VISION 2020: TOWARDS AN ENVIRONMENTALLY SOUND AND SUSTAINABLE DEVELOPMENT OF FRESHWATER RESOURCES IN MALAYSIA

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Introduction

Malaysia became an independent nation in 1957. At independence its population stood at 6.3 million. Today it is about 18.3 million and this figure has been projected to reach 32 million by the year 2020. Over the last 20 years, the country has developed rapidly as a result of careful economic restructure. The New Economic Policy (NEP, 1970-1990), aimed at promoting growth and equity while fostering national unity among the component ethnic groups, was introduced by the Government in 1970. A series of 5-year National Development Plans was formulated and implemented adhering to the guidelines of the First Outline Perspective Plan (OPP1, 1971-1990) and the succeeding Second Outline Perspective Plan (OPP2, 1991-2000). The latter was framed in the context of the National Development Policy (NDP, 1990-2000). By strategically shifting its economic base from one of agriculture-dominance to one of industry- and service-dominance, Malaysia has managed to transform itself from a country with an undeveloped economy to become currently a country with a fast growing, robust industrial and export-oriented economy. The Malaysian economy has been targeted to grow at an average rate of 7% per annum during the decade of OPP2, compared with the average growth rate of 6.7% per annum achieved during the OPP1 period. In 1988 the economy grew by 8.9%, in 1989 by 8.8% and in 1990 by 10.1%. Guided by its so-called Vision 2020 Strategic Plan, Malaysia now strives to become a fully developed nation with an economy which is fully competitive, dynamic, robust, resilient and socially just by the year 2020, for by then, Malaysia would have reached the end of its second generation as a nation of independent people.

National development will continue apace in Malaysia. However, this active pursuit of socio-economic development is already straining the country's finite resources and fragile natural ecosystems. The task of supplying enough water of the required quality to a growing population and the safe disposal of wastewater in a rapidly industrialising environment, is taxing the Government's resources. What are the existing water resource-use pressures and local impacts? How would these influence Malaysia's water resource development policy? What steps have been taken to reconcile the country's pressing water needs with the recognised need to ensure the long-term sustainability of this limited resource? Who else needs to be involved as well? What are the future challenges? This paper examines some of the problems and issues surrounding freshwater resource use and conservation in Malaysia from a Malaysian perspective.

Water Availability, Supply and Demand

Proximity to the equator has given Malaysia a climate of high humidity, high temperature and abundant rainfall (Table 1). Its humid tropical climate is modified by the region's insularity and exposure to a monsoonal wind system that originates in the Indian Ocean

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and the South China Sea. Rainfall cycles are thus linked to the two monsoon seasons. The northeast monsoon begins in October/November and ends by February/March. The southwest monsoon blows from mid-April/May to September/mid-October. In between these are the two inter-monsoonal periods, each lasting generally about eight weeks. There are no prevailing winds during the inter-monsoonal periods but daily convectional rain is abundant. The country experiences between 150-200 rain-days per year. The most intense rainfall occurs during the inter-monsoonal periods, but the northeast monsoon period brings the greatest amount of rain as a whole. The average rainfall in peninsular Malaysia is about 2,500 mm a year; its east coast receives an average of 4,000 mm rain per year. A large area of Sarawak receives 3,000-5,000 mm of rain per year while Sabah gets about 1,600-4,500 mm. Droughts occur in certain areas of the country owing to wide spatial and temporal variations in rainfall. The monsoons govern the variability of river flow, occurrence of floods and agricultural pattern. Malaysia lies just outside the tropical cyclone (typhoon) belt.

High rainfall and forest cover contribute significantly to river flow in Malaysia. The long coast line of peninsular Malaysia is transected by 18 rivers, the Sabah coastline by 37 rivers, and the Sarawak coastline by about 20 rivers of various sizes. Malaysia has few natural lakes. There are 54 man-made impoundments in Malaysia of which 49 are located in peninsular Malaysia, three in Sabah and two in Sarawak. Their water surface areas range from 10 ha (Mahang Dam, Pahang) to 37,000 ha (Kenyir Dam, Terengganu). The oldest one is the Bukit Merah Reservoir (3,500 ha) in Perak which was built in 1906. These 54 dams together provide a living capacity of 12×10^6 Megalitres (Ml). The total reservoir area in peninsular Malaysia has been estimated to be about 80,000 ha. It is envisaged that by the year 2000, this figure could increase to 206,000 ha owing to the demand for irrigation and hydropower dams. The latest addition is the proposed Bakun Dam (69,500 ha) in Sarawak. Beside hydro-power generation (11 dams) and irrigation, the other equally important roles of these dams include drinking water supply, river regulation, flood mitigation, subsistence fishing, fish farming and of late, the added roles as sites for recreation and ecotourism. An account of the general features and status of limnological knowledge of Malaysian rivers, lakes, reservoirs and other wetlands has been given by Ho (1994).

Despite the high rainfall input, the total freshwater resources of Malaysia is only moderate due to the high potential evapotranspiration. The country's average annual rainfall is 990×10^6 Ml. Of this, 370×10^6 Ml (38% of total) return to the atmosphere as evapotranspiration, 64×10^6 Ml (6%) recharge ground water aquifers, and the remaining 556×10^6 Ml (56%) appear as surface runoff. Rivers and other forms of surface water supply about 97% of the country's total water needs while ground water accounts for the rest. In some States, notably Perlis and Kelantan, ground water contributes significantly (30-70%) to the State's water budget. The water availability per capita in 1990 was estimated to be 26.3 Ml/year/person. Thus in comparison with some African countries, Malaysia is considered to be not under water stress (cf. Falkenmark 1989).

The present annual domestic, industrial and irrigation water demand is about 11.6×10^6 Ml (ca. 2% of annual renewable freshwater resources) and has been projected to increase to 13.5×10^6 Ml for 1995 and 15.2×10^6 Ml by the year 2000. On the whole, the total daily water demand is approximately 4,979 Ml while production capacity is approximately 6,513 Ml. Table 2 shows, for 1990 and 1995, the urban and rural water supply coverage in Malaysia in terms of percentage of population (%) as well as the water supply capacity and demand in Megalitres per day (Ml/d) with the corresponding population figures. Today, about 80% of the rural population and 100% of the urban population have access to access to safe drinking water. These same figures also reflect the population's access to sanitation services both in the rural and urban areas respectively. The cost of water production versus Gross National Product in Malaysia, estimated in 1985, was 0.05 sen/litre (or \$US0.18/m^3), giving a GNP per capita value of RM5.08/person (or \$US2.03/person) (WHO, 1987). These figures are undoubtedly higher today.

Under two water agreements with Malaysia, Singapore currently draws a total of 1,500 Ml of water a day from the State of Johor, Malayisa. Despite the apparent excess capacity, there are still States (e.g. Kedah and Malacca) which are experiencing water shortage owing to local geographical barriers and disruption of the hydrologic cycle in degraded drainage basin areas. Certain States had in the past resorted to cloud-seeding efforts to overcome acute water shortage problem but so far the outcomes were disappointing. A study conducted in 1988 found that 43% of the treated water is lost through leakage caused by factors such as pipe deterioration, inferior materials, poor workmanship, earth movement, excessive pressure, irresponsible public usage and water theft. Various remedial works are currently in progress. The target is to reduce such unaccounted-for water losses to at most 32% by 1995. This target figure is still high though not uncommon. Hence it should be further reduced. A global range of such figures is 25-50% (see Gleick, 1993).

Upgrading of water supply and drainage systems

In 1982, the Malaysian Government commissioned a national water resource study with the help of a team of consultants from the Japan International Cooperation Agency (JICA). The study produced a master plan on water resources for up to year 2000. The Malaysian Government updates this plan from time to time to meet the anticipated demand for water beyond that date.

Some States like Penang have developed their own Master Plan for Drainage. Penang consumes more than 380 Ml of water per day. To cope with increasing water demand, the Penang Water Authority upgraded, at a cost of RM10 million, the working capacity Sg. Dua water filtration plant which can now treat about 750 Ml of water a day. Work on the new multi-million dollar Teluk Bahang dam in Penang island would begin this year. The new dam would have a water storage capacity of 15×10^3 Ml, which should meet the State's water need up till the year 2010.

The Perak State has completed the construction of 9 elevated reservoirs in the Krian district, each costing RM1 million. One underground reservoir in Kamunting and another in Gunung Semanggol were also built. All the 11 reservoirs were built under a RM52 million privatisation scheme. Furthermore, a new dam across Sg. Kinta has also been proposed. This dam is to increase the Perak's water supply by 25%. The dam, costing RM150 million, is to be built in year 2000 once approved. The project will also include a water treatment plant at Tanjung Rambutan which will be capable of treating 228 Ml of water. This dam should meet Perak's water demand until year 2010.

Across the nation, efforts are now being made to promote inter-basin and inter-state water transfer, in an attempt to overcome the mismatch between water-source distribution and areas of high water consumption. This form of water-use enhancement is likely to become widespread in the future, with the Malaysian Government playing a central coordinating role. At present, water supply and its management come under the jurisdiction of the respective State Governments in accordance with provisions stipulated in the Federal Constitution.

As much as 93% of the $4,880 \times 10^3$ ha of cropland in Malaysia is rainfed. Stored water from various irrigation schemes accounts for the rest. In accordance with the trend of economic restructure, water need for irrigation is anticipated to decline by 5% from 1990 to 1995. Nevertheless, in 1994, the agriculture sector utilised 78% of the country's water resources. Unlike industrial and domestic water demands, agriculture does not need stringently treated water. Waste water treatment and recycling for reuse can be done at a lower cost. This sensible practice is now strongly advocated. About 15% of the water used in Muda Agriculture Development Authority (MADA) area (125,000 ha) in Kedah is recycled.

Meeting increasing hydro-power demand

According to IWPDC (1991), the installed hydro-electric power (HEP) capacity of Malaysia in 1989 stood at 1,580.5 MW. The amount generated in 1989 was 5,800.62 GWh/yr while the exploitable potential was 108,600 GWh/yr. More recent estimates indicate a potential HEP energy of 1,123,000 GWh/yr with a renewable HEP resource value of 29,000 MW/yr. About 70% of this potential energy is located in Sarawak. Today, the hydro-energy output capacity of peninsular Malaysia alone is 1,920 MW. The country's electricity consumption and projected requirements for the future are shown in Table 3. Malaysia's industrialisation and urbanisation programmes now impose greater demands on the nation's power (electricity) supply grid system. This in turn imposes an added strain on the nation's water resources. Several plans to upgrade the power delivery capacity of the existing hydro-electric power (HEP) stations have been approved for implementation. At the same time, several new HEP dams will be built.

In the case of the Kenyir hydro-power dam in Terengganu, the national energy company Tenaga Nasional Berhad (TNB) plans to reactivate and upgrade two diversion tunnels and install two turbines at the Kenyir HEP dam which can generate 200 MW of electricity. It is also studying the feasibility of constructing another HEP dam (200 MW) in Tasik Kenyir.

Currently under construction in Kelantan is the Pergau Dam. The whole scheme comprises a 74m high earthfill dam, an ungated spillway, an underground power station, a reregulating dam, 24km of aquaduct tunnels and other structures. The reservoir has a gross storage capacity of 62.5×10^6 m^3 and a surface area of about 430 ha at full supply level. The underground power station is capable of generating 600 MW of electricity with an avaerage annual energy output of about 520 million kWh per year of which 340 million kWh is firm energy. This station will function as a peaking station, supplementing (ca. 5 hours a day) the nation's daily needs during peak periods.

The Beris Dam in Sik, Kedah awaits construction this year at a cost of RM140 million. The dam can generate up to 100 MW electricity and will supply water for the region's industrial and agricultural needs.

The latest addition to the list of new dams is the Bakun Dam. This hydro-power project which is to be carried out in the upper Sg. Rejang river basin in Sarawak costs RM15 billion. This once shelved (1990) but now revived (1994) mega-project will occupy 69,500 ha of forest area, a greater part of it is already degraded by logging activities and shifting cultivation while the rest is relatively pristine and rich in wildlife. The project will also displace the people of the native tribes of Kenyah, Kayan, Lahanan, Ukit and Penan from their home land scattered in the upper Sg. Balui (a tributary of Sg. Rejang) area. The water catchment area for the Bakum dam across the Sg. Rajang is 1.5 million ha. The full HEP generating potential of the Sg. Rajang is reported to be in the range of 16,000-20,000 MW. The initial targeted output of the dam, scheduled to be ready in the year 2005, is 2,400 MW.

One problem that is beginning to confront the nation's HEP energy supply system is the threat of water input shortage. A case in point is the Temenggor Dam in the State of Perak. This dam supplies 33% (ca. 207 Ml/d) of the treated water of Perak. It also generates about 340 MW of electricity daily. The recently encountered serious drop in water level to nearly the critical minimum mark has forced both the Perak Water Board and the TNB to take various contingency measures to avert water disruption. These included a reduction in the volume of water released, installation of pontoon pumps and cloud seeding for rain.

This problem of diminishing water supply capability in existing dams is also faced by several other States owing to watershed degradation caused by ill-managed logging and forest clearing activities. Logging and forest clearing in the Ulu Muda catchment has affected water supply to the Pedu and Muda dams. The dams supply water to thousands of hectares of rice farms under the MADA irrigation scheme.

The TNB is currently carrying out feasibility studies on alternative supplementary energy sources for Malaysia. One such option currently under evaluation is wind-power generation on certain off-shore islands in the country. This strategy of "hedging your bets and spreading the risks" is a sensible one.

Water Use and Misuse

Water use in Malaysia can be categorised into domestic water supply, industrial water supply, irrigation water supply, supply to crops, livestock and wildlife, hydro-power generation, navigation (transportation), waste disposal (sewerage), river-flow and urban drainage control, flood mitigation, prevention of seawater-intrusion, recreations and aesthetics (aquascaping).

The rapid pace of socio-economic development has inevitably brought about adverse changes in the natural environment. Foremost among these are the impacts on the hydrology and ecology of Malaysian rivers. Impacts on man-made dams and ricefield ecosystems are also felt.

The level of many river beds in Malaysia has been raised by siltation caused by improper drainage basin development for large-scale projects including urban housing schemes. The negative consequence, when translated into economic terms, means having now to pay the price for degraded water quality, reduced drainage capacity, flash floods, loss of fish breeding habitats and so on. A flood mitigation plan proposed by the Japan International Cooperation Agency (JICA) for Penang island - estimated cost RM260 million - will involve extensive improvement and diversion work on the Sg. Penang drainage system and the construction of dual-purpose retention ponds and water pumping stations. The frequent occurrence of flash floods has also prompted the Federal and Perak State Governments to allocate RM5 million to alleviate flood problems in the Taiping (Perak) district. The Drainage and Irrigation Department (DID) has set aside RM9.5 million to deepen and widen several rivers in Malacca this year; RM5 million to be funded from the Malacca State Government the rest from the Federal Government.

Rivers and man-made waterways in Malaysia are also not spared from pollution by domestic garbage, livestock and farm wastes, raw sewage and limestone quarry sludge, as well as untreated or poorly treated chemical and organic wastes from palm-oil, rubber and wood-based industries. The Department of Environment (DOE) has to date monitored no less than 87 rivers nation-wide. It has ascertained that at least 43 of the rivers polluted, some are on the verge of becoming biologically dead. Cases include the Sg. Cuping (Perlis), Sg. Pinang and Sg. Juru (Penang), Sg. Raja Hitam, Sg. Sepetang, Sg. Kinta, Sg. Tumboh (Perak), Sg. Kelang (Kuala Lumpur), Sg. Sepang (Selangor), Sg. Batang Benar (Negri Sembilan), Sg. Melaka (Malacca), Sg. Seriong (Johor), and Sg. Sarawak (Sarawak). Six rivers have been classified as being very polluted. These are the Sg. Sepang (Selangor), Sg. Duyong (Malacca), Sg. Buloh (Selangor), Sg. Kelang (Selangor), Sg. Ibai (Terengganu) and Sg. Juru (Penang). The DID has set aside RM160 million to rehabilitate these 6 rivers. The rehabilitation programme includes activities like improving river banking and river management, cleaning up toxic wastes, support water quality research, stricter enforcement of related laws and regulations. Rivers in Sabah are generally clean. In Sarawak 8 out of 20 rivers monitored were found to be slightly polluted.

River pollution has reduced the local fish fauna and diminished the fisheries potential of the rivers. According to the Ministry of Agriculture, Malaysia has 52 freshwater fish species which are of commercial importance. Over the last 20 years, the Sg. Gombak (Selangor) has lost about 60% of its indigenous fish fauna which once totalled 27 species. This is a consequence of excessive land clearance in the drainage basin resulting in river bank erosion and severe silt pollution. The Sg. Perak has lost 6 out of 9 commercially important riverine fish species during the last 15 years. In the Tanjung Tualang area, pollution of the Sg. Kinta (Perak) and its tributaries by suspended solids has reduced the harvest of the cultured giant prawn *Macrobrachium rosenbergii* by 50% over the past ten years.

Sediment pollution of reservoirs is another major cause for concern in Malaysia as it leads to silting of dams. This problem occurred at the 50-ha Ringlet Reservoir in the Cameron Highlands (Pahang) and has prompted the national power company, Tenaga Nasional Berhad (TNB) to construct a desander across the Sg. Telom at a cost of RM3 million. This reservoir was also plagued by water hycinth infestation in mid-1989; clearing this weed incurred a cost of RM200,000.

Flooded ricefield habitats receive pollutants and excessive use of pesticides (e.g. gramaxone, thiodan, malathion, gama-BHC and sevin) has resulted in declining fish yields from ricefields. The problem of low fish yield is of course also compounded by the double-cropping practice which shortens the rice-growing season and limits the production of fish in the culture system.

Wastes in waterways

In the urban centres and industrial estates, the problem of waste disposal rivals that of water supply. In the Kuala Lumpur area alone, some $18x10^5$ kg of wastes are generated per day. An estimated $65x10^3$ kg of garbage are dumped daily into the Sg. Kelang in Selangor. A total of 45 pollutants was once reported to enter the Sg. Pinang in Penang. In Penang this year, the Sungai Juru Pollution Prevention Committee has been provided with a grant of RM212,000 from the central Government to clean up the Juru river. Nineteen of the 56 food and beverage firms which were found polluting the rivers were taken to court for dumping wastes into waterways. They failed to respond to DOE's warnings and compound fines. The names of 56 companies were also made public. This action came under the Environmental Quality (Sewage and Industrial Effluents) Regulation (1979) of the Environmental Quality Act (1974, revised in 1985).

In the long-term, the conventional ways of handling solid waste and wastewater are apparently unsustainable. New waste disposal and/or recycling technologies are badly needed to meet present loads. In Malaysia, the search for efficient, cost-effective and environmentally friendly waste treatment and disposal facilities is currently underway. One such scheme, estimated to cost RM 76 million, proposed by a foreign company is under consideration by the relevant government authority. The bioreactor-based process treats and disposes wastes and produces methane and organic manure (bacterial sludge) as end products.

The dumping of toxic wastes into the waterways is another problem of great concern. Most of the factories in Malaysia lack effective waste treatment and disposal facilities. To this end, a Heavy Metal Offsite Recovery Facility (HMORF) is being set up by the Waste Management Centre (WMC) in Malaysia to service the metal finishing industry. The facility will provide a zero discharge wastewater treatment system to semiconductor and electro-plating manufacturers. The HMORF will complement the central integrated waste management (toxic landfill) facility which is to be built by the Danish-Malaysian consortium at a 60 ha site on Bukit Nanas, in the State of Negri Sembilan. The Selangor State Government is also planning to set aside a 20 ha site in the Air Hitam forest reserve for a scheduled waste disposal site to be used by factories throughout the State.

Toxic waste from industries falls under the Atomic Energy Licencing Act (1984) and the Environment Quality (Scheduled Wastes) Regulation 1989. Up to 1994, 18 manufacturers have been prosecuted for indiscriminate dumping of untreated toxic wastes to rivers. Todate, 17 industries using radioactive materials which can produce waste have been identified in Malaysia.

National Water Quality Management Programme (NWQMP)

If a river is reduced to a series of stagnant pools or to an open sewer, then the economic benefits obtainable from its use will not offset the inevitable extra cost incurred, for example, in public health control, additional water purification tasks, contingency water supply measures during dry spells, and loss of recreational and amenity values and tourism revenues. The Sixth Malaysia Plan has accordingly allocated funds for the implementation of several major programmes aimed at:-

- promoting the development of waste disposal facilities for industries and the adoption of environmentally sound technologies and processes.
- minimising the adverse impacts of pollution, erosional sedimentation from development activities.
- enforcing fully the Environmental Impact Assessment requirement for projects which have the potential of damaging the environment.

The Department of Environment (DOE) plays a key coordinating role in river water quality monitoring and management. In 1978, DOE initiated a nation wide water-quality monitoring programme (NWQMP). The approach adopted was one of integrated multidisciplinary study at the river basin level. The programme began with the establishment of the study sites on 33 rivers in 13 river basins. Since then this number has increased significantly. River water-quality data are thus available since 1978 for peninsular Malaysia and since 1980 for Sabah and Sarawak. Many of these rivers were polluted, in particular by discharges from palm-oil and rubber factories. In 1985, the DOE commissioned a follow-up study to develop water-quality criteria and standards for Malaysia. Phase I (1985-86) of the programme involved an extensive water-quality standards study. The targeted beneficial uses included domestic water supply, agricultural use, fisheries and aquatic life propagation, livestock drinking, and recreation. Water-quality for over 120 physical/chemical and microbiological parameters were formulated through a review of international and local literature. A set of interim national water-quality standards (INWQS) was derived from these criteria after taking into consideration the environmental baseline levels and technological and socio-economic factors. The INWQS define six classes of water quality, each targeted for a specific level of sustainable beneficial uses. This study also recommended a river classification method for use in the next phase of study. Phase II (1988-89) dealt with the classification of six selected river basins based on the recommended INWQS. A computerised integrated river basin information system (IRBIS) was developed subsequently for DOE. The user-friendly IRBIS system provides a rational database, including information on catchment characteristics, pollution sources and river water quality. The data were suitable for Geographic Information System (GIS) application. The Phase III (1990) study focussed on the review of the status of effluent discharges to ambient water sources and compliance with the existing Effluent Discharge Standards. Under Phase IV (1992-93), another ten river basins were classified accordingly, based on physical, chemical, biological, hydrological, land-use and socio-economic characteristics of the river basin. A total of five universities and one private consultancy firm were involved at various implementation stages of this whole project. As a whole, this river classification programme has enabled DOE to set its strategy and priority in water quality management.

National "Love Your River" Campaign

The Dublin Conference on Water and the Environment (see Young et al., 1992) called for fundamental new approaches to the assessment, development and management of freshwater resources, which can only be brought about through political commitment and involvement from the highest levels of government to the smallest communities. The need for public support and public awareness was highlighted repeatedly at this conference. All protection, conservation and management efforts will come to nought unless they are backed by public support. Indeed, while the burden of ensuring a steady water supply is a governmental responsibility, the public has the responsibility of ensuring rational water use.

In order to educate the Malaysian public on the ecological and landscape values of natural rivers, a year-long, nation-wide "Love Your River" community awareness campaign was launched by the DID in 1994. The project, costing RM1 million, was targeted at all members of the society, in particular the youths in schools and local riverine communities in all States. Some States have since initiated their own river beautification campaigns. The Malacca State Government recently allocated RM1 million to beautify Sg. Malim, Sg. Duyung and Sg. Melaka. There is also indication that certain town planning policies are gradually changing to incorporate and to inculcate the "love your river" spirit amongst members of the local communities.

Water Resources Management Needs

According to Falkenmark and Lindh (1993), a culture's prevailing use of its water resources goes through three phases, each reflecting a different stage of development of the country. On the basis of their classification, Malaysia is considered to have advanced well into Phase II, where active water exploitation occurs involving dam-construction and irrigation projects. There is also the expected need for inter-basin water transfer to ensure even distribution. A situation like this implies unquestionably an urgent need for the wise and efficient use of water. Unrestrained water demand will outstrip the amount that can be sustainably provided within the country. As a matter of fact, the imminent need for "demand management", one of several characteristics of Phase III, is already being felt. This form of management is aimed at making better use of existing water supplies instead of automatically investing in a new supply capacity to satisfy projected future requirements. In short, a change from extensive to intensive use of water should take place. It entails treating water more like a commodity, as opposed to an automatic public service (see Winpenny, 1994). Water has always been underpriced compared to its real cost of provision. Often the environmental costs incurred in the use of water are not reflected in the price. Such costs are absorbed by the government and not passd down to the comsumers.

Management at a cost

According to Ackers and Thompson (1987), although man may alter the rate of change or induce changes that would not have occurred naturally, many under-developed or developing nations are too near the borderline of hunger and poverty to feel able, politically, to invest in environmental protection if it is at the expense of food and power. The environmental cost of water supply schemes are increasing each day. These costs arise both in supply (e.g. depleting aquifers, damming rivers, destroying wetlands) and in the disposal of wastewater (runoff, effluent, sewage). Bhatia and Falkenmark (1991), in their survey of similar World Bank schemes, have estimated that the cost of producing a unit of water for a new project is often two or three times that of the current one. The cost for environmental protection is likewise high and ever escalating. In the case of Malaysia, whatever that is being done in the name of development is done with the knowledge of the need to pay a price the nation can afford for both the present and the future. Underpinning this of course is the obvious need to balance the goals of socio-economic development with the maintenance of a sound environment. Only through sustainable use of our renewable resources coupled with the sound management of its natural environment can we pave the way for the continual growth of the Malaysian economy. As such, the nation cannot afford to discount environmental values from economic analysis.

Being aware that water is a precursor and controlling factor for socio-economic development, the water resources sector was given high priority support by the Federal Government under the current Sixth Malaysia Plan. In fact, water resources development has always been one of the principal elements of every one of the country's past development plans. About 7% of the total national budget has been allocated for the water resource sector under the Sixth Malaysia Plan. This sum represents a 40% increase over the amount spent (RM 2,667.2 million) under the Fifth Malaysia Plan. Water supply, sewerage and urban drainage are the three main developmental foci of the Water Resources Sector. These three areas have been allocated operational funds amounting to 75%, 15% and 10% of the sector's total budget respectively.

As reflected in the examples cited above, the main thrusts of development call for both medium-and long-term undertakings. These include the development of new water supply sources and distribution systems; upgrading of the efficiency and capacity of existing water treatment facilities; provision of centralized sewerage systems and communal sewage treatment plants; and preservation of water quality and quantity of the existing sources and waterways by implementing appropriate pollution control and abatement measures and improving drainage. To address the problem of uneven distribution of water, projects on inter-state and inter-basin water transfers are being implemented. All these are aimed at ensuring that the anticipated increasing demand for water especially in new growth centres will be met through increased supplies. In an attempt to complement the Government's efforts, a working mechanism has also been evolved to encourage participation of the private sector in the development of both water and energy resources in the country.

Under the Sixth Malaysia Plan, a management information system on water resources is to be developed. With regards to other resource management instruments, apart from relevant incentives, the institutional setting especially the legal provisions will be streamlined for greater focus and also to provide for cost-effective resource development. This will also provide the necessary legislative support for water pollution control and the protection and conservation of all water catchment areas for water quality management is just as important as water quantity management.

Environmental protection and pollution control

Protection, conservation and management will of course come to nought unless they are backed by appropriate and effective legislative constraints. The responsibility of environmental management in the country falls on the Department of Environment

(DOE), Ministry of Science, Technology and Environment. The DOE was established in 1976 to give form and substance to environmental management. The Environmental Quality Act (1974) of Malaysia provides the legal tool and mechanism for the regulation of all pollution related activities. It enables the development of pollution control legislation as and when required. Some of the water resource related legal provisions already in existence are as shown below:-

- Federated Malay States Silt (Control) Enactment (1922)
- Environmental Quality Act (1974, amended 1985)
- Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulation (1977, amended 1982)
- Environmental Quality (Prescribed Premises) (Rubber) Regulation (1978, amended 1980))
- Environmental Quality (Sewage & Industrial Effluents) Regulation (1979)
- National Forestry Act (1984, amended 1993)
- Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order (1987)
- Environmental Quality (Prescribed Activities) (Scheduled Wastes & Disposal Facilities) Regulation (1989)

Malaysia is apparently well equipped legislatively to protect its environment. It is hoped that with increased environmental awareness, new or revised legislation intended to protect the environment, especially from the repercussions of a particular detrimental action will be adopted. What needs to be further strengthened, however, is the environmental monitoring and law enforcement arms of DOE. There is a need for more trained personnel, as the control of pollution demands continual vigilance.

Some ecological considerations

1) Large reservoirs in rainforests

The Malaysian Government is often confronted with dilemma of having to reconcile the nation's immediate socio-economic developmental needs with long-term sustainability in terms of an ecologically sound and culturally acceptable environment. It often faces intense critism from some conservationists claiming that some water-based projects, in particular large dams, are inevitably destructive, and that the socio-economic benefits obtained from them do not counter-balance the long-term ecological and indigenous cultural losses. Indeed, ecological and societal disruptions are inevitable in all dam building projects. Yet without dams and other forms of impoundments, there are few management options through which to augment low flows or generate electricity in a cost-effective and "clean" manner. Some dams can act as settling ponds, improving downstream water quality. New dam projects also mean new employment opportunities. In the majority of past cases, due consideration of urgent socio-economic needs or the implications and costs of not implementing the proposed project have out-weighed the plea for environmental preservation in the final decision making. One should however bear in mind that decisions on developmental costs are not simply a matter of social or economic preference, but have environmental and moral dimensions as well. It is the ecosystem type that sets the limits as to what extent its inherent resources can be used in a sustainable and non-destructive manner.

Although dams can realize considerable economic and socio-cultural benefits, nevertheless their construction must be based upon sufficient knowledge of the river and its catchment to allow for due consideration of the long-term ecological consequences. Dams are highly individualistic. Different responses can be induced by the application of the same stimulus (Petts, 1984). The spatial extent of the effects can be considerable, some of which only become apparent after a long period. Dams across rivers have traditionally be seen by river ecologists as a disruption of the ecosystem (e.g. Ward and Stanford, 1979). Dams are also excellent sediment traps, especially in the tropics. There are many reservoirs in existence in the world today which are performing sub-optimally because of exogenous sediment loading. Sediment deposition in reservoirs leads to loss of water storage and consequent loss of yield, increased floods upstream, blockage of intakes, abrasion of turbines, and downstream problems involving both aggradation and degradation. For hydropower projects, loss of storage may not be too serious for the dam still provides the head necessary to generate power although the periods over which the turbines can operate are reduced and the risk of blockage of intakes is increased. For a water supply scheme, any loss of live storage increases the risk of supply failure and this is often unacceptable. Therefore when either evaluating an existing reservoir or planning a new dam project, sediment-based reservoir half-life studies are required to predict the loss of storage as a function of time (see Pitt and Thompson, 1984). An interesting and revealing account of dam developments in Africa and their environmental impacts has been given by Massinga (1992).

About 18.5 million ha (56.3%) of Malaysia's 32.86 million ha land area is covered by tropical rainforests. Many of the natural hill forests are located in water catchments. Thus, the construction of dams invariably causes destruction of natural rainforests and displacement of their inhabitants. On the basis of its richness in forest plant and animal species, Malaysia has been identified as one of twelve megadiversity countries in the world (McNeely, 1990). Forests also play an important role in the hydrologic cycle and in maintaining the water balance of drainage basins. In Malaysia, natural forested land has 38% water retainability, whereas rubber estates have 27% and oil-palm estates only 16%. Tree plantations (rubber, oil-palm, cocoa and coconut), occupy about 4.2 million ha. Clearly, in terms of the water retaining capacity, tree plantations are poor substitutes for natural rainforests. The Sixth Malaysia Plan has prioritized goals and provided funding for the implementation of several major programmes aimed at :-

- sustaining 12.73×10^6 ha of land area as permanent forests and 1.16×10^6 ha as national parks, nature reserves, habitats and wildlife sanctuaries.
- rehabilitation of 101,300 ha of logged-over areas annually and sustaining 1.65×10^6 rehabilitated areas as permanent forests as well as enforcing rules on the destruction of mangroves and control of rivers and water quality standards.
- implementaing agro-forestry projects, involving some 90,000 ha of land, and planting trees in unused agricultural land and beautifying the natural surroundings of urban areas.

2) Rehabilitation of over-channelized rivers

Rivers are our natural resources. They are also sensitive to imposed stressed. Therefore we need to ensure that the basic functions which make our rivers valuable natural resources are maintained. A significant number of rivers or river segments in Malaysia have been channelized for purposes of flood protection, drainage improvement and the prevention of river-bank erosion. Such activities disrupt the equilibrium of the natural fluvial ecosystem. The main consequences of channelization include a reduction in natural habitat types by elimination of pools, riffles and irregular channel configurations and flow obstructions; increased water temperatures due to removal of riparian and in-stream vegetation; river-bed and bank erosion; and downstream flooding and sedimentation (see Maksimovic et al., 1993). The combined effects of these changes produce a wide range of biological impacts, principally upon benthic invertebrates, fish and aquatic vegetation. Over-channelization can result in the lowering of the water-table in adjacent floodplains, which in turn can affect people's livelihood as well as the plants and wildlife inhabiting the area. There are methods for mitigating and enhancing channelized river segments against such adverse effects to accelerate biological recovery (see Brookes, 1988).

3) Swampland conversion for aquaculture

Scott and Poole (1989) reported that out of the 37 wetland sites (predominantly mangroves and peat swamps; total area: 31,200 km^2) in Malaysia, 10 sites are threatened by human activities. McVey (1988), in his survey of the loss of mangroves to aquaculture throughout southeast Asia, estimated that the area of loss to aquaculture as a percentage of total mangrove area is about 9% for Malaysia. Swampland plays a vital ecological function in the environment. It is a vital link in nature's hydrological system. Swamps store water. In coastal areas, they check saline intrusion into groundwater aquifers located underneath the peat layer in swamps. It is this freshwater wedge which ensures a supply of water for drinking and washing to local communities and also irrigation water for agriculture. Peat swamps and their forests are rich in biodiversity. Some have tourism potential. In the absence of adequate ground-water recharge, excessive abstraction of water from the aquifer layer, e.g. for large-scale aquaculture pusposes, can result in effects like subsidence of underlying clay-rich earth, coastal sandy soil erosion, water supply shortage and water quality degradation (see Foster, 1993). Aquaculture projects in swamplands are generally only economically viable for a limited number of years. Potable groundwater exhaustion, formation of acid sulphate soils and pollution are some of the common causative factors. Such worked-over swamplands seldom regain their original ecological identity.

One reason for the popular conversion of swamplands for aquaculture is because there is little awareness, on the part of the decision makers, of their other inherent properties and economic potentials as a resource? Indeed there are other forms of development which are just as economically viable, more ecosystem friendly, hence more sustainable. Conversion to nature parks is one such example. Admittedly, decisions not to drain specific swamplands but to manage them for their nature conservation or landscape value require valuation of their other inherent properties. This is not an easy task owing to paucity of information on such ecosystems, their functions or their possible responses to different forms of developmental pressures. Those concerned for swampland conservation should develop convincing criteria by which the costs and benefits of conservation and of such conversion can be evaluated. Once this is done, the value of swampland preservation will most likely measure up much better than is commonly thought. Meanwhile, people should be made to appreciate the true socio-economic, biological and scientific importance of swamplands.

Knowledge gaps and R&D needs

How much of the available freshwater can realistically be mobilized over the medium term? In what ways can we further ensure environmental sustainability of our freshwater systems? The answers lie of course in how much we already know of our existing freshwater resources and in our technical competence and management capabilities.

The management of our aquatic resources and ecosystems requires the pragmatic application of scientific knowledge and key data to cope with complex, dynamic, and ever changing systems which are only partially understood. This knowledge has to be gained if it is to provide value-judgements in making management decisions. According to Luiten (1995), three basic elements are needed for an optimal policy on water management within a catchment: verifiable objectives, knowledge of the water systems and sufficient measures. If these elements are not optimal, then the management is not optimal in effectiveness. It is the job of scientists of the relevant disciplines to quantify how far these aquatic resources can be exploited yet still remain functionally acceptable. It is the responsibility of managers to ensure that exploitation is not taken beyond those limits. Only then can water volumes in excess of environmental requirements be allocated to users without fear of permanent damage to the resource. The looming threat of global warming also means that the various economic and political structures in place for handling our finite water resources will have to be made more resilient than they presently are.

Malaysia is still in need of high-level manpower specialised in science and technology and in research and development (R&D). This inadequacy is currently being redressed by the Government. Meanwhile, we need to promote further institutional cooperation to improve our understanding of freshwater systems in the context of environmental change and change in human needs. Thus issues on water availability (quantity and quality), aquatic ecosystem integrity, and public health and safety can provide the framework for R&D efforts. Such efforts should aim at seeking information which are scientifically acceptable, socio-politically relevant, enlightening to the decision makers, and applicable by the resource managers. This calls for the drawing up of a proper research agenda which, other than identifying and prioritising research directions, should include man power training and development of new management tools and environmental protection technologies. A sum amounting to 1.1% of the nation's total development budget for the period 1986-1995 has been allocated by the Malaysian Government for R&D work. It is hoped that this emphasis on R&D funding will continue into the Seventh Malaysia Plan and that a significant portion of this R&D budget could be mobilized for water resources related research and development work.

A new contributary role of the private sector

The coming years will see greater participation of the private sector in the joint development of Malaysia's economy. An increasing number of private companies in the country are displaying a greater awareness of the need for environmental protection. Are all companies, both local and foreign, prepared to integrate environmental issues into their businesses in order to reduce the conflict between sustainability and profitability? Environmental sustainability is not just something we should be seeking for its own sake, but also because it will increasingly be part of the price of access to the marketplace. The contribution from the business community towards meeting the sustainability challenge is necessary and much welcome. A few of the larger multi-national companies have clearly already initiated their own plans of action towards this end. Some could do with some additional guidance from those who could provide it. For example, we should formulate an action programme which would put across the key messages to small and medium-sized enterprises. As a start, relevant seminars could be organised for the benefits of the business leaders of tomorrow, allowing them to bring added value to their organisations and the economy through their appreciation of the linkages between business and the environment. Such seminars will offer a unique opportunity for small groups of senior executives from a wide range of business sectors to tackle these issues at a highly strategic level, perhaps even in consultation with leading national and international figures in the field. To the participants, many problems, whether common or unique, can be given new perspective. They become involved with other businesses, hear their concerns and problems. It focuses their minds to the issues of integrating the environment into the business. The real sense of commitment to the sustainable development agenda, and the crucual role that business leaders have to play in it, can be powerfully reinforced in such seminars.

Concluding remarks

It cannot be denied that the quality of life in Malaysia has improved very significantly as a result of the nation's socio-economic endeavours. For such development to remain sustainable in the future, water and land management efforts must be environmentally sound. As far as water resources (including hydro-energy) development is concerned, the options are limited as described above. Unless and until there are other equally or more economically viable alternatives, it is likely that the same pattern of water-based resource development will continue to be practised, hopefully with acquired wisdom. In this respect, critical post-audits of what in reality has happened in the trail of large-scale development projects undertaken so far within the country should be carried out so that similar mistakes will not be repeated. Case history are important for both reactive and proactive management.

According to Meadows et at. (1992), a sustainable society is technically and economically feasible, provided the transition to a sustainable society is made by carefully balancing our long- and short-term goals and emphasizing equity and the quality of life. Thus, much depends on our present and future actions. The nation's will and commitment towards this end are clearly reflected in the first statement of Malaysia's Vision 2020 Declarations which states that "In the persuit of economic develoment, Malaysia will ensure that her invaluable natural resources are not wasted. The land must remain productive and fertile, the atmosphere clear and clean, the water unpolluted, the forest resources capable of regeneration.". Only through better management now, sensitive planning in the future and undoing at least some of the damage of the past can we ensure that our vital water resources remain the most valuable legacy we leave behind for the future generations of Malaysia.

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Table 1: Geoclimatic features of Malaysia.

Location	Latitude	-	0° 60' - 6° 40'N
	Longitude	-	99° 35' - 119° 25'E
Climate	Mean relative humidity	-	80%
	Annual mean temperature	-	26.7 °C
	Diurnal temperature range	-	8.9 °C
	Temp. drop/100 m climb	-	0.6 °C
	Annual rainfall	-	2000 - 5000 mm
	Raindays per year	-	150 - 200 days
	Daily sunshine hours	-	8 hours
Land Area	Peninsular Malaysia	-	131,235 km^2
	Sabah	-	76,115 km^2
	Sarawak	-	124,499 km^2
	Total	-	331,849 km^2
Dominant Natural Vegetation		-	Tropical rainforest
Natural forest area		-	18.5 million hectares (56.3% of total land)

Table 2: Water supply situation in Malaysia for 1990 and 1995

(i) Percentage of total population coverage (%)

	Urban		Rural	
	1990	1995	1990	1995
Peninsular Malaysia	96	98	66	79
Sabah	100	100	52	80
Sarawak	98	100	47	74

(ii) Water treatment capacity and supply (Ml/d)

	Treatment Capacity		Water Supply	
	1990	1995	1990	1995
Peninsular Malaysia	5,587	9,062	4,334	6,845
Sabah	567	708	363	488
Sarawak	388	709	282	433
Whole nation	6,542	10,479	4,979	7,766

Source: Water Resources Sector, Sixth Malaysia Plan (1991-1995)

Table 3: Malaysia's electricity supply and projected requirements up till 2010.

(i) Electricity supply capacity

Year	Peakload (MW)		
	Peninsular Malaysia	Sabah	Sarawak
1982	1,430	100	90
1990	1,900	315	260
2000	6,750	840	595
2010	15,000	1,885	1,160

(ii) Energy demand

Year	Energy Demand (GWh)		
	Peninsular Malaysia	Sabah	Sarawak
1982	8,630	535	450
1990	17,500	1,780	1,340
2000	40,800	4,900	3,180
2010	91,500	10,900	6,180

Sources: TNB, SESCO, SEB