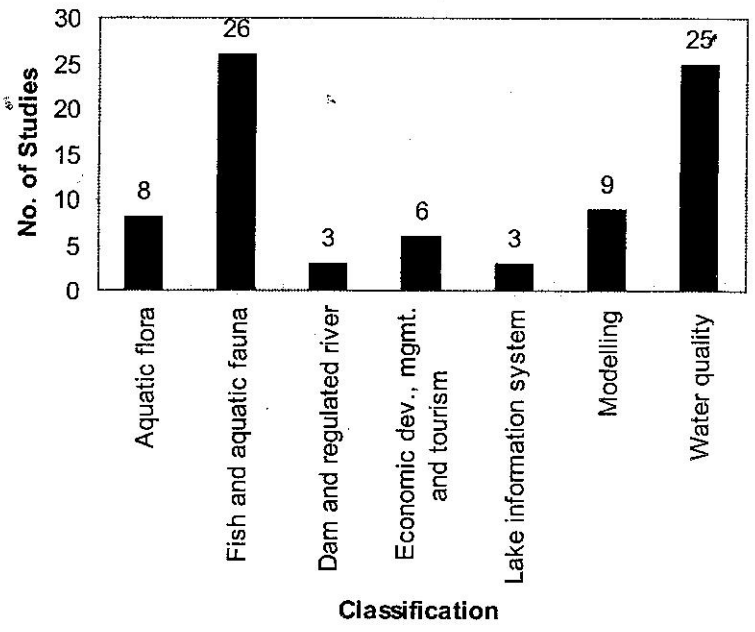

Figure 1. Classification of previous studies

such as diffused air aeration techniques in Terip and Layang reservoirs and wetlands concept at Putrajaya Lake.

Studies on aquatic flora included the identification of the composition and production of the phytoplankton in the water body and review on the effects of environmental changes on aquatic species. These are also publications documenting lake development for economic and tourism purposes and lake management, but these are limited to lakes such as Tasik Kenyir, Tasik Chini, Putrajaya Lake, and Kelana Jaya Lake.

The development of a Lake Information System has been reported for Pergau reservoir and Putrajaya Lake only. There were also studies involving the development and application of water quality and hydrological models. Water quality modelling studies included phosphorus loading estimation for Layang reservoir, hydrological catchment management at Langkawi, and rainfall-runoff hydrological models for Bekok, Klang and Langat reservoirs. A study to model the water quality of Sg. Sembrong, which flows into the Sembrong reservoir was also identified. The commonly used softwares for lake modelling include MIKE11, QUAL2E, HEC-HMS and DYRESM.

Studies on lake and reservoirs in Malaysia were found to cover diverse issues. The studies, however, appear to be limited to the individual researchers' objectives and interests. As no lake has been studied extensively in an integrated manner, the database of lakes and reservoirs in Malaysia could not be properly developed.

Status of Lake Eutrophication

The classification of lakes is based on the trophic state which defines the biological productivity of a lake. The most commonly determined biological variable to define trophic state and lake quality is chlorophyl a (chl a), and several empirical relationships between chlorophyl a and Total phosphorus (TP) exist. The TP-chl a relationship was used to develop a numerical trophic state index (TSI), which is identified as one of the most commonly used index. Many TSI criteria were identified and used in this study, such as Carlson's TSIs, and the Lake Evaluation Index which uses 6 parameters.

Despite its limitation, this study uses the Carlson's TSIs for the classification of lakes due to its simplicity, less number of parameters needed and its wide usage (Carlson, 1977). For lakes in which data for the above 3 parameters were not available, TP values were estimated based on the relationships between general land use and Total Phosphorus. After the computation of the TSIs, the lakes were graded as good, **medium** or **bad** based on the allowable nutrient loadings.

Based on the 90 lakes and reservoirs assessed, only 9 lakes have data from previous studies which can be used to compute the TSIs. This includes 2 lakes in Selangor i.e. Tasik Titiwangsa and Tasik Aman, 3 lakes in Johor i.e. Upper Layang, Lebam and Linggiu Reservoirs, 1 lakes in Negeri Sembilan i.e. Sungai Terip Reservoir, 1 lakes in Perlis i.e. Timah Tasoh Reservoir, 1 lakes in Terengganu i.e. Tasik Kenyir and 1 lakes in Putrajaya i.e. Tasik Putrajaya. The TSI values for the other 81 lakes were computed from estimates of TP concentrations based on their dominant land uses.

Of the 90 lake studies, 34 lakes (39%) are **mesotrophic** whilst the other 56 lakes (62%) are **eutrophic**. A word of caution is necessary here when looking at these results. Whichever scenario is taken based on this initial survey of our lakes and reservoirs i.e. either TSI based on previous studies or TSI based on landuse estimates of TP, the situation looks serious enough for an immediate follow-up study to be undertaken to confirm these TSIs based on actual site data collection especially for lakes in the BAD category. If they are confirmed to be highly eutrophic, then immediate steps have to be taken to arrest the water quality deterioration.

TREATMENT AND RESTORATION TECHNIQUES

Based on experiences from various parts of the world, various treatment options and environmental management strategies for lake management, particularly for the control of eutrophication were highlighted. The major options can be summarized as follows:

- Treating incoming discharges and effluent by using natural and/or man-made wetlands, and waste stabilization pond (WSP)
- Separating wastewater compositions to facilitate treatment and opportunities for reuse and recycling
- Practicing proper disposal and management of solid waste and sludge which may include recycling, emission reduction, decomposition to harmless compounds and disposal.
- Controlling or minimising erosion and subsequent sedimentation in lakes and reservoirs through best land management practices with emphasis on minimising land disturbance and rehabilitation of degraded land
- Bottom lake sediment problem such as anoxia can be controlled by aeration, capping (blanketing polluted sediment by clean sediment) or chemical treatment.
- Polluted sediment can also be removed by dredging. However, this method is very expensive and only realistic for relatively small lakes.
- For a deep lake it is possible to reduce phosphate concentration by precipitating excess phosphate into the lake bottom
- Reducing the rate of phosphorus release from sediment by shifting anaerobic to aerobic conditions in the hypolimnion. The method is particularly effective when sediments contain high concentration of iron (III) phosphate, which is formed under aerobic conditions and has a very low solubility.
- Changing the ecological structure of the lake ecosystem through biomanipulation techniques. Intermediate improvement of the lake water can be achieved if phosphorus concentration is greater than 150 µg/l.

Environmental Management Strategies for Lake Conservation

The proposed lake environmental management strategies include eutrophication control, ecosystem conservation and increase in aquatic production. The strategies can be divided into five broad categories as follows:

a) Integrated catchment management (ICM)
b) Regular water quality monitoring program
c) Aquatic plant management
d) Proper setup of an agency responsible for lake management.

Integrated Catchment Management (ICM)

Recommendations for ICM can be divided into short and long terms strategies. For the short term the tasks are divided at local, regional, state and federal levels.

a) Short term management.

Local Level

At a local level, control of lake pollution must be carried out at the early stage by incorporating conservation into zoning. This requires the following inputs or tasks:
- Complete master plan and wetlands inventory
- Storm water management plan
- Support conservation easements
- Identify high priority areas contributing to surface water quality degradation
- Increase efficiency of water and waste water treatment
- Implement enterprise accounting
- Develop and/or adopt an environmental education curriculum for all grades
- Implement public education programs at a local level

Regional Level

- Coordinate and supplement local environmental education efforts
- Coordinate local land use planning by establishing a framework for all master plans.
- Establish standards for storm water management
- Establish economic incentives for the installation of conservation measures.
- Expand efforts of Soil Conservation Service to include all agricultural lands and non-point source issues.

State Level

- Focus efforts on a watershed basis, particularly with regards to pesticides and point-source effluent permits.
- Establish "minimum flow" standard to maintain river health during drought conditions.
- Facilitate local/regional efforts at planning and watershed-level management
- Coordinate state departments to comply to conservation regulations uniformly.

Federal Level

- Improve funding for soil conservation activities, and encourage participation of activities
- Increase and prioritize funding for initiatives that promote a local/regional approach to water quality improvement.

b) Long-Term Management.

- Establish a watershed-based institution with statutory authority to regulate flow in each watershed.
- Formulate enabling legislation to strengthen watershed level institution which include methods for raising revenue and a specific minimum level of authority.

Water Quality Monitoring Program

Monitoring of lake water quality is carried out to achieve the followings objectives:

a. Identify relative contribution of different pollutant sources
b. Allow calculation of nutrient input/output budgets into receiving river, lake, or reservoir
c. Predict change in trophic condition that would result from specific management interventions
d. Assess alternative management interventions in terms of cost/benefit.

Chemical Monitoring

Most monitoring and management programmes for eutrophication control have focused on phosphorus management. Conventionally, phosphorus is measured in two forms, namely total phosphorus (TP) and soluble phosphorus. The soluble form is unstable and must be immediately analysed. Fortunately, for most practical purposes, management strategies for phosphorus control can be made using values of total phosphorus. Chemical monitoring is more difficult in a lake or reservoir environment. The association of phosphorus with fine-grained sediments (i.e., silts and clays) requires an estimate of the amount of phosphorus, which is transported with the sediment load to the lake, and with the sediment that has been deposited in the bottom of the lake.

Bio-Assessment

Eutrophication is associated with abundant growth of biomass. Different levels of eutrophication tend to be associated with different types and quantities of algal species. The most common biological parameter in a monitoring regime for eutrophication is chlorophyll-a which is a measure of primary production (algal biomass) in the water column. Another measure of primary production is particulate organic carbon (POC).

Estimation Techniques

A particular problem in many countries is the lack of necessary and reliable data to estimate the nature and scope of the eutrophication problem. This data is necessary to develop nutrient loading and to make management decisions on the type of source controls that are likely to make significant improvement in the level of eutrophication. The estimation techniques must include both point sources and non point sources pollution.

Aquatic Plant Management

Effective management of aquatic plants is crucial to ensure an ecologically healthy lake or reservoir. Aquatic plants can be removed manually or mechanically. The manual methods include hand-pulling, cutting, raking and clean-up. Hand-pulling is different from cutting because the latter does not remove the plant root. Raking literally tears plants from the sediment, breaking some plants off and removing some roots as well. Mechanical weed cutters cut aquatic plants several feet below the water's surface. Unlike harvesting, cut plants are not collected while the machinery operates. There are several versions of underwater weed cutters commercially available.

Whether plant removal is carried-out manually or mechanically, it is important to remove or clean-up all fragments from the water to prevent them from re-rooting.

Other commonly used techniques for plant management include:
Bottom screening: this technique involves smothering the lake bottom using materials such as burlap, plastics, perforated black Mylar, and woven synthetics.
Sediment agitation: this technique mechanically disturbs the lake bottom to remove aquatic plants and prevent their regrowth.
Biological control: The biological control of aquatic plants focuses on the selection and introduction of organisms that have an impact on the growth or reproduction of a target plant. Theoretically, by stocking an infested water body or wetlands with these organisms, the target plant can be reduced and native plants can recover.

Knowledge Gaps

Knowledge gaps in lake research and management were assessed by benchmarking local research with global knowledge, mostly in the West and Japan. The gaps in the understanding of our own lakes and reservoirs were compared to Lake Biwa in Japan and the management of lakes in Lake Webster, Indiana and all the lakes in the State of Iowa, USA. In general, the followings research needs were identified:

- Complete documentation of physical characteristics of all lakes
- Patterns of stratifications in warmer temperature regions where temperature does not drop below 4°C.
- Effects of vertical stratification on the lake chemical, biological and biogeochemical characteristics
- Lake water balance and resident time
- Solute/nutrient budgets and nutrient retention
- Mechanism of pollutant transport and degradation
- Development of mathematical model for predicting the impacts of tropical lake contamination and eutrophication
- Development of effective control measures
- Improvement of assessment and monitoring methods

Setting-up an Agency for Lake Management

In view of the importance of lakes ecosystems for various hydrological and conservation functions it is crucial to set up a federal agency to manage lakes in Malaysia. Research activities on local lakes are scanty and lack focus. This issue

can be addressed through the setting up of a lake management agency with the following task:

a) Plan for lake management and restoration.
b) Execute planning of lake management and restoration.
c) Plan and execute human resource development on lake management.
d) Conduct studies on lake management and technical issues.

The national research agenda that can be considered are as follows:

a) Funding mechanism.
b) Institutional and human resource development.
c) Prioritization of lakes (based on this study).
d) Prioritization of research topics (based on this study).
e) Coordination and cooperation of R&D programs.
f) International linkages.
g) Publications.
h) Knowledge dissemination.

Strategies for Capacity Building

National strategies for capacity building are essential to guide the implementation of medium and long terms lake management plans in Malaysia. Six strategies have been formulated to promote sustainable management of lakes in Malaysia, particularly to control eutrophication. They are shown in Table 2, as follows

CONCLUSIONS

This desktop study reviewed the existing information and status of lakes in the country and identified existing and potential threats to the ecosystem.The study was based on a total of 85 reports and publications on lakes and reservoirs in Malaysia. The past studies dealt with at least 30 lakes and reservoirs which covered aspects of aquatic flora and fauna, water quality and lake information system. An inventory of lakes and reservoirs was developed. The lakes and reservoirs were then classified based on their trophic states. However, since the data was quite limited, further studies are needed to ascertain the results of the analyses.

Recommendations on appropriate remedial measures and environmental management strategies for the restoration and conservation of lakes and reservoirs in Malaysia were also discussed. These include treatment options for inflowing discharges, effluents and sediments, and restoration techniques. The proposed environmental management strategies include integrated catchment management, water quality monitoring and proper setup of an agency responsible for lake management.

Finally, the knowledge gaps between lakes and reservoirs in Malaysia and those in developed countries such as Japan (i.e. Lake Biwa) and USA (i.e. Lake Webster, Indiana and lakes in State of Iowa) were identified. Several research needs for local lakes were recognized. With reference to the best lake management practices in these countries, the national strategies for lake research agenda and capacity building programs were also recommended.

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Table 2: Strategies for Sustainable Management of Lakes in Malaysia.

No.	Strategy Recommended	Rationale	Explanation
1.	Lake management shall be treated as a single entity in national and regional planning	Expertise and resources in lake research are specific and not generic for other water bodies. Lakes and reservoirs are distinct due to the fact that they are important for water resources, flood mitigation, fisheries, recreational and tourism.	1. Laws and regulations related to lake management at federal, state and local levels *: a) Environmental Quality Act 1974. b) Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979. c) Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order, 1987. d) Street, Drainage and Building Act 1974 (Act 133). e) Water Supply Enactment 1993. f) Waters Act 1920 (Act 418). g) Town and Country Planning Act 1976 (Act 172). h) National Forestry Act 1984 (Act 313). 3. Managing lake authorities need to equip themselves with O & M of lakes.
2.	A national center for Lake (and reservoir) Management and Research should be initiated	Lake management requires extensive resources, expertise and policy, therefore the existence of a national center is vital for its sustainability	Provide support for state of the art knowledge and trouble shooting problem in lake management.
3.	A National Lake Policy should be formulated	Lake management requires sound and sustainable management and implementation.	
4.	Lake studies shall be focused with emphasis on nature tourism and water resources	Tourism and water resources are the backbone to development. Therefore focus on this issue will create more interest and attention from policy makers	
5	Grants and scholarship on lake management under a special scheme or program	Grants and scholarship will attract more professionals to be involved in lake studies and management	1. Lake managing agencies (DID,DOE,local authorities,TNB etc.) need to identify their personnels to pursue further studies in lake related disciplines (limnology, ecohydrology, ecotoxicology, aquatic ecosystems) 2. Negotiate with JPA for special grants to be given to pursue higher studies in lake related disciplines. 3. NAHRIM, JPA and Universities have an arrangement for encouraging to pursue further studies in lake related disciplines (as dictated by NAHRIM) and to serve NAHRIM upon completion of studies.
6.	Professorship Chair in Lake Management to be initiated in local public university	A professorial chair is instrumental in enhancing research activities in any subject, provided that the chair is well funded and headed by a well established professor	1. NAHRIM to provide office space and supporting staff (secretary, RO and technical staff) 2. Get government funding to pay salary and research projects 3. Can source funds from private companies

* Note:

a) Environmental Quality Act 1974.
- Under Part I, Clause 2 (Interpretation): "inland waters" means any reservoir, pond, lake, river, stream, canal, drain, spring or well, or any part of the sea above the low water line along the coast, or any other body of natural or artificial surface or subsurface water.
- Under Part II, Clause 25 - Restriction on pollution of inland waters.

b) Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979.
- Under Part I, Clause 2 (Interpretation): "inland waters" include any reservoir, pond, lake, river, stream, canal, drain, spring or well, or any part of the sea abutting on the foreshore, and any other body of natural or artificial surface or subsurface water.
- Under Part III, Clause 8 - Parameter limits of effluent to be discharged into inland waters.

c) Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order, 1987, requires detail EIA report for the following activities:
- Clause 3 (Drainage and Irrigation), "(a) Construction of dams and man-made lakes and artificial enlargement of lakes with surface areas of 200 hectares or more".
- Clause 19 (Water Supply), "(a) Construction of dams or impounding reservoirs with a surface area of 200 hectares or more".

d) Street, Drainage and Building Act 1974 (Act 133).
Under Part III (Drains), Clause 55 - "Water closets and trade effluent not to communicate with river, canal, stream, pond, lake, sea or with any public surface or storm water drain without approval".

e) Water Supply Enactment 1993.
Under Part VII (Catchment Areas), Clause 24 - "The State Authority may, by notification, in the Gazette, declare any lake or river or part thereof or its surroundings to be a catchment area of an impounding reservoir or water supply intake if it appears to the State Authority that such declaration is necessary for the purpose of conserving or protecting the same".

f) Waters Act 1920 (Act 418).
Under Clause 7A - Prohibition of pollution of rivers:
" (2) For purpose of this section the word 'river' shall without prejudice to section 2 be deemed to further include - (a) any inland waters whether or not such inland waters fall within the definition of "river" in section 2; (b) any subterranean water resources; and (c) any water in an estuary or sea adjacent to the coast of the State.

g) Town and Country Planning Act 1976 (Act 172).
The definition of "land" includes "land covered by water". Thus planning, development and preservations of "land covered by water" require permission and control by the Local Authority.

h) National Forestry Act 1984 (Act 313).
Under Part III, Chapter 2 (Classification of Permanent Reserved Forests) provides power to the Director to classify permanent reserved forests under various purposes, which include flood control and water catchment forest.

Apendix 1:

Distribution of Lakes and Reservoirs Reported in Literature

No.	Lakes/reservoir	Classification*						
		A	B	C	D	E	F	G
1	Bekok reservoir						1	
2	Chenderoh reservoir		2					
3	Durian Tunggal reservoir		1					
4	Kenering reservoir		1					
5	Klang gates reservoir						1	
6	Langat reservoir						1	
7	Oxbow lakes, Sabah							1
8	Pansoon reservoir	1						
9	Pergau reservoir					2		
10	Putrajaya lake and wetlands		1		2	1		3
11	Semberong reservoir						1	
12	Semenyih reservoir		5					
13	Sungai Baru reservoir							1
14	Sungai Gumum (Tasik Chini)							
15	Sungai Kincir (Tasik Chini)			1				
16	Sungai Mempelas (Tasik Chini)							
17	Sungai Layang reservoir						4	7
18	Sungai Terengganu (Tasik Kenyir)			1				
19	Sungai Terip reservoir							3
20	Tasik Aman	1						
21	Tasik Biru							2
22	Tasik Chini	3			2			
23	Tasik Dayang Bunting		1					1
24	Tasik Kenyir	1	7		2			1
25	Tasik Paya Bungor	1						2
26	Tasik Titiwangsa	1						
27	Temenggor reservoir		1					
28	Timah Tasoh reservoir		1					1
29	Zoo Negara Lake							1
30	Tin mining pools (abandoned)			1				2
31	General		6				1	
	Total	8	26	3	6	3	9	25

Notes: A - Aquatic flora, B - Fish and aquatic fauna, C - Dam and regulated rivers, D- Economic development, management and tourism, E - Lake information system, F - Modelling, G - Water quality