Sultan Abu Bakar Dam

Key Issues:
4-Reservoir Sedimentation

Climate Zone:
Af: Highland Tropical Humid

Subjects:
- Sediment Management

Effects:
- Prevention of sediment entering into the Telom Tunnel
- Prevention of sediment accumulation in Ringlet Reservoir

***Project Name*:** Cameron Highlands Hydroelectric Scheme
Country: Pahang, Malaysia (Asia)

Implementing Party & Period
- Project: Tenaga Nasional Berhad (TNB)
1978 (Completion of construction) -
- Good Practice: Tenaga Nasional Berhad (TNB)
1970's -

Key Words:
Sediment, Land Use Change, Desilting Work, Desander (Settling Basin)

Abstract:
Since the early 1970s, mitigation measures for sedimentation have been carried out periodically at various locations in the Cameron Highlands Scheme to minimize its impact on the operation and maintenance of the five hydro stations. These measures include construction of a silt retention weir, pumping of sediment, and de-silting of tunnels, and have successfully reduced sediment inflow into the reservoir.

1. Outline of the Project

The Cameron Highlands Hydroelectric Scheme is situated in the northwest of the state of Pahang, Malaysia. It was constructed in the period between 1957 and 1964. The scheme consists of four small run-of-river and one storage hydro projects and has five power stations.

The main features of the storage project beside the 100 MW underground power station are a 40-m high concrete buttress dam with gated spillways, four side-stream diversion schemes of Sg. Plau'ur, Sg. Kial, Sg. Kodol, and Sg. Telom, some 20 km length of tunnels, the Bertam Intake and other appurtenant structures. The major specifications and the layout plan of the scheme are shown in Table 1, Table 2 and Figure 1 respectively.

Table 1 Specifications of the Sultan Abu Bakar Dam (the Ringlet Reservoir)

Gross Storage	[MCM]	6.7
Usable Storage	[MCM]	4.7
Dam Height	[m]	40
Dam Type	[m]	Concrete & Rockfill
Normal Water Level	[EL. m]	1,068.3
Low Water Level	[EL. m]	1,065.3

Table 2 Specifications of the Hydro Projects

item		Kampung Raja P/S	Kuala Terla P/S	Robinson Falls P/S	Habu P/S	Sultan Yussuf P/S
Max. Output	[MW]	1 x 0.8	1 x 0.5	3 x 0.3	2 x 2.75	4 x 25.0
Max. Discharge	[m^3/sec]	1.253	1.718	0.173	4.347	5.493
Rated Head	[m]	80	37	235	91	573
Gross Head	[m]	83.8	39.3	243.7	97.5	587.3
Annual Generation	[GWh]	6	5	7	32	320
Operational Year		1964	1964	1959	1964	1963
Intake Water Level	[EL. m]	1,378.3	1,284.7	1,410.6	1,165.7	1,070.8
Tail Water Level	[EL. m]	1,296.3	1,245.62	1172.0	1,071.2	493.5
Catchment Area	[km^2]	30.8	43.3	21.4	132.7	183.4
Generation Type		Run-of-river	Run-of-river	Run-of-river	Run-of-river	Dam & Waterway
Turbine Type		HF	HF	HP	HF	HP

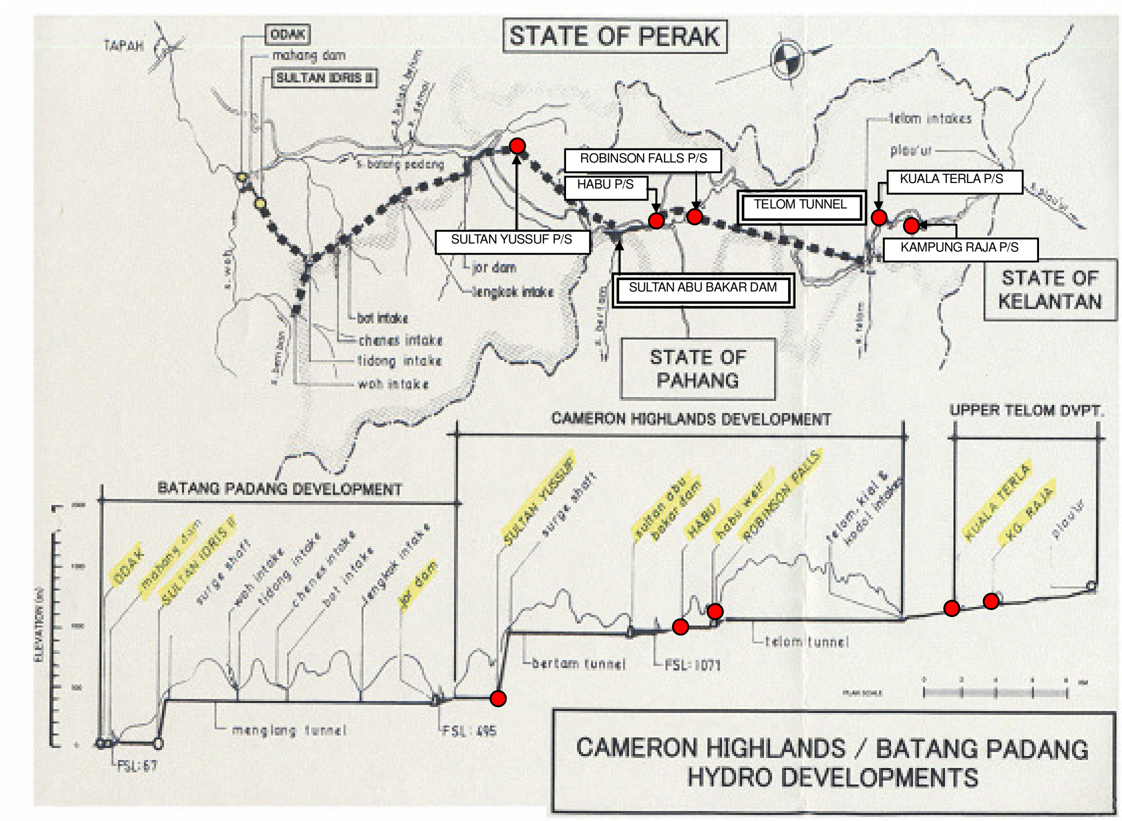

Figure1 Layout Plan of the Cameron Highlands Hydroelectric Scheme

The Ringlet Reservoir is a man-made lake created upstream of the concrete dam on Sg. Bertam. It impounds the waters of Sg. Bertam and its tributaries and those of Sg. Telom, Sg. Plau'ur, Sg. Kodol and Sg. Kial which have been diverted from the Telom catchment through the Telom Tunnel into the Bertam catchment. The designed gross storage of the reservoir is about 6.7 million cubic meters, of which, 4.7 million cubic meters is usable storage. Water from the Ringlet Reservoir is channeled through a tunnel to the Sultan Yussuf (Jor) Power Station and then is discharged through a tailrace tunnel into the Jor Reservoir of the Batang Padang Hydroelectric Scheme.

The Ringlet Reservoir, which has an estimated dead storage of 2.0 million cubic meters, would have a useful life of approximately 80 years.

2. Features of the Project Area

2.1 Catchment Characteristics

The Cameron Highlands catchment is situated on the Main Range of the Peninsular Malaysia. The average elevation of the catchment area is approximately 1,180 m with the highest peak, Gunung Brinchang at approximately 2,032 m above sea level and many of the other peaks are over 1,524 m.

The Cameron Highlands catchment that contributes water to the Ringlet Reservoir includes several sub-catchments and has an area of 183 km^2. The main rivers of the Cameron Highlands catchment, namely the Sg. Telom and Sg. Bertam drain eastwards into the Sg. Pahang and subsequently into the South China Sea in the eastern coast of the Peninsular Malaysia.

Table 3 Detailed Breakdown of the Cameron Highlands' Catchment Area

Major Catchment	Sub-Catchment	Area [km^2]	Total [km^2]
Telom	Plau'ur	9.6	110
	Kial	22.7	
	Kodol	1.3	
	Telom	76.4	
Bertam	Bertam	73	73

2.2 Land Use Changes

The construction of the Cameron Highlands/Batang Padang Hydroelectric Scheme in the sixties has provided in addition to the power generation facilities, some reasonable good access into the interior of the Cameron Highlands area. It may have therefore helped to encourage land development and other economic activities growth in the area during and post construction periods. Forest in the Cameron Highlands area is progressively being cleared to make ways for agricultural and construction activities.

Table 4 Land Use Changes in Bertam Catchment

Vegetation/ Land Use	Bertam Catchment [km^2]		
	1950's	1980's	1990's
Forest	46.5	45.1	43.5
Tea/Orchards	15.2	10.4	6.6
Vegetable/Flower	5.1	7.0	8.1
Urban	-	4.1	4.2
Open/Grassland/Scrub Forest	5.8	6.0	10.2

Table 5 Land Use Changes in Telom Catchment

Vegetation/ Land Use	Telom Catchment [km^2]		
	1950's	1980's	1990's
Forest	99.1	90.3	74.1
Tea/Orchards	6.3	6.2	6.2
Vegetable/Flower	5.0	10.7	23.2
Urban	-	0.5	1.1
Open/Grassland/Scrub Forest	-	2.7	5.8

3. Major Impacts

Extensive deforestation and indiscriminate earth bulldozing in the Cameron Highlands area for agricultural and housing development has resulted in widespread soil erosion over the land surface. The extent of soil erosion occurring in the area particularly that of Cameron Highlands Scheme catchment is increasing, the impact of natural vegetation destruction on the environment and the stations' generation/operation is a major cause for concern. It leads to sedimentation of the streams and the Ringlet Reservoir from which water is drawn to the power station. Excessive sediment particles drawn into the power station will cause damage and shorten the useful life of the mechanical parts of the generating plant, whereas excessive sediment deposited in the Ringlet Reservoir will affect its storage as well as useful life of the reservoir.

There were incidences of water qualities and aquatic lives in the Ringlet Reservoir being badly affected in the past when excessive sediment/silt content and high chemical content (e.g. pesticides and fertilizers) resulted in dying of fish and wide spread of water hyacinth. Cases of landslide have also been reported which have led to the destruction of properties and crops as well as loss of lives.

A number of studies were conducted in the past to examine the effects of development in the hydro scheme catchment on the hydro power station. The studies (Choy, 1987, 1989, and 1991) have shown that the operation and maintenance as well as energy generation of the hydro stations of the Cameron Highlands Scheme are affected by the land development. The severity of sedimentation has led to a study which reported that the carrying capacity of the Telom Tunnel had been reduced to 40% (WLPU, 1986).

Further studies of the land use impact (Choy & Hamzah, 2001, and Choy 2002) and a review of some previous studies recently done, give the following findings:

- Average annual temperature for urbanized area in the catchment has increased slightly in recent years.
- There is an increase in the annual mean runoff for the catchment subsequent to the land use changes (Figure 2 and Figure 3).

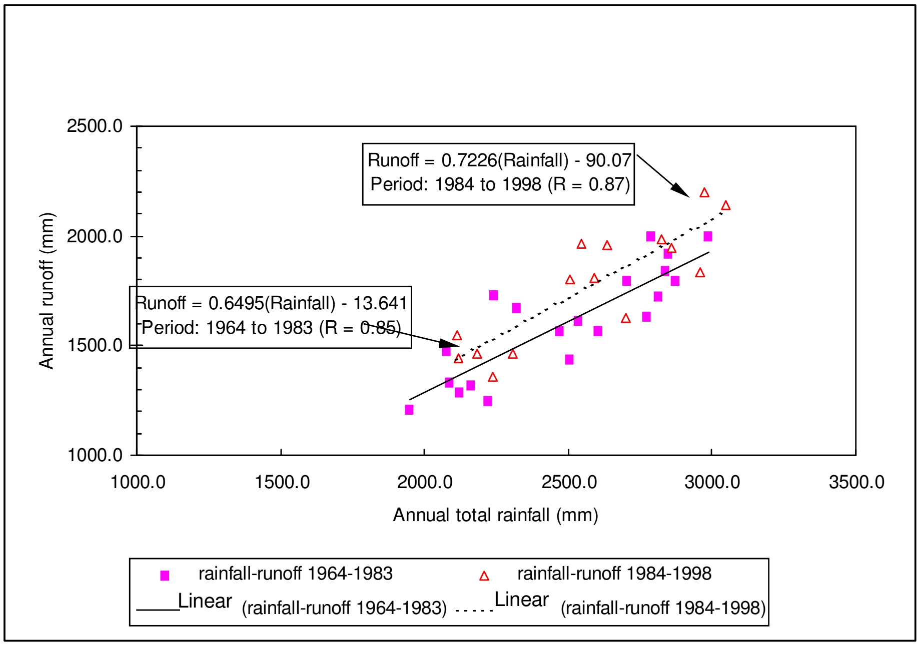

Figure 2 Rainfall-Runoff Correlation for Upper Bertam (at two different periods)

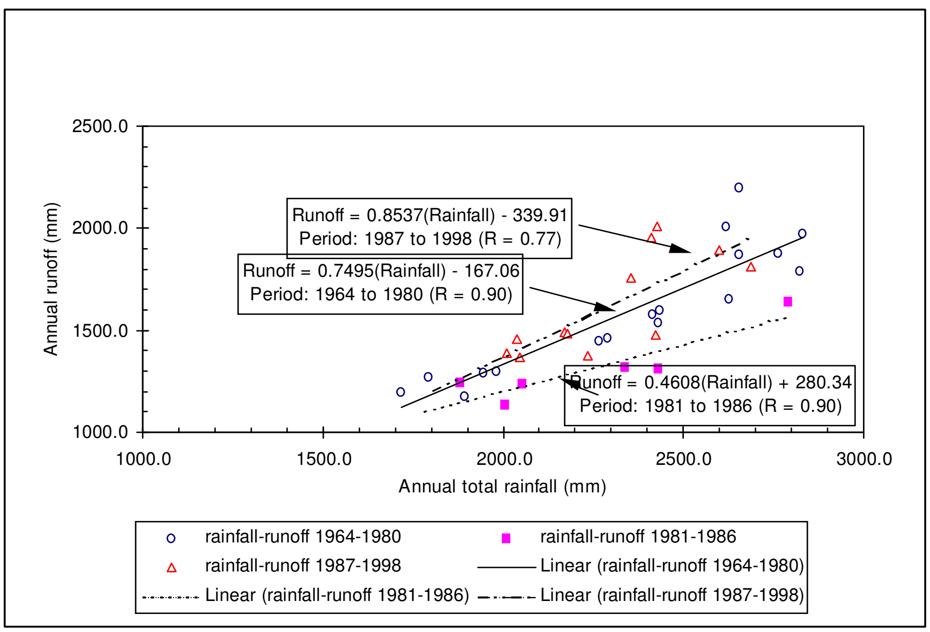

Figure 3 Rainfall-Runoff Correlation for Sg. Telom (at 3 different periods)

- Water utilization for generation decreases due to increased infiltration losses in dry days and spilling losses in wet days because of intake closing or increases in peak flow (Figure-4 and Figure-5).

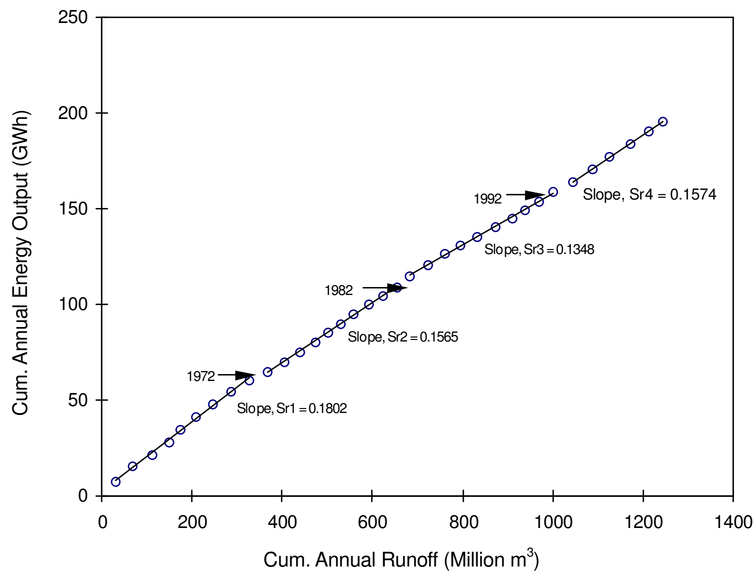

Figure 4 Double Mass Curve (Annual Runoff vs. Annual Energy Output) of Robinson Falls Power Station (1964 to 1998)

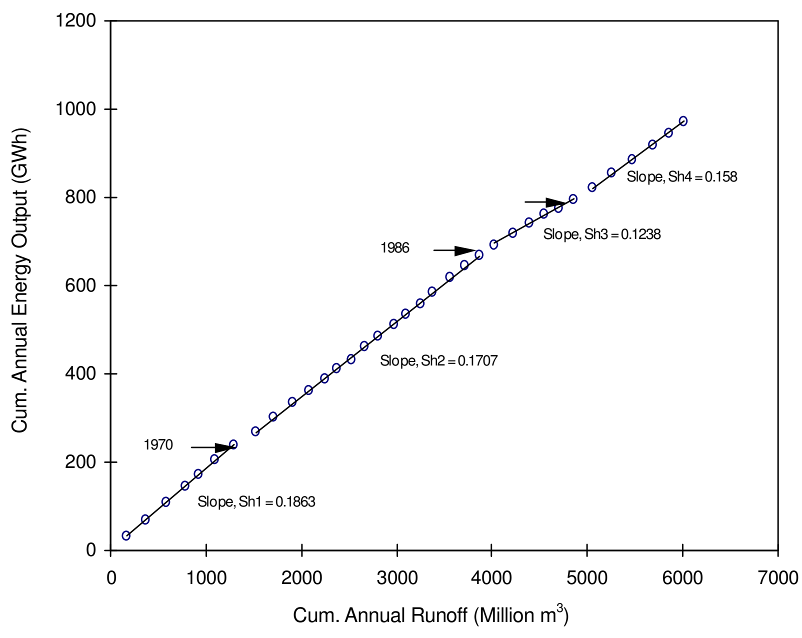

Figure 5 Double Mass Curve (Annual Runoff vs. Annual Energy Output) of Habu Power Station (1964 to 1998)

- The suspended sediment load in the Sg. Telom and Sg. Bertam River have increased by twentyfold and seventeenfold respectively since 1960's (Figure 6 and Figure 7).

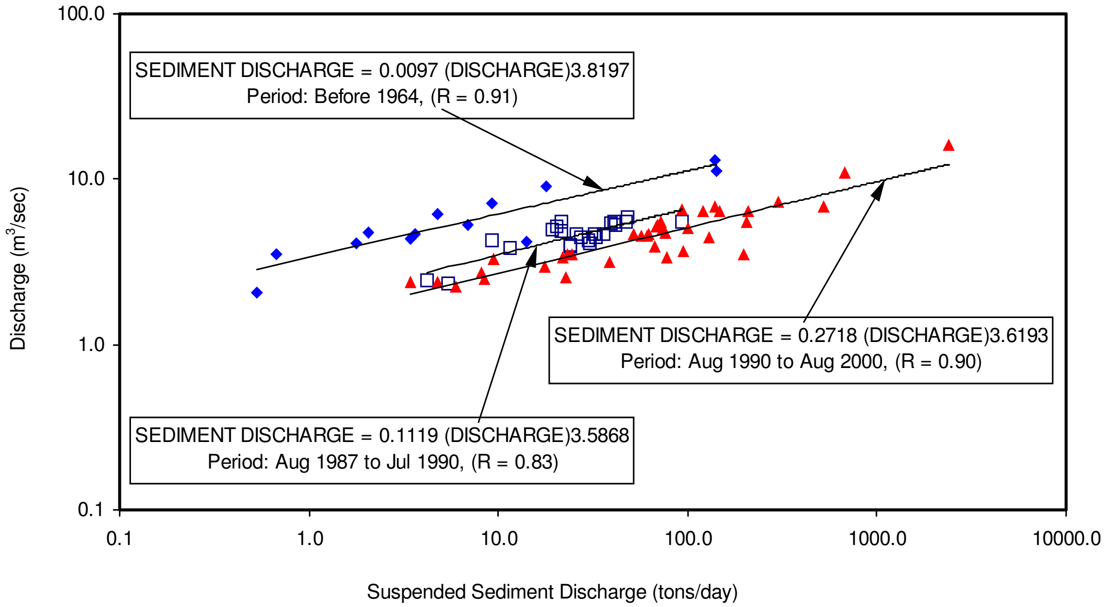

Figure 6 Sediment Rating Curve – Sg. Telom at 49 M.S.
(before 1964 and from August 1987 to now)

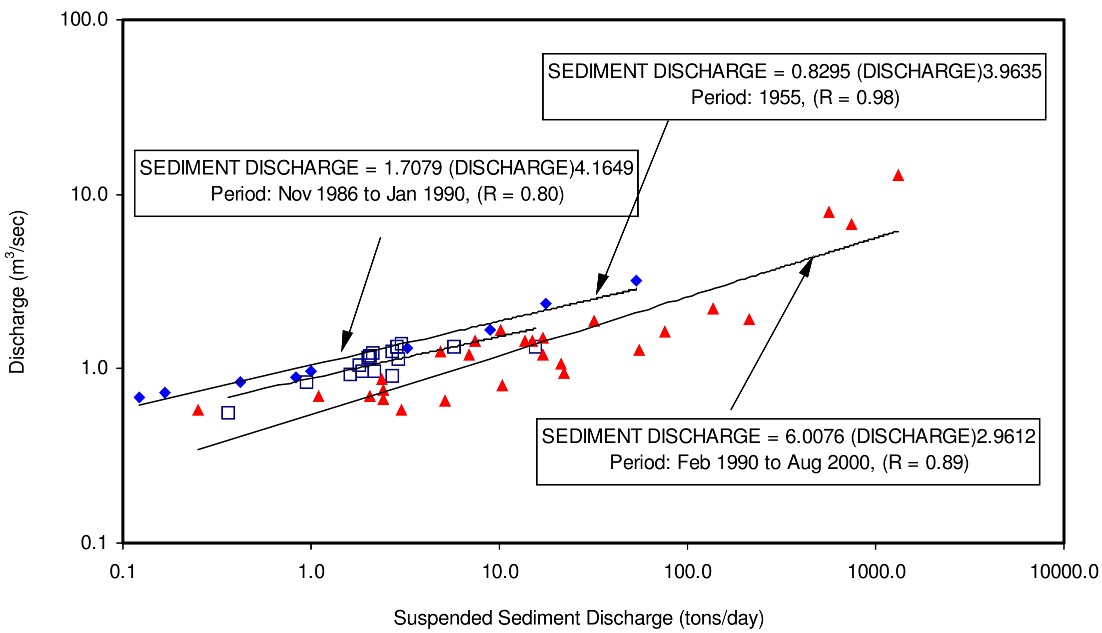

Figure 7 Sediment Rating Curve – Sg. Bertam at Robinson Falls
(before 1955 and from November 1986 to now)

Since its operation in 1963, the Ringlet Reservoir has lost nearly 53% of its gross storage to sedimentation, which is presently estimated as reaching a volume of about 3.5 – 4.0 million cubic meters. Figure 8 shows the storage capacity curve of the Ringlet Reservoir. The currently estimated sediment deposition rate in the Ringlet Reservoir is in the range between 350,000 to 400,000 cubic meters per year. Figure 9 shows the decline in trap efficiency over time for the Ringlet Reservoir calculated using the Brune's method on an annual basis, which shows the current trapping efficiency of the reservoir to be about 56 % as shown in Figure 9.

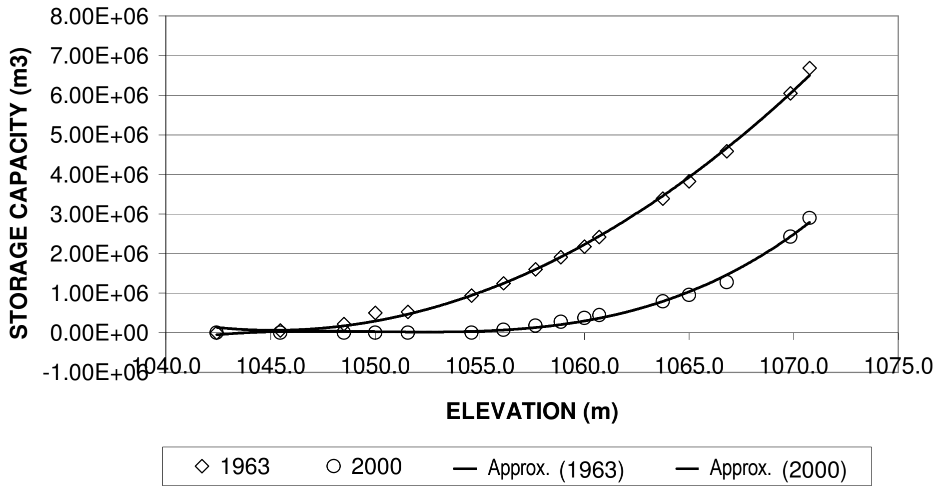

Figure 8 Ringlet Reservoir – Reservoir Capacity Curve (1963 vs. 2000)
(Choy & Hamzah, 2000)

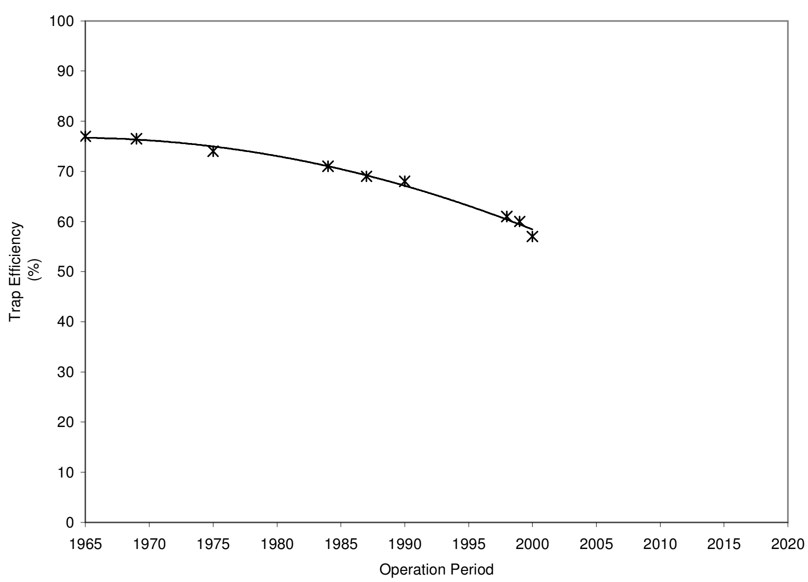

Figure 9 Ringlet Reservoir – Trap Efficiency vs. Operation Period

Most of the incoming sediment is therefore unlikely to be deposited in the Ringlet Reservoir and will be carried down to the Sultan Yussuf Power Station and discharged into the Jor Reservoir. Presently, 45.2% of the 3.9 million cubic meters gross storage of Jor Reservoir is filled with sediment.

A study in 1999/2000 (SNC-Lavalin, 2000) indicates that the sediment deposition in the Ringlet Reservoir has not affected the safety of the dam. However, the substantial reduction in the live storage of the reservoir would largely reduce the capability of the Sultan Yussuf Power Station to generate peaking power for the load requirement of the National Grid and would also reduce the capability of the reservoir to regulate incoming high flow. The former will make the Sultan Yussuf Power Station to be no different from other run-of-river stations and will result in financial loss; the latter will pose a risk of the dam being without flood control capacity, hence leading to frequent spillage and flooding of the downstream Bertam Valley during monsoon.

4. Mitigation Measures

Since the early seventies, mitigation measures (Choy & Fuad Omar, 1990; Choy & Fauzan, 1997) have been carried out periodically at various locations of the Cameron Highlands Scheme to minimize the impact of sedimentation on the operation and maintenance of the five hydro stations. These measures include:

- Manual removal of sediment accumulating behind the intake weirs of Kampung Raja, Kuala Terla and Habu.
- Construction of a small timber silt retention weir on Sg. Ringlet in the late seventies and a concrete silt retention weir downstream of the Habu Power Station in the early nineties.
- Pumping and excavation of sediment accumulating at upstream of the Telom Intake and Robinson Falls Intake and in the Ringlet and Habu Silt Retention Ponds.
- Desilting of the Telom Tunnel in the seventies and again in the early nineties.
- Construction of a new desander (settling basin) in front of the original Telom Intake structure to improve the sediment self-scouring efficiency (Photo 1).

Photo 1 Desander in front of the Telom Intake

5. Results of Mitigation Measures

As a result of the above mitigation measures, the inflow and accumulation of sediment in the Ringlet Reservoir has been checked and reduced by a significant amount as shown in the following Figure 10.

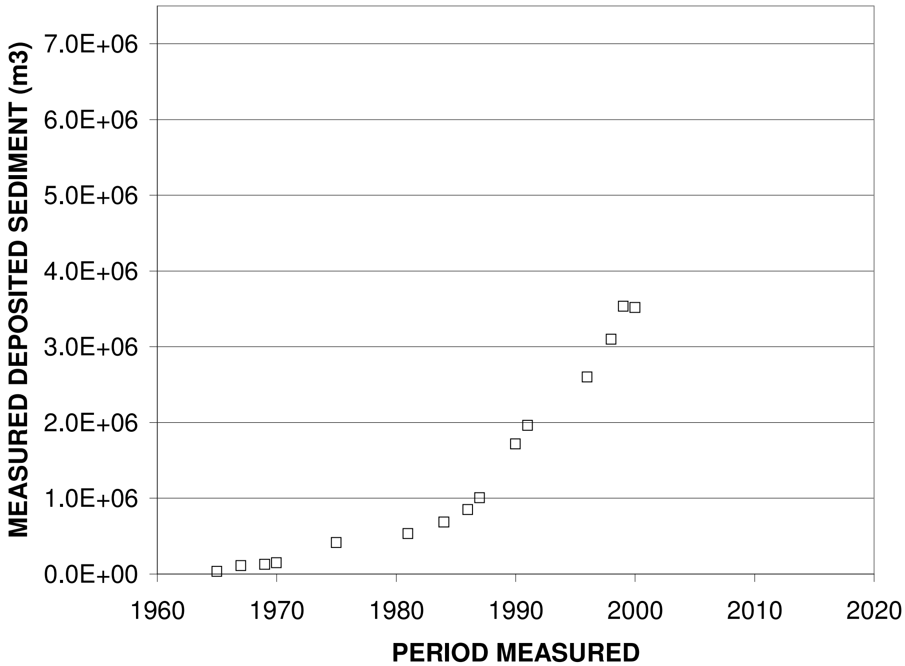

Figure 10 Ringlet Reservoir – Sediment Deposition Rate

- If there is no action at all to check the sediment inflow, the reservoir will theoretically lose its entire storage before or by the end of the year 2000 due to sedimentation.
- The desilting works carried out during the period between mid-seventies and early nineties appears to have prevented more than 1.5 million cubic meter of sediment from entering and accumulating in the Ringlet Reservoir.
- The completion of the new Telom Desander and the Habu Silt Retention Weir and subsequent desilting works has apparently prevented at least another further 1.5 million cubic meter of sediment from accumulating in the Ringlet Reservoir during the last few years.
- There is an improvement in energy production per unit of river discharge (kWh/m^3).

6. Reasons for Success

The desilting works, new Telom Desander and Habu Silt Retention Weir completed in the period between the seventies and early nineties has produced positive and fruitful results of reducing the inflow of sediment into the Ringlet Reservoir.
However, the following should be taken into account:

- The mitigating measures are only able to lessen but not stop the sediment accumulation in the Ringlet Reservoir.
- Nearly 53% of the storage capacity of the Ringlet Reservoir has already been filled with sediment.
- There is a plan to expand the development area in the Cameron Highlands area in the future.
- It is prudent to take early action on the following:

- To construct another silt retention weir on Sg. Ringlet at the Ringlet end of the Ringlet Reservoir so as to further reduce the sediment inflow into the reservoir.
- To examine the feasibility of desilting the reservoir so as to regain portion of the lost storage capacity due to sedimentation.
- To implement a watershed management plan and to impose the requirements for soil conservation practices in all future development.

7. Further Information

7.1 References

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