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HYDROLOGICAL REVIEW OF THE KAFUE RIVER, ZAMBIA

An investigation of the potential for the Zambian Sugar Industry to abstract more water for irrigation

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Executive summary

This report is presented to the Zambia Sugar Company via Booker Tate Ltd. The work carried out was a hydrological investigation of the Kafue River Basin, downstream of the Itezhi-tezhi reservoir. The primary objective of the study was to ascertain if there is sufficient water in the Kafue River to service the future requirement of the Zambian Sugar Industry to irrigate 17,400 ha of cane. The impact of the proposed future abstraction on energy production at the Kafue Gorge hydroelectricity plant was determined using both existing and possible future operating rules.

This report summarises the various data collected and describes their subsequent validation and processing. Details of water rights for abstraction from the Kafue River were obtained. The water rights presently granted to the Sugar Industry allow abstraction of 925,000 m^3d^{-1}. However, only during periods of peak irrigation requirement, in the dry season, does the water taken approach this value. For most of the year significantly less water is taken. If based on monthly crop water requirements, the annual requirement for irrigation of 17,400 ha is 22 % less than the total the sugar industry is presently allowed to abstract, although peak demand in September and October would exceed 1,000,000 m^3d^{-1}.

The IH reservoir simulation model HYDRO-PC, was used to simulate the operation of the Itezhi-tezhi and Kafue Gorge reservoirs. Model runs under existing conditions produced results that were very similar to those produced in earlier studies and verified that the firm energy of the Itezhi-tezhi/Kafue Gorge System is 430 MW (99.5 % reliability).

The model was then run to simulate the effect of changing the irrigation demand. The simulations run indicated that increasing abstractions to the irrigation requirement for 17,400 ha would not affect the reliability of the firm energy. However, diversion of the future irrigation requirement from the Kafue River would result in a reduction of the mean total (firm plus secondary) energy produced annually from 5773 GWh to 5722 GWh (i.e. a reduction of less than 1 %).

If in future the March freshet is not released the simulations conducted in this study, confirm earlier study findings that 430 MW can be met continuously (i.e. 100 % reliability). This will not be affected by the proposed irrigation demand for 17,400 ha. A possible increase in the full supply level of the Itezhi-tezhi and Kafue Gorge reservoirs by 1.0 m and 0.4 m respectively would increase the firm energy of the system, but result in a significant increase in evaporation losses, particularly from Kafue Gorge reservoir. Consequently there would be a reduction in secondary energy production.

In order to safeguard municipal supplies and energy production, it is believed that Zambia Sugar Company and the other cane growers are willing to cutback irrigation demand during periods of extreme drought, such as occurred in 1991/92. Since the recession of the Kafue River flow through the dry season is very predictable, a proposal for water use during exceedingly dry years is put forward. It is suggested that in future the Zambian Electricity Supply Corporation warn agricultural users several months in advance, if it will be necessary to reduce the application of irrigation water. This would enable all parties to develop plans to utilise the limited water resources in the best way possible. IH strongly supports the recommendation that an integrated water resources management strategy is developed for the whole of the Kafue Basin.

Contents

1. Introduction

Since the early 1960s the Kafue Flats region of Zambia has been developed as an area for sugar cane production. Today all of Zambia's sugar is grown in and around Mazabuka in the Kafue Basin. The Nakambala Sugar Estate is the largest single producer of sugar in the country, with just over 10,000 ha under cane. The estate is managed by the Zambia Sugar Company (ZSC) which is at present a subsidiary of the Zambia Industrial and Mining Corporation. Other cane growers in the region include private farmers and the Kaleya Smallholders Company (KASCOL). The total area presently under cane is 13,250 ha with a capacity of about 170,000 tonnes per year. Over the next decade, ZSC and other growers, some new, hope to expand the area under cane to 17,400 ha, thereby increasing the potential annual capacity to 230,000 tonnes.

The dry-season (May to October) in the Kafue Basin means that irrigation is a fundamental necessity for cane cultivation in the region. The water required for irrigation is taken from the Kafue River, which flows through the Kafue Flats. All the cane growers have water rights, issued by the Department of Water Affairs. The water rights place a limit on the quantity of water that they can abstract from the Kafue. The cane growers recognize that further expansion will require additional water rights.

The largest water right holder on the Kafue is the Zambian Electricity Supply Corporation (ZESCO). ZESCO operate a hydro-electric power station that has been constructed to exploit the large potential for power production at Kafue Gorge at the eastern end of the Kafue Flats. The power station requires a minimum flow of about 120 m^3s^{-1} in order to maintain its firm energy target of 430 MW. Other users with water rights for abstraction within the Kafue Flats include Lusaka Urban District Council and other smaller municipal supplies, as well as non-cane growing agricultural users (e.g. winter wheat producers). Many of these are net consumers of water and so reduce the amount of water reaching Kafue Gorge. To date there is no integrated water resource management plan for the Kafue Basin, but it is recognised that in future there will be increasing inter-sectoral competition for the limited surface water resource (Burke *et al.*, 1994).

Against this background, Booker Tate Ltd. who are currently contracted to manage ZSC, commissioned the Institute of Hydrology (IH) to undertake an independent hydrological review of the Kafue Basin. The aim was to ascertain the availability of water for the irrigation of sugar cane around Nakambala. Consideration was to be given to the feasibility of servicing the long-term requirement of the Zambian sugar industry, taking into account the industries desire to expand. This report details the work undertaken in this study and the conclusions drawn.

In section 2, a general description of the Kafue Basin is followed by a description of the Nakambala Sugar Estate and the sugar industry around Mazabuka and an explanation of the existing water rights. In section 3, a brief summary of previous work undertaken is given, and section 4 presents the methodology of the current study. In section 5, details are given of the water rights within the Kafue Basin, and a more detailed analysis of the present and future requirement for water by the sugar industry in Zambia. Section 6 is a summary of the data collected in this study, and gives details of how data series were established for the purposes of hydrological simulation of the Kafue Flats. Section 7 describes the model used and various simulation scenarios conducted. Finally, section 8 is a discussion of the results obtained, an outline of recommendations, and a list of conclusions that can be drawn from this study. Appendix A is a glossary of terms used, Appendix B contains tables of all the data used in the simulation exercise, and Appendix C presents the simulation input files and results.

2. Background

2.1 DESCRIPTION OF THE KAFUE BASIN AND HISTORY OF HYDROELECTRICITY GENERATION

The Kafue River Basin lies in the Central African Plateau and is a principal sub-catchment of the Zambezi River. It lies completely within Zambia occupying some 155,000 km^2, 20% of Zambia's total land area (Figure 1). The headwaters are located in North Western Province close to the border with Zaire and the river flows in a general southerly direction through the Copperbelt and on to Itezhi-tezhi. Downstream of Itezhi-tezhi it turns sharply to the east and flows to its confluence with the Zambezi river. It is the most significant waterway in terms of the national economy in Zambia; most of the mining, industrial and agricultural activities and approximately 50% of Zambia's total population are concentrated within the catchment area (Burke *et al.*, 1994). Three regions are recognised in the Kafue Basin:

- Upper Kafue - extending from the headwaters to Itezhi-tezhi
- Middle Kafue - extending between Itezhi-tezhi and Kafue Gorge
- Lower Kafue - extending between Kafue Gorge and its confluence with the Zambezi

Much of the Kafue Basin, down to the end of the Kafue Gorge, lies at elevations of 1300 m to 1000 m above sea level. Downstream of Itezhi-tezhi the Kafue flows 450 km through the Kafue Flats with a slope of just 0.022 ‰. The total area of the Flats is estimated to be 7,000 km^2 and is characterised by floodplains swamps and marshy lands. Below the Flats, the Lower Kafue River flows 25 km through the Kafue Gorge with a sharp drop of 24 ‰ (Obrdlik *et al.*, 1989).

The considerable head drop (just under 400 m) and consequent hydropower potential of the Lower Kafue led to the realization of the Kafue Hydroelectric Project. The first stage involved the construction of a dam and power station at Kafue Gorge, the latter with an installed capacity of 600 MW. The dam was closed early in 1971 and the first 150 MW unit of the hydroelectric power plant went on line in October 1971. The dam resulted in the permanent flooding of an area of some 800 km^2. However, because of the low topographic relief of the area the reservoir created is very shallow. It has a live storage of about 785 Mcm and produces noticeable backwater effects as far upstream as Nyimba (Shawinigan-Lavalin and Hidrotecnica Portuguesa, 1990a).

To enable more power generation, the second phase of the Hydroelectric Project was started. This brought the total installed capacity at Kafue Gorge to 900 MW and led to the completion of the 65 m high Itezhi-tezhi dam in May 1977. The Itezhi-tezhi reservoir is located 450 km upstream of the Kafue Gorge dam and has a live storage of just under 5000 Mcm. Its main purpose is to provide seasonal storage for flow regulation throughout the year for the Kafue Gorge plant. The storage is equivalent to about 56% of the long-term mean annual flow into the reservoir (Shawinigan, 1993a). The Kafue Flats themselves flood every year, thereby providing regular additional, though uncontrolled, flow regulation on the Kafue River upstream of the Kafue Gorge power plant.

The Kafue Hydroelectric scheme has changed the natural flow pattern of the river. Despite temporal changes in the flow regime, the high evaporation from the Flats has remained after regulation. The dredging of new channels and the implementation of river engineering schemes (e.g the construction of dykes and levees) aimed at reducing losses through evaporation, have been considered in other studies (e.g. DHV, 1980), but to date none have been implemented.

2.2 NAKAMBALA SUGAR ESTATE AND THE SUGAR INDUSTRY AROUND MAZABUKA

The entire Zambian sugar industry is situated near Mazabuka in Southern Province, 130 km south-west of Lusaka (Figure 2). Excellent agronomic conditions exist for growing sugar cane as an irrigated crop. The climate is generally hot and humid with maximum and minimum temperatures of 32°C and 24°C respectively in October, usually the hottest month. The cooler season lasts from April to August when mean maximum and minimum temperatures are about 20°C and 10°C respectively (Booker Tate, 1990).

The rainy season November to March corresponds to the southern hemisphere summer and results from the movement of the intertropical convergence zone over Zambia. The mean annual rainfall determined from the raingauge on Nakambala Sugar Estate (1965 - 1993) is 710 mm. The distribution and pattern of rainfall during the rainy season is variable, but on average there are 35 raindays (> 5 mm) in the season.

The largest producer of cane is the Nakambala Sugar Estate, owned by ZSC. From its establishment in 1964, when a pilot scheme of 120 ha of cane was planted, the estate has expanded to its present size of just over 10,000 ha, with a nominal annual capacity of 145,000 tonnes of sugar (ZSC, 1994). Within the estate the ground rises from very low slopes of about 0.5% in the areas bordering the Flats, to some 1.5 - 2.5% at the top of the estate. The estate is composed of many soil types, the majority being sandy clays loams with reasonable permeability and generally good structure. There are some areas of heavy black clays, mostly in the low-lying parts of the estate. These have poor permeability and suffer from waterlogging during the rains. In some of these areas, cane cultivation has been attempted and found to be impractical (Booker Tate, 1990).

In addition to the ZSC estate, there are other growers who supply cane to the estate factory. The largest of these is the Kaleya scheme which was established by the Commonwealth Development Corporation (CDC) in conjunction with ZSC in the early 1980's. The scheme is located on the western boundary of the Nakambala Sugar Estate, but is managed separately by the Kaleya Smallholders Company (KASCOL). The aim of the project is to involve 300 small holders, each renting a small plot for the production of cane. Presently the Kaleya nucleus estate grows 1216 ha of cane and there are 155 smallholders who grow another 684 ha of cane. Overall irrigation management of the scheme rests with the estate, but individual smallholders are responsible for maintaining recommended regimes on their own plots (Njobvu, 1990). There are presently also four private farmers who grow cane with a combined area of 933 ha. It is expected that in future some new growers will cultivate cane, and these in addition to expansion of existing growers, particularly of the Kaleya scheme, will increase the total area under cane to 17,400 ha.

2.3 WATER RIGHTS

Table 1 is a list of existing water rights, detailing allowed abstractions from the Kafue between the Itezhi-tezhi and Kafue Gorge reservoirs. This list was provided for the current study by the Water Development Board of the Department of Water Affairs (hereafter referred to simply as the Water Board). The Water Board is responsible for issuing water right licences. The water right system presently applied in Zambia fixes a single upper limit on the amount of water that each water right holder can extract from the river on any day. Other rules governing abstractions may also be stipulated in the licence.

Table 1 Water right holders (other than ZESCO) between Itezhi-tezhi and Kafue Gorge

Holder	Amount of Water m^3d^{-1}
Primary Users	
Namwala Township Council	1,360
Mazabuka District Council	3,000
Kafue Township Council	6,000
Kafue Secondary School	6,500
Lusaka Urban District Council	180,000
Secondary Users	
Nakambala Sugar Estate[*]	717,000
Kaleya Small Holders[*]	140,000
Garner[*]	20,000
Marshall (= Ceres Farm)[*]	26,000
Cantley (= Pyinga Enterprises)[*]	11,000
Cowley (= Syringa Farms)[*]	11,500
CDC Nanga	155,000
NIRS, Mazabuka Research Plots	3,000
Marshal MGM, Mazabuka	30,000
Anchor Ranch Co. Mazabuka	30,000
Chanyanya Rice Scheme	50,000
ZNS, Kafue	2,000
Ndunda M.J.G, Kafue	100
Malawo J.L.	50
Lusaka Nutrition Group	300
G.M. Muyanguna	120
F. Weathley	150
Kafue Fisheries	109
Riverside Farm	1,500
Shanzete Shangone	700
Kafue Wheat	1,015
TOTAL	1,396,400 m^3d^{-1} = 16.16 m^3s^{-1}

[*] Water rights for sugar cane irrigation

The largest water right holder on the Kafue is ZESCO. A water right issued to ZESCO in 1974 allowed the Corporation to impound the Kafue River at Itezhi-tezhi and to abstract up to 215 m^3s^{-1} over and above the normal spillway discharge for the purposes of hydropower production at Kafue Gorge. There are several conditions attached to this water right, the most relevant to the current study being:

- ZESCO must store and release sufficient water to ensure that a minimum of 15 m^3s^{-1} is available for other users between Itezhi-tezhi Dam and Kafue Gorge Dam.

- ZESCO is required to ensure that a minimum flow of 25 m^3s^{-1} is maintained in the river between Itezhi-tezhi Dam and Kafue Gorge Dam at all times.

- ZESCO should release a minimum of 300 m^3s^{-1} on each day over a period of four weeks in each year to preserve the ecological balance of the Kafue Flats.

In the past ZESCO have fulfilled the last requirement in March each year, by releasing what is known as the March "freshet". The ZESCO water right expired in November 1993 and was not automatically renewed; however, it is believed that a new application is presently being processed by the Water Board. Whether the same rules governing the operation of the Itezhi-tezhi reservoir will be applied in a future water right remains to be seen.

ZSC have the largest water right (717,000 m^3d^{-1} or 8.3 m^3s^{-1}) of the other users between Itezhi-tezhi and Kafue Gorge. The total water right for the sugar industry is presently 925,000 m^3d^{-1} (10.7 m^3s^{-1}). Lusaka Urban District Council also have a significant water right (180,000 m^3d^{-1}) which allows them to pipe water from the Kafue to Lusaka for municipal supply.

In 1992 the Water Board sent letters to agricultural water right holders, amending their water rights downwards and fixing monthly abstraction limits. These new limits were based on crop water requirements. However, they were vigorously contested by ZSC and other cane growers who felt that they had been incorrectly computed and did not allow sufficient water for their irrigation requirements. Of particular concern to ZSC, was the reduction in the dry season months of July and August (correspondence between ZSC and the Water Board, 1992/93). At a meeting in November 1992, the case was put to the Water Board that ZSC and the other cane growers required more water than they were being allowed in the amended water rights. At this meeting ZSC gave details of their method for calculating crop water requirements. From the minutes of the meeting it would seem that the Water Board accepted the ZSC case and agreed to revise their computations in line with ZSC. However, there has been no subsequent confirmation of this decision from the Water Board. In the meantime ZSC, and it is believed the other cane growers, continue to abstract water from the Kafue as required, and not as specified in the official amendments.

Location map

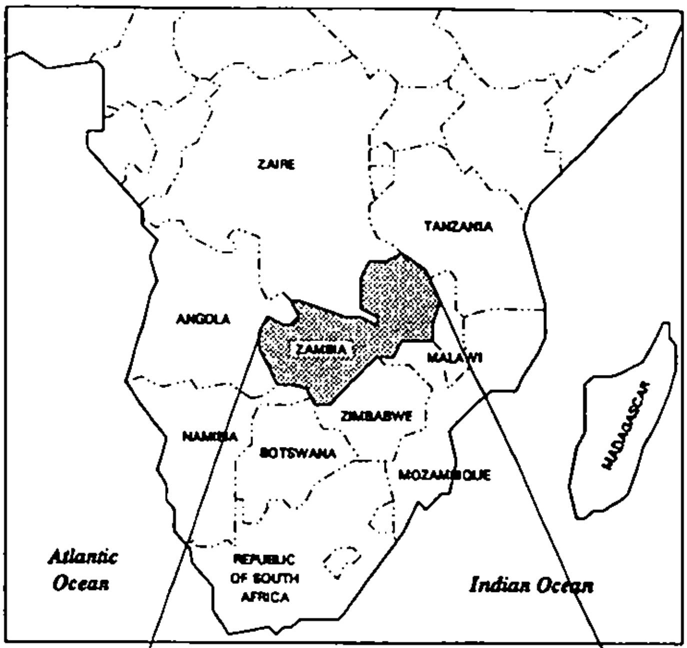


Figure 1a

Kafue Basin

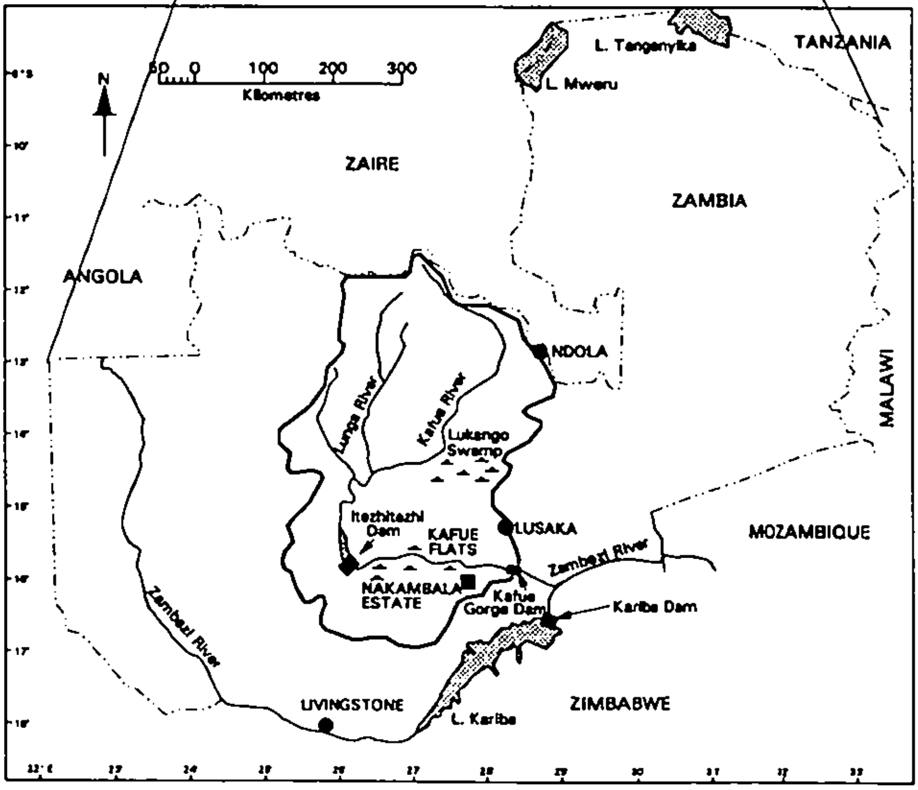


Figure 1b

Kafue Flats: location of river gauging and rainfall stations used in this study

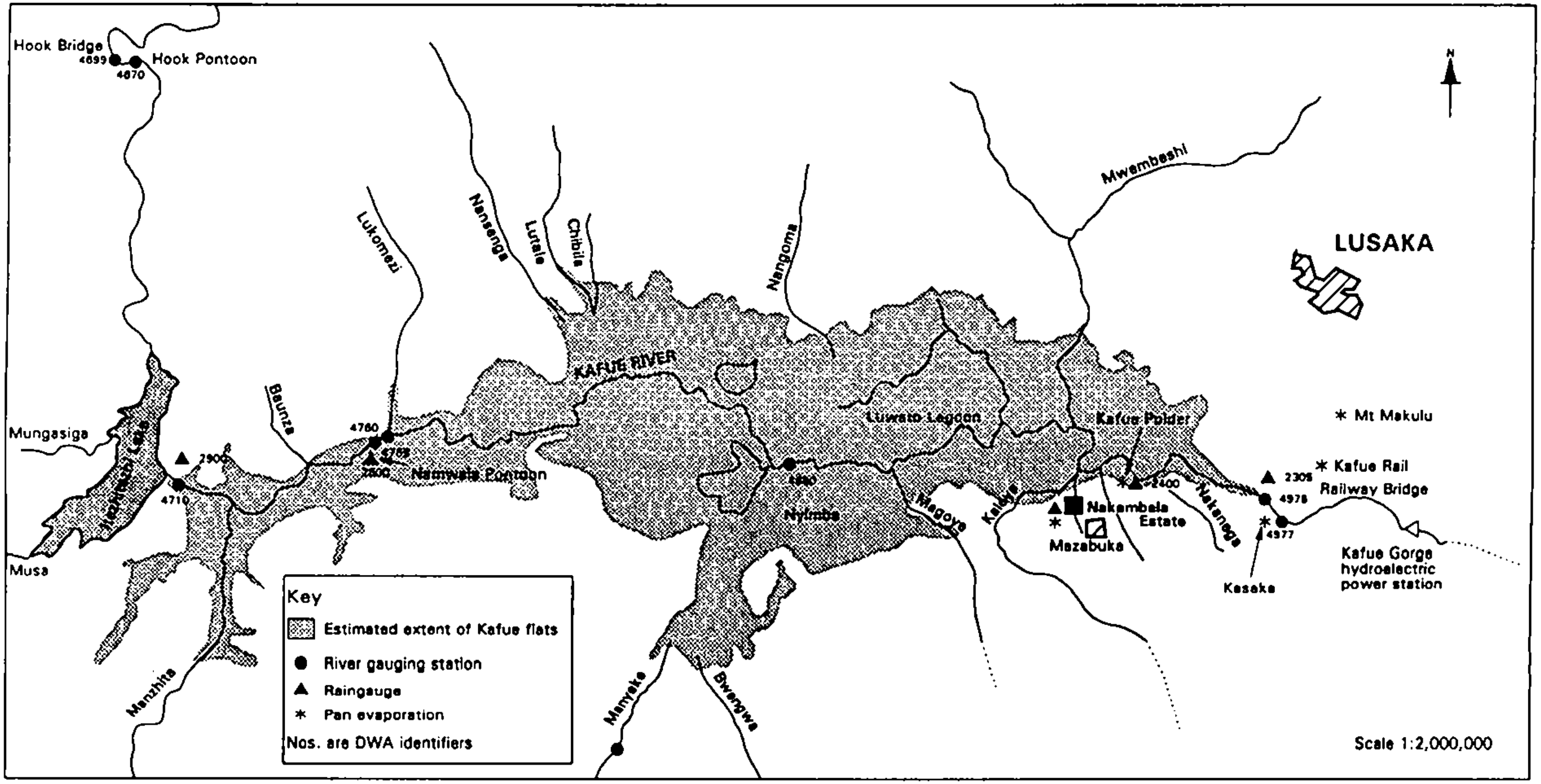


Figure 2

3. Review of previous work

Partly as a consequence of its important role in the economy of Zambia there is a considerable amount of literature relating to the water resources of the Kafue Basin. However, a full understanding of the complex hydrological processes occurring within the area of the Kafue Flats is still to be realised. In this section the publications of primary interest to the current study are described briefly.

DHV(1980) conducted what is to date probably the most detailed hydrological study of the Middle Kafue Basin. A semi-distributed water balance model based on nodes and branches was developed for the Kafue Flats. A node was used to represent a certain part of the river or the Flats. Water levels were computed for each node. The nodes were linked by branches which were water conveying connections. Taking into account inflows and outflows, rainfall, evaporation and the operation of the Itezhi-tezhi and Kafue Gorge reservoirs, the model was used to simulate the hydrological behaviour of the Flats and to investigate the affect of proposed measures such as poldering, canalization and controlled flooding.

The following are the conclusions drawn by the DHV study which are of most relevance to the current study:

- The sources for irrigation in the area are the tributaries and the Kafue River. Groundwater cannot be considered as a main source of water because of the poor aquifer characteristics within the Lower Kafue Basin.

- On average a spill of 2.2 Mcm per year occurs at the Kafue Gorge dam. However, during periods of severe drought (such as 1965-1968, believed to occur once in every 20 years) water availability would be much reduced. Even for such a dry period there is enough water in the Kafue River to put an additional 10,000 ha outside the Flats under irrigation, or up to 20,000 ha inside the Flats without affecting the required discharge (then stated as 168 m^3s^{-1}) at the Kafue Gorge hydroelectric plant.

- Considerable savings of evapotranspiration in the Flats could be obtained if controlled flooding measures such as low levees in the Flats were combined with pumping water from areas protected by these levees. A controlled flooding scheme could provide enough water to irrigate 60,000 ha outside the Flats without affecting the required discharge at the Gorge Plant, for droughts that occur on average once every 20 years.

- Raising the upper storage level of the Itezhi-tezhi reservoir by 1.5 m would provide enough storage to develop an additional 25,000 ha outside the Flats under irrigation, again without affecting the required discharge at the Gorge Plant, for droughts that occur on average once every 20 years.

Although no direct reference can be found, it is understood that ZESCO did not accept the findings of the DHV study. ZESCO would be unhappy with any increase in the abstraction of water from the Kafue River that would have a detrimental effect on power production. The value of hydropower generation depends on the available firm capacity of the plant which is determined by the minimum regulated flow which is available. Even an occasional decrease in available water flow occurring at intervals of some years means a reduction in the firm capacity, and reduces the value of the hydropower because additional supply has to come from other more expensive sources, such as thermal power stations.

Over the years ZESCO has commissioned numerous studies into the various aspects affecting the production of hydroelectricity in the Kafue Basin. Many of these studies have been conducted within the framework of the SADC Hydroelectric Hydrological Assistance Project, and have been carried out either by, or in conjunction with, Shawinigan Engineering.

In 1990, Shawinigan-Lavalin and Hidrotecnica Portuguesa (hereafter referred to as SLHP) simulated the Kafue Gorge power plant operation using the HEC-3 program which is described in detail in Shawinigan (1992). An inflow series to Itezhi-tezhi that was extended back to 1905 made it possible to simulate 84 years of operation of the Itezhi-tezhi and Kafue Gorge scheme. A rule curve was developed for Itezhi-tezhi to improve operation of the system. This study showed that, on the basis of the long-term flow record, the firm energy capability of the system was 430 MW (99% reliability). This result has been confirmed by a more recent study (Shawinigan, 1993a) which again used the flow record extended back to 1905, but included the drought years of 1991/1992. Indeed this study showed that 430 MW could be considered to be the absolute firm energy capability of the Kafue Gorge/Itezhi-tezhi system, assessed on a criteria of 100% reliability if the requirement for the March freshet was removed. These results are discussed in more detail in section 7.5.

In 1992, the Japan International Cooperation Agency (JICA) completed a Master Plan study on the hydrologic observation systems of the major river systems in Zambia. This contains details of the hydrometric and meteorological stations within the Kafue Basin, and also includes water balance calculations for both the Itezhi-tezhi and the Kafue Gorge reservoirs for the period October 1979 to September 1991. These data proved useful for purposes of comparison with results obtained in the current study. Useful information was also obtained through discussion with members of the JICA team presently in Zambia.

Burke *et al.* (1994) investigated the need for integrated water resource development and management in the Kafue catchment. This study concluded that:

- Continued economic development of the basin is not sustainable if inter-sectoral competition continues over limited surface water resources.
- Plans for the basins development are currently based on very limited understanding of its resources.
- There are prolific groundwater resources in the dolomitic aquifers in the vicinity of Lusaka and the Copperbelt. In the past these have been under-utilised, but if developed could ease the demand for water from the Kafue.
- There is a need to develop an overall water resource management strategy to optimise the use of existing resources and plan for future developments within the basin.

There are numerous other publications relating to both the hydrology of, and the hydro-electricity production in, the Kafue Basin. Many were written before and soon after construction of the dams. Turner (1983) is a bibliography of these Kafue Flats reports. Those reports commented on above are the most relevent to the current study and, it is felt, represent the most up-to-date thinking on the issue of water resources in the Middle and Lower Kafue Basin.

4. Current study methodology

The aim of the current study was to investigate the requirements for water of the Zambian sugar industry, principally to see if enough water was available for future expansion. In the limited time available a detailed analysis of the hydrology of the Kafue Flats was not possible, and consequently it was necessary to develop statistical, rather than deterministic, relationships in some instances.

The approach used in the current study was to set up IH's reservoir simulation model, HYDRO-PC (Plinston, 1989) for both Kafue Gorge and Itezhi-tezhi reservoirs. The outflow from Itezhi-tezhi was linked to the inflow to Kafue Gorge by simple regression analysis. Using an inflow series to Itezhi-tezhi extended back to 1905, the operation of both reservoirs was simulated for an 88-year period. The results were compared with those obtained by SLHP (1990a) and Shawinigan (1993a). The additional water requirement necessary for the increased area under cane was taken from the Kafue Gorge Reservoir, and HYDRO-PC re-run with the new abstractions. The effect of the additional abstraction for sugar cane irrigation on both the firm energy production and the secondary energy production of the station was ascertained. It has been proposed that the March freshet should no longer be implemented (Shawinigan, 1993a), and the full supply level of Itezhi-tezhi and Kafue Gorge should be increased in order to provide increased regulation of the Kafue River flow (Mwasile, SADC Project Manager, ZESCO, personal communication). The effect of both these measures was investigated.

4.1 DESCRIPTION OF HYDRO-PC

HYDRO-PC is a computer program based on a LOTUS 123 worksheet format. It produces a month by month simulation of reservoir performance. It performs a continuous recalculation of water balance, given a sequence of inflows and rainfall over the reservoir area. For a given set of operating rules and constraints, the program can be used to calculate optimum releases to meet demands, and if necessary flood control targets. Spills, energy and power generated are determined and a running balance of the reservoir status is maintained. Necessarily the simulation is based on average conditions during each month, usually derived from the start and end of month conditions. As end of month conditions are not known until the monthly balance is complete the procedure is iterative with the average conditions for reservoir area, water level and so on being successively re-estimated until the monthly balance is consistent.

This procedure implies a uniform inflow and a uniform change in reservoir contents through the month, conditions which are not entirely realistic. If, in reality, excess inflows are concentrated towards the end of the month, spill will tend to be underestimated by the simple reservoir balance. Furthermore the form of the reservoir area curve may mean that a simple average area derived from beginning and end of month values will always be an overestimate and that evaporation will be overestimated correspondingly. However, the larger the reservoir and the more uniform the inflows, the less these approximations matter.

Details of the input series required for simulation of both the Itezhi-tezhi and Kafue Gorge reservoirs are given in sections 6 and 7.

5. Cane irrigation

5.1 EXISTING WATER REQUIREMENT

Table 2 lists the areas under cane and the current water rights (i.e. before the 1992 amendments) of the cane growers in the Lower Kafue Basin. By far the largest cane grower, and consequently the largest user of water for irrigation, is ZSC at Nakambala. Their water right is 717,000 m^3d^{-1} (8.3 m^3s^{-1}). The Kaleya smallholders and the Garner Farm and Ceres Farm have their own water rights but obtain most of their water from the ZSC distribution network. Pyinga Enterprises and Syringa Farms have small areas under cane, and only small water rights. They pump their water separately from ZSC.

Table 2 Irrigation for cane growing in the Kafue Basin

1994		Area under cane	Water Right	
		ha	m^3d^{-1}	Mcm
Nakambala:	ZSC Estate	10,429	717,000	261.9
	Kaleya Small Holders	1,889	140,000	51.1
	Garner	386	20,000	7.3
	Ceres Farm	347	26,000	9.5
Elsewhere:	Pyinga Enterprises	100	11,000	4.0
	Syringa Farms	100	11,500	4.2
	TOTAL @ Nakambala	13,050	903,000	330
	TOTAL	13,250	925,000	338

Water for irrigation at Nakambala is pumped from the Kafue river and enters the estate distribution network via a 14.3 km long canal. From the main canal the water is lifted into a number of storage reservoirs, and from these it is gravity fed to secondary and tertiary canals for irrigation purposes. Figure 3 is a schematic of the irrigation distribution network. Apart from a trial 5.5 ha plot being used to investigate the feasibility of drip irrigation, all of the cane is surface irrigated by means of syphons. Although most of the water is used for irrigation some relatively small amounts are used for domestic purposes on the estate and in the estate factory. A small amount is also diverted to Mazabuka for the town water supply.

The water is pumped from the Kafue at two pump stations, PS1 and PS11, both of which are located at the upstream end of the main canal. PS1 is the original pump station built in the mid-1960s with six pumps. When the estate was expanded in the early 1970s, the station was extended by building the PS11 station alongside. This has five pumps and boosts the total capacity of the intake to 14.4 m^3s^{-1} (Booker Tate, 1990). Water is pumped from the main canal at four locations; pumping stations PS2, PS4, PS14 and PS41 (Figure 3). Although planned for the future, the volume pumped is not at present measured at stations PS1 and PS11. Instead, pumped volumes are recorded using chart recorders at the four stations on the main canal. To determine the volumes extracted from the river, ZSC sum the measured totals from the four stations.

Before the figures could be analysed in detail it was necessary to make a quantitative estimate of likely losses from the main canal, in order that the 'true' amounts of water being abstracted from the Kafue could be obtained. The main canal is an unlined channel passing through predominantly clay soils. Losses will occur through seepage into the soil and evaporation from the water surface. Using the engineering diagrams of the canal (ZSC, 1973 drawing 27E/CAN/MAIN/9 and ZSC, 1986 drawing 27E/CAN/MAIN/11) the surface area and the area of the wetted perimeter of the canal were estimated to be 215,000 m^2 and 228,000 m^2 respectively. Monthly open water evaporation rates as determined in section 6.3.6 and a seepage rate for clay soil of between 0.07 and 0.15 $m^3m^{-2}d^{-1}$ (Booker Tate, 1990) were assumed. Table 3 shows the average likely loss from the canal on the basis of these figures.

Table 3 Water losses from the main canal

	Evaporation		Seepage Mcm		Estimated Total
	mm	Mcm	Min⁺	Max•	Mcm
Apr	157	0.03	0.48	1.03	0.79
May	136	0.03	0.49	1.06	0.81
Jun	109	0.02	0.48	1.03	0.78
Jul	125	0.03	0.49	1.06	0.81
Aug	157	0.03	0.49	1.06	0.81
Sep	202	0.04	0.48	1.03	0.80
Oct	233	0.05	0.49	1.06	0.83
Nov	191	0.04	0.48	1.03	0.80
Dec	168	0.04	0.49	1.06	0.82
Jan	172	0.04	0.49	1.06	0.82
Feb	154	0.03	0.45	0.97	0.74
Mar	176	0.04	0.49	1.06	0.82
TOTAL					9.63

⁺Seepage = 0.07 $m^3m^{-2}d^{-1}$
•Seepage = 0.15 $m^3m^{-2}d^{-1}$

There is significant re-use of drainage water on the estate with a large proportion of the drainage water from the estate being channelled into the main canal. Flows in the main drains on the estate were measured using flumes from June 1983 to January 1987. The monthly totals are given in Table 4. When compared with the possible range of losses that may be occurring from the canal, it seems that if between 50% and 75% of the drainage water is assumed to re-enter the canal, this water adequately compensates for the losses. Since the losses could not be determined any more accurately, for the purposes of the current study it was assumed that drainage water into the canal equalled water loss from the canal by evaporation and seepage. The abstraction figures were therefore left unchanged.

The agricultural year in Zambia is from April to March. The figures relating to water abstraction and use on the estate were presented to this study in this way, and for purposes of convenience have all been left in this format. Weekly abstraction totals are available from April 1979 to March 1994. These include a breakdown of the water use by the estate, the outgrowers who take their irrigation water from the ZSC distribution network, and Mazabuka town. Tables B.1 to B.3 (Appendix B) show the historic monthly figures for water supplied to the town, the water used on the estate, and the total water use by the estate and the outgrowers (excluding the town supply).

Table 4 Drainage (Mcm) from Nakambala Sugar Estate 1983-1986

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	TOTAL
1983			1.32	2.00	1.54	1.36	1.80	1.41	1.77	1.07	0.92	1.40	
1984	1.41	1.43	1.68	1.59	1.55	1.79	1.31	1.50	1.72	1.08	1.60	1.80	18.46
1985	0.80	1.04	1.00	1.00	1.24	1.11	0.98	1.47	1.95	1.20		0.79	
1986	1.26	1.55	1.71	1.79	2.10	1.75	1.70	0.76	0.40	0.97			
MEAN	1.16	1.34	1.43	1.60	1.61	1.50	1.45	1.29	1.46	1.08	1.26	1.33	

Figure 4 shows the annual totals abstracted for the estate, and for the estate and the outgrowers combined. Since 1979 the estate has expanded from 9,707 ha to 10,428 ha, an increase of 7.4%. In the same period the outgrowers have expanded from 632 ha to 2,528 ha, which represents a 4-fold increase. In this period by far the largest outgrower expansion has been KASCOL. Much of the outgrower expansion occurred in the early 1980s, and is clearly reflected in the higher proportion of the total water use that is associated with the outgrowers from 1983 onwards.

Figure 5 compares the mean, maximum and minimum monthly abstractions taken just by Nakambala Sugar Estate for the period 1979 to 1993. The figures were not normalised by dividing through by the area irrigated each year, since as mentioned above there has only been a relatively small increase in area under cane on the estate over this period. Furthermore, much of the year-to-year variation in abstraction is a reflection of rainfall distribution and other influences, such as operational constraints, rather than the size of the area being irrigated.

Figure 5 and the coefficients of variation (CV) shown in Table B.2 (Appendix B) demonstrate the annual variation in the amount required for irrigation in any particular month. This is particularly the case in the wet season months, November to April. In the wet season, both the quantity and the temporal distribution within any given month are critical factors in deciding the need for cane irrigation. If the rains are "poor" then it is necessary to apply large volumes of irrigation water because temperatures, and consequently evapotranspiration, are very high at this time of year. In the dry season there is less variation in rainfall (it is always zero or nearly zero), and so large amounts of water are required for irrigation in these months every year, and consequently there is less variation in the quantity applied.

The maximum ever abstracted by ZSC for the estate is 20.62 Mcm in November 1989. This is equivalent to an abstraction rate of 687,333 m^3d^{-1} (7.96 m^3s^{-1}), slightly lower than the maximum allowed by the ZSC water right. In most years the abstraction approaches the permitted water right maximum on only a few days during the peak irrigation period in the dry season (Spitteler, General Manager, Nakambala Sugar Estate, personal communication).

Also shown in Figure 5 is the ZSC stated water requirement for the Nakambala Sugar Estate.

These are the figures that were presented to the Water Board in November 1992. These values are monthly crop water requirements based on crop stage, crop cover, rainfall, evaporation and an area under cane of 10,000 ha. The figures were derived using 27-year means of climatic data collected from the meteorological station on the estate. The method applied is standard practice throughout the Sugar Industry in Southern Africa (ZSC, correspondence with the Water Board, 19/10/92). In some months the stated water requirement significantly exceeds the average monthly value derived from the 14 year period of historic data; most notably in September, when it even exceeds the historic maximum taken in that month. There are four reasons why this may be the case:

- Between 1979 and 1986 ZSC irrigated slightly less than 10,000 ha.
- In the past constraints have been applied to the pumping, as a consequence of both pump and pipe limitations. These problems are now being addressed by ZSC.
- In the past the ZESCO method of charging for electricity included a tariff that was based on the peak power consumption in a 12-month period. As a consequence ZSC tended to impose power ceilings in order to keep electricity costs down. The ZESCO regulation has recently been changed so that a tariff is now imposed on the peak power used in each month, rather than the peak power in a year. ZSC feel that this is fairer way of charging, and will more readily pump at the required rate during periods of peak irrigation requirement, and will be less concerned with limiting power consumption during these critical periods.
- ZSC are attempting to improve the cane yield and this requires the application of slightly more water per hectare.

Figure 5 also shows that in some months, December, January and February, the stated water requirement is significantly lower than the average historic value. In January the historic records show that the abstractions have always exceeded the stated requirement, except in two years (i.e. 1981 and 1990). Similarly in February historic abstractions have always exceeded the stated requirement except in two years (i.e. 1980 and 1989). Hence while the long-term mean climatic data indicates that there is little requirement for irrigation in these months, recent history suggests otherwise. This may be a consequence of the fact that rainfall patterns have changed, but is also possibly an indication of the importance of the temporal distribution of rainfall in these months. Even if there is sufficient rainfall in total, if its temporal distribution within the month is poor, the amount of "effective" rainfall may be insufficient to meet the crop water requirement and it is then necessary to apply irrigation water. This is an inherent weakness of using historic mean data on a monthly time step.

Table 5 compares the average historic abstractions, the ZSC stated requirement, and the monthly abstraction figures in the amended water right sent to ZSC by the Water Board in 1992 (section 2.3). Figure 6 is a histogram comparing these data. The calculations the Water Board used to derive the amended water right figures are not known. Of primary concern to ZSC are the June and July figures which are significantly less than their calculated requirement.

Table 5 Comparison of the average monthly historic abstractions for Nakambala Sugar Estate, the ZSC stated requirement and the abstraction figures in the amended water right

	Average historic abstraction 1979-1993		ZSC stated requirement		Water Board suggested water right	
Apr	12.39	(413)	13.50	(450)	15.96	(532)
May	14.49	(467)	14.66	(473)	13.45	(434)
Jun	12.99	(433)	13.59	(453)	6.21	(207)
Jul	12.72	(410)	14.04	(453)	6.98	(225)
Aug	13.90	(448)	15.97	(515)	15.75	(508)
Sep	14.55	(485)	20.97	(699)	18.75	(625)
Oct	15.50	(500)	20.55	(663)	22.32	(720)
Nov	13.21	(440)	15.75	(525)	13.44	(448)
Dec	6.92	(223)	3.16	(102)	2.98	(96)
Jan	4.24	(137)	1.27	(41)	4.22	(136)
Feb	3.88	(137)	0.96	(34)	5.65	(200)
Mar	6.62	(214)	8.80	(284)	6.79	(219)
TOTAL	131.40		143.23		132.49	

Values in Mcm, Nos in brackets are equivalent values in thousands of m^3d^{-1}

5.2 FUTURE WATER REQUIREMENT

Table 6 and Figure 7 compare the abstractions that would be required for irrigation of 17,400 ha based on a pro-rata increase of the average historic and the ZSC computed monthly figures i.e.

17,400/10,000 * ABS

where: ABS is the maximum of the average historic value or the ZSC stated requirement for irrigation of 10,000 ha.

Table 6 Future irrigation requirement for 17,400 ha based on a pro-rata increase of the average historic and the ZSC stated requirement for 10,000 ha

	Based on stated requirement		Based on average historic abstraction 1979-1993		Maximum	
Apr	23.5	(783)	21.6	(720)	23.5	(783)
May	25.5	(823)	25.2	(813)	25.5	(823)
Jun	23.7	(788)	22.6	(753)	23.7	(788)
Jul	24.4	(788)	22.1	(713)	24.4	(788)
Aug	27.8	(896)	24.2	(781)	27.8	(896)
Sep	36.5	(1217)	25.3	(843)	36.5	(1217)
Oct	35.8	(1154)	27.0	(871)	35.8	(1154)
Nov	27.4	(914)	23.0	(767)	27.4	(914)
Dec	5.5	(177)	12.0	(387)	12.0	(387)
Jan	2.2	(71)	7.4	(239)	7.4	(239)
Feb	1.7	(59)	6.8	(241)	6.8	(241)
Mar	15.3	(494)	11.5	(371)	15.3	(494)
TOTAL	249		229		266*	

Values in Mcm, Nos in brackets are equivalent values in thousands of m^3d^{-1}

Please note that a calculation error in determining the pro-rata increase in the early stages of this study gave an annual water requirement of 262.5 Mcm rather than the value of 266 Mcm presented here. The value of 262.5 Mcm was used in model simulation runs. Table 6 and the main body of the text have been corrected, but the model run results and the tables referring to these results in section 7 remain unchanged. The small overall increase (1.5%) in the total irrigation abstractions that would arise from using the correct figure will not alter the conclusions of this report, presented in section 8.

In the simulation analysis that follows (section 7), the highest abstraction value, derived from either the stated requirement or average historic value, was taken to be the requisite future water right in each month. Table 6 includes a column with these maximum values. On the basis of these figures it is clear that while the peak dry season requirement (in September and October) will be greater than the present water right for the sugar industry allows, the total annual abstraction will be less than the present water rights permit. The present total water right for the sugar industry is 338 Mcm (Table 2), which corresponds to a maximum abstraction of 925,000 m^3d^{-1}. Using the maximum figures in Table 6, for the irrigation of 17,400 ha, the peak September requirement is 36.5 Mcm (i.e. 1,220,000 m^3d^{-1}), but the annual total is 266 Mcm i.e. 22% less than the total the present water rights allow.

Nakambala Sugar Estate: Irrigation distribution network

Schematic layout of pump stations and night storage dams

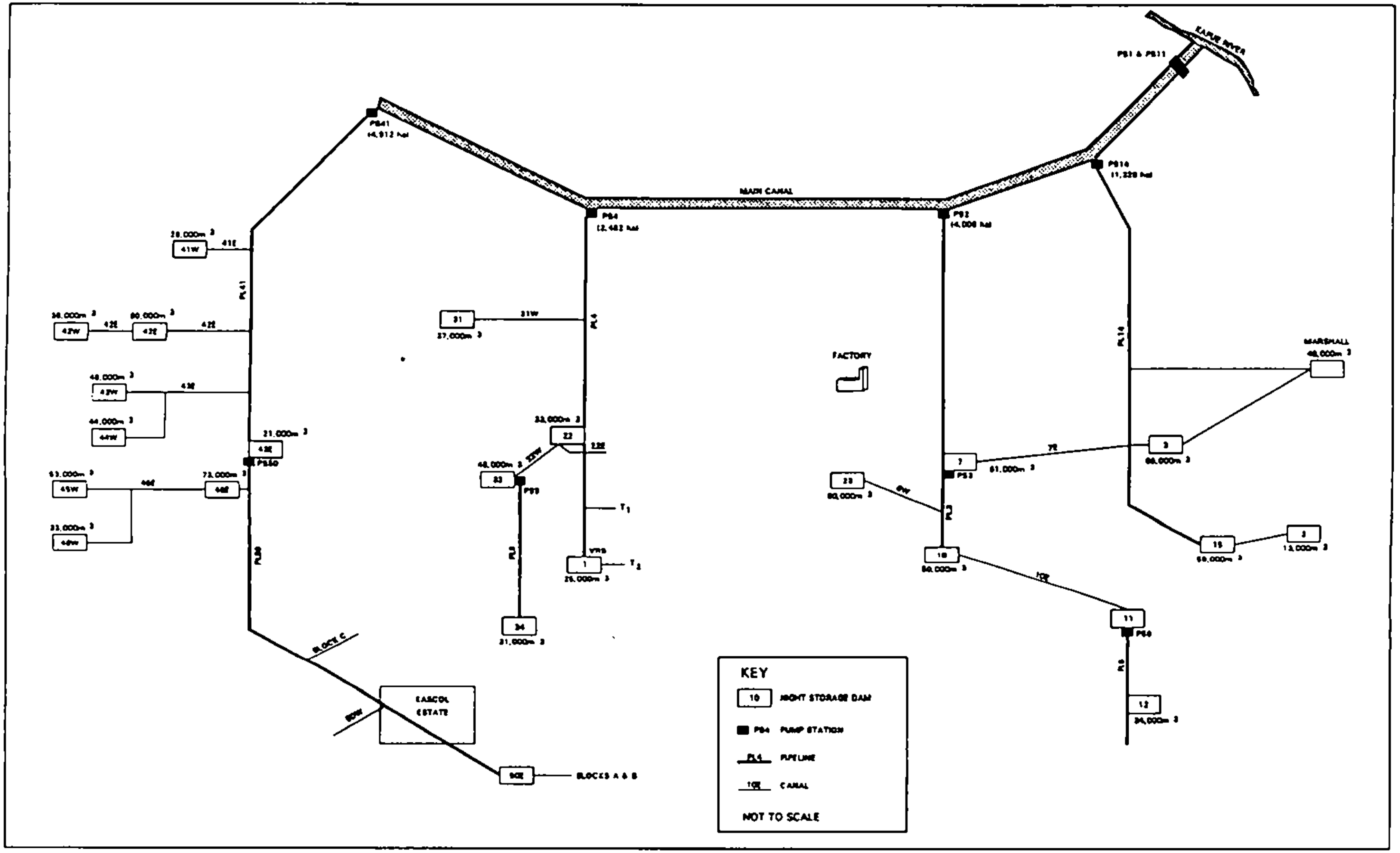
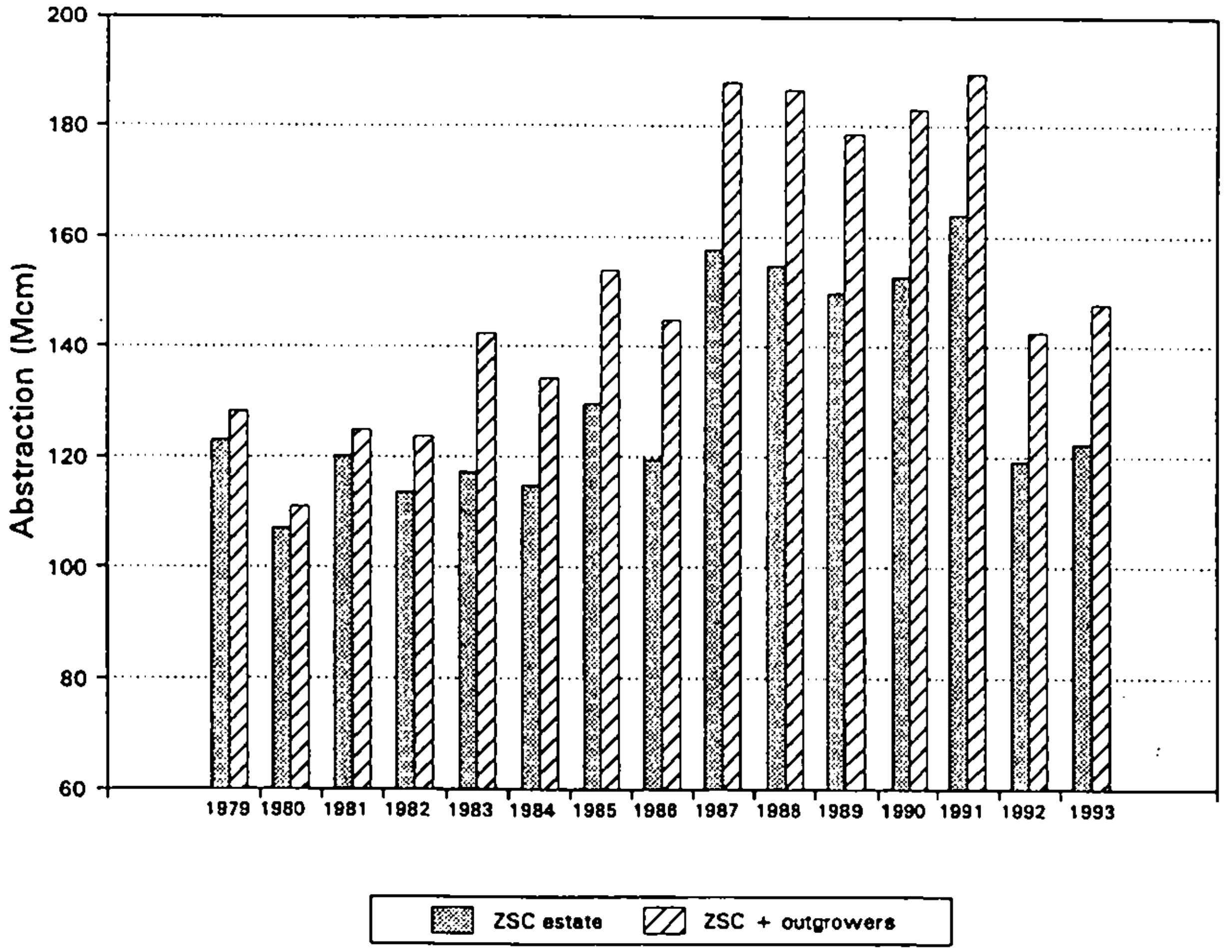


Figure 3



Nakambala Sugar Estate annual abstractions
(excluding town supply)

Figure 4

Nakambala Sugar Estate irrigation: comparison of historic monthly mean, maximum and minimum abstractions together with the ZSC stated requirement for 10,000ha

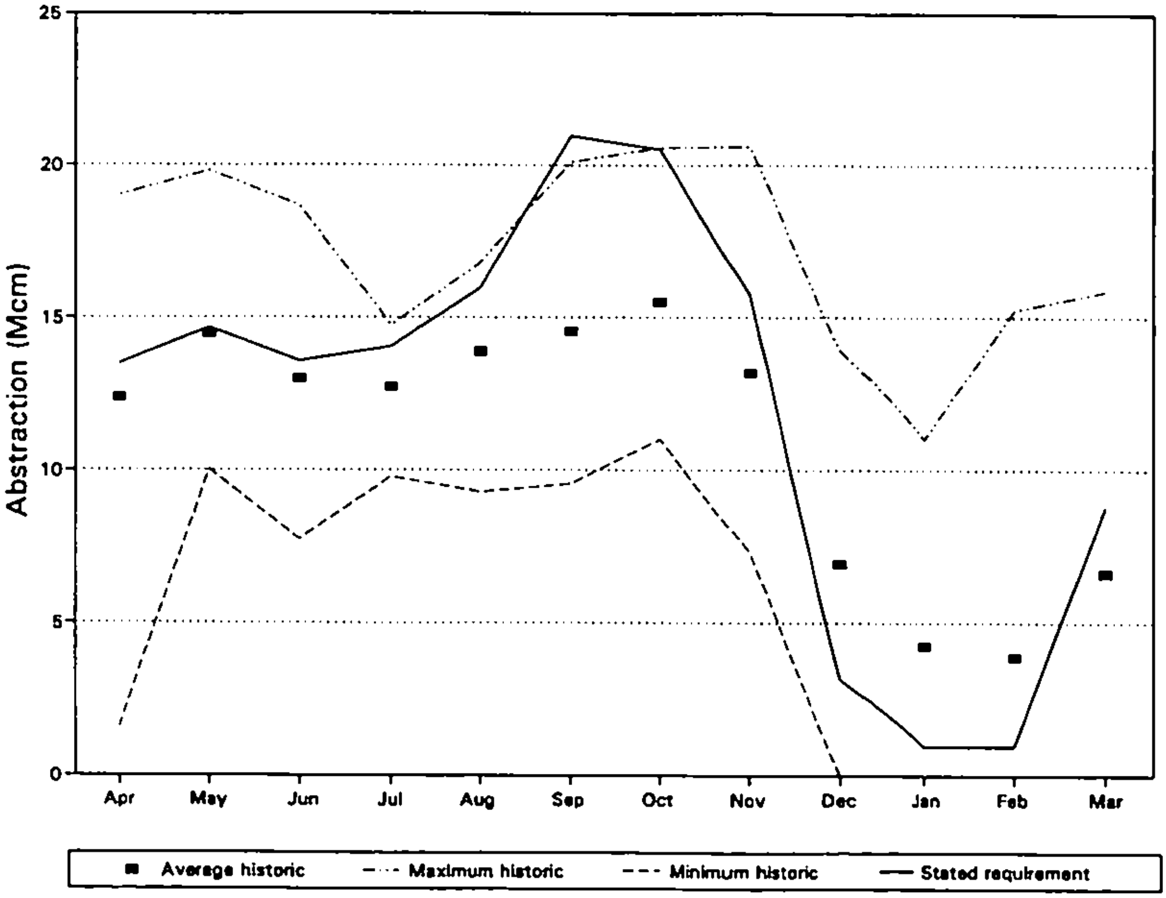


Figure 5

Nakambala Sugar Estate abstractions from the Kafue excluding the outgrowers and the town requirement

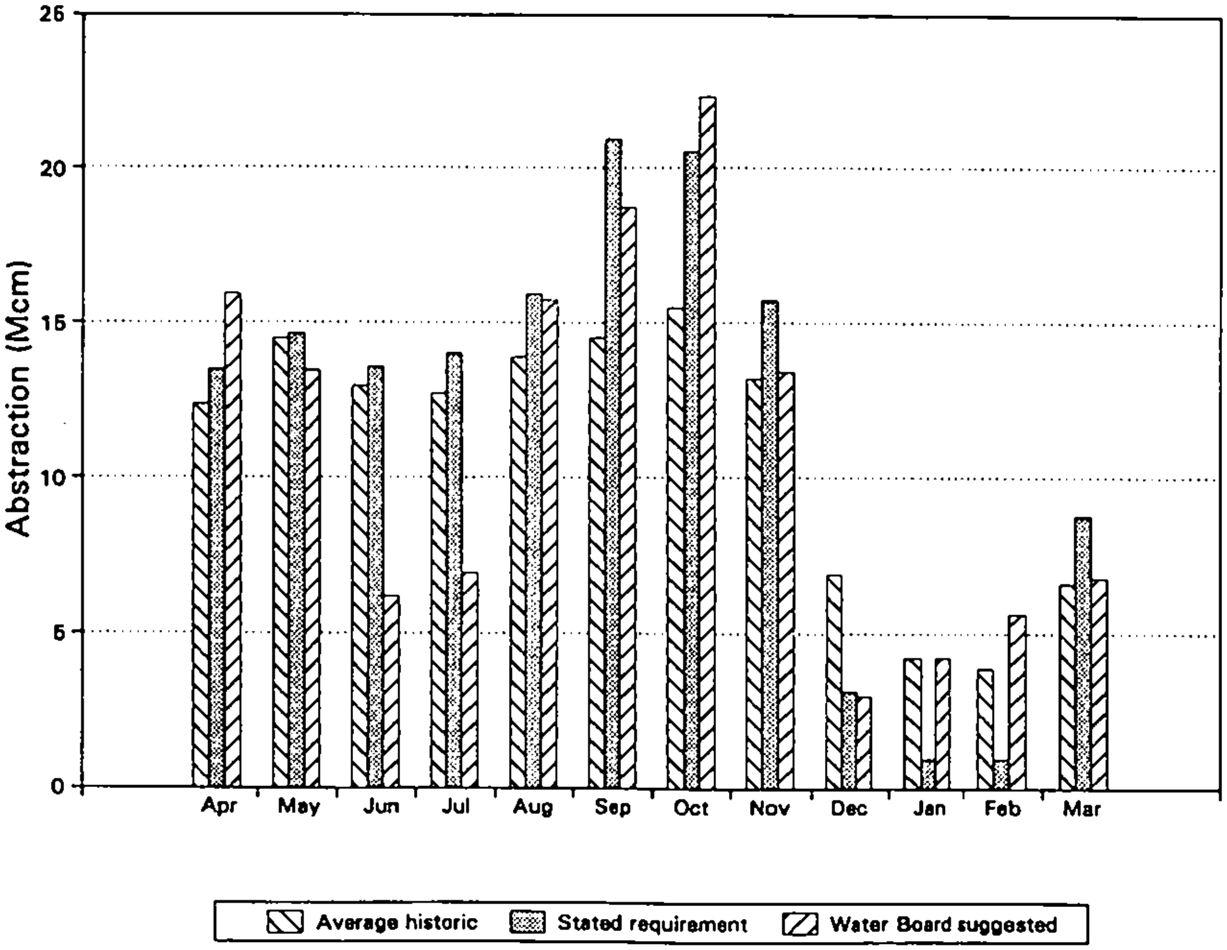


Figure 6

Future irrigation requirement for proposed 17,400 ha

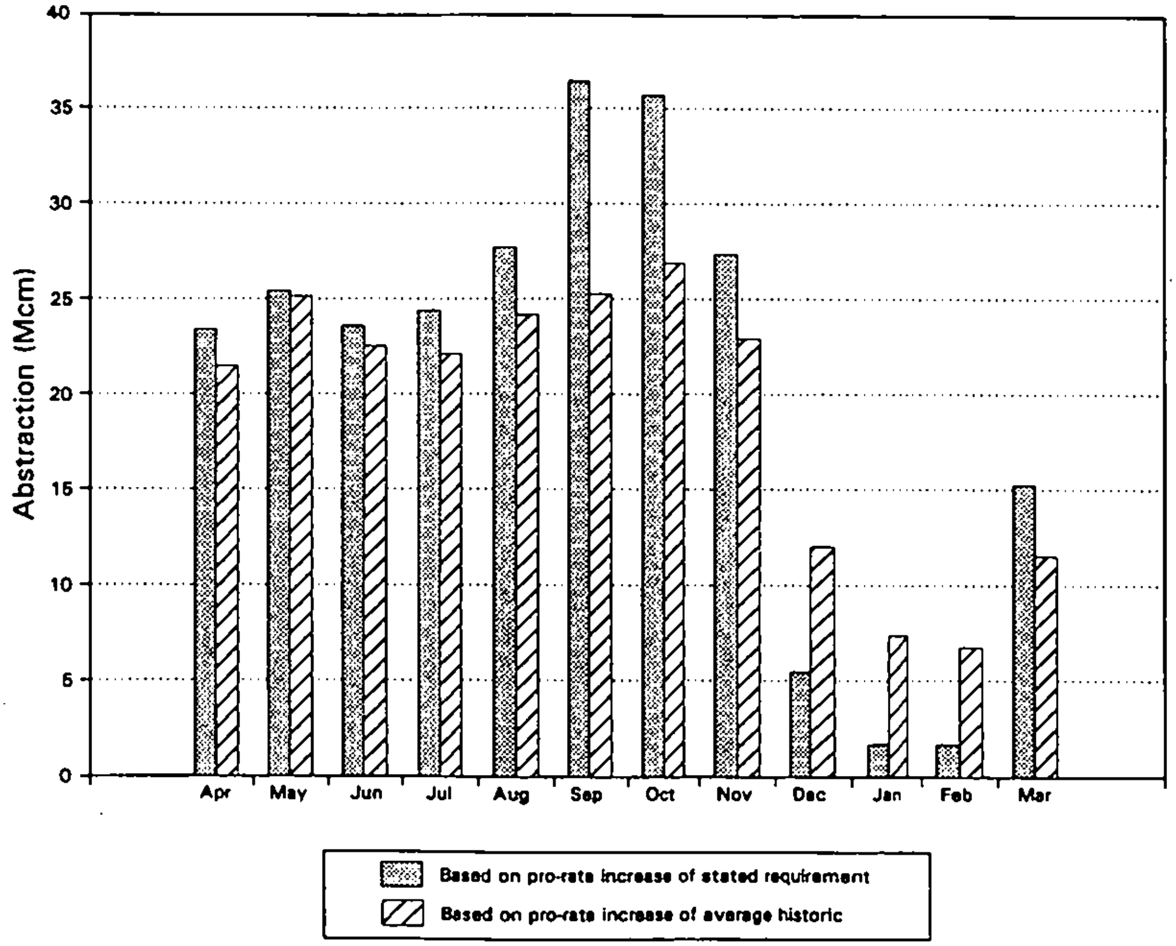


Figure 7

6. Data collection and processing

In this section details of the data collected, and the analyses done to derive the series required for the simulation of reservoir operation under both present conditions and future sugar cane irrigation scenarios, are given. The component hydrological inputs required to run HYDRO-PC are as follows:

- Itezhi-tezhi
  - inflow from the upper Kafue catchment
  - rainfall on to the reservoir
  - an estimate of open water evaporation from the reservoir surface
- Kafue Gorge
  - inflow, regulated by the Itezhi-tezhi reservoir
  - rainfall on to the reservoir
  - an estimate of open water evaporation from the reservoir surface

Also required were the reservoir characteristics for both Itezhi-tezhi and Kafue Gorge, as well as details relating to the production of electricity at Kafue Gorge (e.g. turbine ratings and efficiencies, etc.).

6.1 RAINFALL

Within the Kafue Basin there are two distinct seasons: the rainy season lasts for approximately five months from November through to March, and the dry season lasts from April through to October. DHV(1980) noted that "although a large areal variation in rainfall by shower can be observed, it has been concluded from previous surveys that the monthly and annual totals for stations within the study area differ only slightly". This is primarily attributable to the flat topography of the Kafue Flats area.

An isohyetal map of mean annual rainfall for the Kafue Basin, derived from 88 stations and published in SLHP (1990a) is reproduced in Figure 8. These data indicate that the Kafue Flats region receives an average annual rainfall of about 850 mm.

Data were obtained for five raingauges in the Kafue Flats area. Table 7 gives details of the gauges and the records collected from each gauge. The data from Nakambala Estate were provided as monthly totals by ZSC. The data from the Itezhi-tezhi meteorological station were provided as monthly totals by ZESCO. The data from the other stations were collected as monthly totals from the Zambia Meteorological Department. The longest record is that for the raingauge at Kafue Rail. At this station the record extends back to January 1910, but there is a break from July 1964 to June 1971. The record at Namwala Pontoon starts in July 1920, but since 1970 the record at this station is very poor with most years missing. These data are given in Tables B.4 to B.8 in Appendix B.

Time restrictions prevented detailed checking of the monthly rainfall data, but cumulative mass and double mass plots for each of the stations did not reveal any significant discrepancies in the data.

Table 7 Details of raingauges

Gauge No.	Name	Location	Altitude m	Period of Record	No. of complete years
2305	Kafue Rail	15°46'S 28°10'E		Jan 1910 - Feb 1993	71
2400	Kafue Polder	15°46'S 27°55'E	987	Jun 1956 - May 1994	35
2800	Namwala Pontoon	15°44'S 26°27'E	1000	Jul 1920 - Jan 1993	51
2402	Nakambala Sugar Estate	15°48'S 27°48'E		Jul 1965 - Mar 1994	28
460990	Itezhi-tezhi. ZESCO Met. Stn	15°45'S 26°01'E		Oct 1979 - May 1994	13

6.1.1 Rainfall at Itezhi-tezhi

In order to conduct the water balance on the Itezhi-tezhi reservoir (described in section 6.5.2) it was necessary to extend the rainfall measured at the Itezhi-tezhi meteorological station from October 1979 back to June 1977. For the simulation exercise, described in section 7, it was necessary to extend the rainfall even further back, to October 1905. Ideally the record would have been extended using a nearby raingauge, but the choice was restricted by record length and quality. The nearest gauge for which data were obtained is Namwala Pontoon, and although this gauge has a record back to 1920, it is very poor for the period after 1970. Therefore the principal raingauge used for extension was that at Kafue Rail, which has a record back to 1910. When Kafue Rail was not operating, the raingauge at Kafue Polder was used.

Figure 9a shows the double-mass plot for Itezhi-tezhi and Kafue Rail. There appears to be a change in the relationship between the two stations in February 1989, and inspection of the data for this month indicated that 581 mm were recorded at Kafue Rail while 189 mm were recorded at Itezhi-tezhi. For the same month 211 mm were recorded at Namwala Pontoon, 390 mm were recorded at Nakambala, and 516 mm were recorded at Kafue Polder. It therefore seems likely that in this month heavy rainfall occurred in the east, but not in the west, of the Kafue Basin. The isohyetal map of mean annual rainfall over the Kafue Basin (Figure 8) shows that in the southern area of the Kafue Basin there is a slight east-west trend with rainfall decreasing to the west (i.e. 800-850 mm in the vicinity of Itezhi-tezhi and 900-950 mm in the vicinity of Kafue town). If the 1989 year is removed from the analysis the correlation is improved, as shown in Figure 9b, and the following relationship is derived by regression:

$$\mathrm{RAIN}_{\mathrm{ITT}} = 0.9076\ \mathrm{RAIN}_{\mathrm{KAFUE}} \qquad R^2 = 0.72$$

where: $\mathrm{RAIN}_{\mathrm{ITT}}$ is the rain measured at Itezhi-tezhi
$\mathrm{RAIN}_{\mathrm{KAFUE}}$ is the rain measured at the Kafue Rail

This relationship was used to extend the rainfall record at Itezhi-tezhi from October 1910 to June 1964, and again from July 1971 to October 1979.

Figure 10a shows the double-mass plot for Itezhi-tezhi and Kafue Polder. Again, there appears to be a change in the relationship between the two stations in February 1989, with 516 mm being recorded at Kafue Polder compared to 189 mm at Itezhi-tezhi. Therefore, with the 1989 year again removed from the analysis, the correlation is improved, as shown in Figure 10b. The following relationship is derived by regression:

$$\mathrm{RAIN}_{ITT} = 0.8700\ \mathrm{RAIN}_{KP} \qquad R^2 = 0.68$$

where: RAIN_{ITT} is the rain measured at Itezhi-tezhi
RAIN_{KP} is the rain measured at the Kafue Polder

This relationship was used to infill the gap in the Itezhi-tezhi record between July 1964 and June 1971.

The Itezhi-tezhi record was extended back to October 1905 by infilling the 5 missing years with the mean monthly rainfall values from the rest of the record to produce an 88-year rainfall record for Itezhi-tezhi Reservoir.

6.1.2 Rainfall at Kafue Gorge

The water balance conducted on the Kafue Gorge reservoir (described in section 6.6) used the rainfall measured at Kafue Polder. Because of its location, this raingauge was felt to be more representative of the rain falling on the reservoir than Kafue Rail. However, for the simulation exercise, described in section 7, Kafue Rail, with the longest record was used. However, it was necessary to infill the period between July 1964 and June 1971, together with some odd months in the latter part of the record, and extend the rainfall back to October 1905. The principal raingauge used for infilling was that at Kafue Polder. The odd months were infilled from Itezhi-tezhi.

Figure 11 shows the double-mass plot for Kafue Rail and Kafue Polder. The relationship between the stations appears to remain fairly constant for the length of the record, and the following relationship is derived by regression:

$$\mathrm{RAIN}_{KAFUE} = 1.0510\ \mathrm{RAIN}_{KP} \qquad R^2 = 0.85$$

where: RAIN_{KAFUE} is the rain measured at Kafue Rail
RAIN_{KP} is the rain measured at the Kafue Polder

This relationship was used to infill the rainfall record at Kafue Gorge between July 1964 and June 1971.

To infill the few missing values in the more recent part of the record, the relationship between Itezhi-tezhi and Kafue Polder described earlier was simply rearranged to enable missing values to be filled in from observed values at Itezhi-tezhi. The months infilled in this way were October 1981, March and April 1982, and March 1993 onwards.

The Kafue Rail record was extended back to October 1905 by infilling the 5 missing years with the mean monthly rainfall values from the rest of the record to produce an 88-year rainfall record for Kafue Gorge Reservoir.

6.2 FLOW

The Department of Water Affairs (DWA) have responsibility for maintaining and collecting data from most of the hydrometric stations in the Kafue Basin. The JICA study team and ZESCO also collate the data from those stations which are interest to them. The location of all the stations mentioned in this section are given in Figure 2. A summary of station details is given in Table 8.

Table 8 Details of flow gauging stations

DWA Station No.	Name	Location	Catchment Area km²	Period of Record
4669	Kafue at Hook Bridge	14°56'S 25°55'E	95,053	Jan 1968 - still open
4670	Kafue at Hook Pontoon		95,053	Jun 1951 - Jul 1973
4710	Kafue at Itezhi-tezhi	15°46'S 26°01'E	105,672	Apr 1951 - 1975 (moved?)
4759	Kafue at Namwala Boma		116,450	1914-1940 & 1951-1966
4760	Kafue at Namwala Pontoon		116,450	Nov 1951 - 1966
4975	Kafue at Railway Bridge	15°48'S 28°11'E	148,265	1905 - still open
4977	Kafue at Kasaka	15°50'S 28°13'E	150,971	Aug 1943 - still open

6.2.1 Upstream of Itezhi-tezhi

As noted in SLHP (1990a), the primary hydrological component required for modelling the operation of the Itezhi-tezhi and Kafue Gorge system is the series of monthly inflows to the Itezhi-tezhi reservoir. Generally, flows in the Kafue river start to rise in December and reach a peak by mid-March, with a second lesser peak sometimes occurring in late April. From May the flow decreases steadily until November.

For the current study there are two gauging stations upstream of Itezhi-tezhi that are of particular interest; Hook Bridge and Kafue Hook Pontoon. The latter is located slightly nearer to Itezhi-tezhi. The catchment to Hook Bridge is 95,053 km² and makes up 90% of the catchment to Itezhi-tezhi dam, which itself has a catchment area of 105,670 km². The station at Hook Bridge was established in January 1968, with the intention that it would replace the station at Kafue Pontoon which was established in June 1951 and closed in July 1973. The Hook Bridge station is located 70 m downstream of the bridge carrying the Lusaka to Loma road and 15 km upstream of the old Kafue Pontoon. However, only occasional stage readings were made at Hook Bridge before the closing of Kafue Pontoon. Regular measurements commenced in September 1973. Henceforth the combined series is referred to as Kafue Hook.

6.2.2 At Itezhi-tezhi

A gauging station was established at Itezhi-tezhi in April 1951 at the request of the Central

African Inter-Territorial Hydro-Electric Power Commission. This station was located 0.5 km downstream of the confluence of the Kafue and the Musa tributary. The stage-discharge relationship at this station was controlled by the reach of the channel downstream of the gauge. Due to the flat slope of this channel, the stage-discharge relationship was influenced by variable backwater as the general stage in the upper Kafue Flats increased. This variable backwater produced shifts in the discharge of up to 40%. However, from the DWA station history file it is clear that, because this was such an important station prior to the construction of the dam, a considerable effort was made to determine reliable stage-discharge relationships at this location. For example, during the hydrological years 1961 to 1964, 252 current meter measurements were made; a single rating table was derived for rising stages, but four different tables were developed for falling stages.

A report in the station history file states that to extend the record at Itezhi-tezhi, stages measured here were correlated with stages measured at Namwala Boma, located 45 km east of Itezhi-tezhi, for the period 1952 to 1964. This correlation was used to extend the Itezhi-tezhi record back to 1914, but with a gap from 1939 to 1950 when the station at Namwala Boma was not operating. A note in SLHP (1990a) indicates that the Itezhi-tezhi station closed when dam construction commenced in 1975. However, there is still a DWA station 4710, located just downstream of the dam. It would therefore seem likely that the station was moved rather than closed in 1975, although no details of such a move were found in the station history file.

6.2.3 Downstream of Itezhi-tezhi

Between the Itezhi-tezhi and Kafue Gorge reservoirs there are several DWA stations. However, for much of the length of this reach the hydraulic characteristics make it unsuitable for conventional discharge measurement techniques. The station at Kasaka has better hydraulic characteristics, but this location was inundated by the Kafue Gorge reservoir in 1971. For this reason, and because the flow is now regulated by the Itezhi-tezhi reservoir, DWA have not attempted to update the rating equations of the stations between Itezhi-tezhi and Kafue Gorge. Consequently, there are level data for several locations, but there are no stations between the two reservoirs for which flow data can be determined for the period since the completion of the Itezhi-tezhi and Kafue Gorge reservoirs. However, there are useful historic records at some stations.

The station of most interest for the current study is the Kafue at Kasaka. This station has a catchment area of 150,971 km^2. A station was established here in August 1953. Prior to construction of the Kafue Gorge Dam, the stage-discharge was controlled by the downstream channel. Since February 1971, the stage has been controlled by the Kafue Gorge Dam and the operation of the turbines. The Kafue at Kasaka is 6.4 km downstream of a gauging station at the Kafue Rail Bridge. At the Rail Bridge stage has been measured since 1905, but no rating equation has ever been developed for this location. Through correlation of the stage measured at the Rail Bridge and that measured at Kasaka, it was possible to extend the flow record at Kasaka back to 1905. Details of the methodology used are given in the DWA station history file.

Several tributaries enter the Kafue between Itezhi-tezhi and Kafue Gorge. However, there are gauging stations only on a small number of these and time restrictions prevented examination of data obtained for these stations.

6.2.4 Previous work

SLHP (1990a) combined the records from the stations at Itezhi-tezhi, Namwala Boma, Kafue Hook and Kasaka to produce a monthly flow series for the Kafue at Itezhi-tezhi for the period October 1905 to September 1989. The details are described in SLHP (1990a). From the description of the analysis given in SLHP (1990a) it is not clear if, for the period since September 1973 when Hook Bridge flows have been used, an allowance was made for the contribution of inflow from the catchment between Hook Bridge and Itezhi-tezhi. However, it is believed that the same data series was used in the development of the reservoir operation program KAFGEN, described in Shawinigan (1993a), and here it is noted that local (tributary) inflow between Kafue Hook and Itezhi-tezhi was ignored, although it is acknowledged that during the wet season, a substantial amount of incremental inflow can come from the extra catchment between Hook Bridge and Itezhi-tezhi Dam.

Shawinigan (1993a) found discrepancies in observed and simulated levels (determined using KAFGEN) within the Itezhi-tezhi reservoir, and noted that these were most likely attributable to the fact that the stage-discharge relationship established at Hook Bridge underestimated flows for low stages. Subsequently a new rating equation has been developed by ZESCO for this station.

Burke *et al.* (1994) published a hydrograph of monthly flow for Kafue Hook covering the period 1905 to 1993. These data were obtained for the current study (Burke, personal communication). This series is the same as that published as the unregulated flow series at Itezhi-tezhi by SLHP (1990a) for the period up to February 1952 (i.e very soon after the station at Itezhi-tezhi opened). After this date the two series are slightly different, with the Burke series sometimes being greater and sometimes less than that published by SLHP (1990a). The difference is discussed further in section 6.2.5.

6.2.5 Current study

In the current study the various ratings used at Hook Bridge, from September 1973, for the stage-discharge relationship were compared. A total of 108 current meter measurements covering the period from 15/03/73 to 10/05/94 were provided by ZESCO. Figure 12 compares these measurements with the rating equations presently used by ZESCO (Mwasile, SADC Project Manager, ZESCO, personal communication), DWA (DWA station history file) and JICA (Ngata, JICA hydrologist, personal communication). The two-part rating equation used by ZESCO provides the best fit to the data, and so this rating equation was used in this study. The rating is as follows:

$$Q = 61.063(h - 0.767)^{2.800} \qquad hmax = 2.20m$$
$$Q = 304.938(h - 1.531)^{1.395} \qquad hmax = 6.50m$$

It was assumed that this rating had not changed over time and it was applied to the daily stage measurements (also provided by ZESCO) for the period September 1973 to April 1994. The daily flows were converted to mean monthly flow and these are given in Table B.9 (Appendix B). In those months where fewer than 5 consecutive stage values were missing the daily flows were infilled by interpolation and marked as estimated. The computed monthly flow was then also marked as estimated (i.e. 'e' in Table B.9). If more than 5 days were missing the mean monthly flow was not computed and is set missing in Table B.9. The monthly data series thus produced is believed to be the best Hook Bridge series presently available for the period

September 1973 to April 1994.

Relationships between the flow at Kafue Hook and the inflow to Itezhi-tezhi were developed, in order to allow estimates of the intermediate inflow to be derived. Two relationships were derived, one for the wet season (November to April) and one for the dry season (May to October). The flow at the two locations were compared for the period when flow was measured simultaneously at Itezhi-tezhi and Kafue Hook Pontoon (i.e. February 1952 until July 1973). Figure 13 is a time series plot of the difference in flow between the two stations. It would seem that there is sometimes a net gain, and sometimes a net loss, in the reach from Kafue Hook to Itezhi-tezhi. Figures 14a and 14b are scatter plots of the flow at Itezhi-tezhi against the flow at Kafue Hook, for the wet and dry seasons respectively. There is clearly a lot of scatter but from linear regression the following equations were derived:

Wet season:	$Q_{ITT} = 1.082Q_{KH} + 30.573$	$R^2 = 0.96$
Dry season:	$Q_{ITT} = 1.103Q_{KH} - 5.818$	$R^2 = 0.97$

where: Q_{ITT} is the flow at Itezhi-tezhi
Q_{KH} is the flow at Kafue Hook

No attempt was made to allow for time-lag in the flow measured between the two stations.

The long Itezhi-tezhi flow series, from October 1905 to September 1993, used as input in the Itezhi-tezhi simulation study was made up from two sources. From October 1905 to September 1974, the record used was as published in SLHP (1990a) and described in section 6.2.4. From October 1974 to September 1993, the record used was the inflow series as derived from the Hook Bridge flows using the relationships described above. A few months of Hook Bridge flow data were missing: April 1982 and June and September 1989; the Itezhi-tezhi inflows were therefore infilled for these months from the water balance figures (described in section 6.5.2).

6.3 EVAPORATION

Evapotranspiration[1] is a very significant component of the water-balance of the Kafue Basin. At the entrance to the Kafue Gorge at Kasaka, mean annual flows amount to approximately 66 mm, which represents only 6.2% of the average catchment rainfall of 1060 mm (Burke *et al.*, 1994). Of principal concern to the current study is the evaporation from the Itezhi-tezhi and Kafue Gorge reservoirs. Several previous studies have produced estimates of evapotranspiration within the Kafue Basin. A detailed review of all the work up to 1980 is given in DHV(1980). The most salient points of the DHV study and work published since 1980 are described below. Also considered are the effects of the aquatic vegetation present in the Kafue Gorge reservoir, which may affect the evaporation losses.

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[1] In this report a distinction is made between evaporation, the loss of water from a free water surface, either open water or a wet surface such as soil or wet vegetation, and transpiration, loss of water through transpiring vegetation. This latter process involves movement of water through the stomatae of plant leaves, which can be employed by the plants as a water conservation measure to suppress actual water loss during periods of water scarcity. Evapotranspiration is used in this report to mean combined water loss to the atmosphere through direct evaporation from open water and also through transpiring vegetation.

6.3.1 Pan evaporation

Pans can provide a useful estimate of evaporation but the need to apply a coefficient to pan data limits their usefulness in a wider context. It is often necessary to estimate pan coefficients from other estimates of evaporation within the region. The pan coefficient typically varies from 0.6 to 0.9 throughout the world.

DHV(1980) reported average monthly data for class A pan evaporation from 4 stations within or on the perimeter of the Kafue Flats, namely: Kasaka, Namwala Pontoon, the National Irrigation Research Station at Kafue Polder and Mount Makulu. For the first two stations average values determined over three different periods are reported: 1959-1968, 1963-1968 and 1971-1977. At Kafue Polder and Mount Makulu the data are reported for two periods: 1963-1970 and 1968-1977. The choice of periods was determined primarily by the availability of data. The results converted from mmd^{-1} to mean monthly totals are given in Table 9. DHV(1980) report that errors were observed at Namwala Pontoon in determining evaporation during rainy periods.

SLHP (1990a) also gives mean monthly pan evaporation observations for the Kasaka and Namwala Pontoon stations. However, the periods over which the data were obtained are not given, and the quoted Namwala Pontoon data are different from those published in the DHV(1980) report. These are compared with pan data collected by the current study for the pans at Itezhi-tezhi (1978 - 1994), Kafue Polder (1968 - 1994) and the meteorological station on the Nakambala Sugar Estate (1965 - 1994) in Table 9. SLHP (1990a) questions the validity of the Itezhi-tezhi data, particularly in the last few years, stating that there may have been errors in the observation procedure.

Omitting the data from the Itezhi-tezhi and Namwala Pontoon pans, it can be concluded that, for the remaining stations, the data for the different periods are very consistent and the difference between stations is minor. The average pan evaporation for the Kafue Flats, determined using the data from these stations is approximately 2030 mm annually.

DHV (1980) state that in previous studies of the Kafue Flats, a pan coefficient of 0.86 has been applied to convert the pan data to open water evaporation figures. If applied to 2030 mm this would give an estimate of annual open water evaporation of 1745 mm. However, when comparing pan data with estimates of open water evaporation determined by other methods, DHV(1980) concluded that, on an annual basis, the pan results were comparable with the open water (reservoir) evaporation, and consequently a pan coefficient need not be applied. In SLHP (1990a) a reservoir to pan ratio of 0.79 was estimated, which if applied in this case would give an annual open water evaporation of 1605 mm.

6.3.2 Evapotranspiration based on water balances

Sharma (1988), in a study of evapotranspiration in tropical central Africa, conducted a water balance of the Lukanga swamps in the upper Kafue Basin. From the water balance, which was based on 20-year runoff records at Chilenga (upstream of the swamps) and Mswebi (downstream of the swamps), Sharma derived an estimate of annual evaporation of 1800 mm.

Table 9 Mean monthly pan evaporation estimate (mm)

	From DHV (1980)										From SLHP(1990a)		Current Study		
	Kasaka			Namwala Pontoon			Kafue Polder		Mount Makulu		Kasaka	Namwala Pontoon	Itezhi-tezhi	Kafue Polder	Nakambala
	1959-1968	1963-1968	1971-1977	1959-1968	1963-1968	1971-1977	1963-1970	1968-1977	1963-1970	1968-1977			1978-1994	1968-1994	1965-1994
Jan	143	136	130	158	164	164	149	149	124	124	137	155	177	130	136
Feb	102	122	102	138	147	141	130	130	113	116	117	130	143	121	121
Mar	152	161	127	174	183	171	164	164	146	133	150	169	165	143	143
Apr	144	150	138	165	174	156	180	162	150	144	150	165	200	150	155
May	143	143	136	155	164	155	162	150	138	141	142	148	198	146	154
Jun	126	126	126	132	138	135	138	138	123	129	127	128	175	132	140
Jul	143	140	136	146	152	152	164	155	143	158	140	144	193	146	160
Aug	186	186	177	186	195	189	186	189	198	192	185	186	246	183	205
Sep	234	231	225	237	240	249	225	219	255	258	238	234	304	222	248
Oct	291	279	267	288	288	295	270	233	288	279	290	279	310	245	267
Nov	198	207	216	225	213	249	189	201	201	204	202	187	246	201	204
Dec	155	161	149	174	189	202	146	158	152	143	150	162	200	146	156
TOTAL	2016	2041	1930	2178	2248	2257	2103	2048	2031	2021	2028	2087	2556	1965	2089
	Mean 1959-1977 = 1973			Mean 1959-1977 = 2218			Mean 1963-1977 = 2076		Mean 1963-1977 = 2026						

Mumeka (1992) estimated evapotranspiration (i.e. combined open water evaporation and transpiration from vegetation both in the water and on land) from the Kafue Flats on the basis of a water balance. This estimate is based on the inflow to the Kafue Flats at Itezhi-tezhi and outflow at Kasaka. The area of the Flats was assumed to be 7,000 km^2 and mean annual rainfall was estimated as 800 mm. Using these figures, a mean annual evapotranspiration of 947 mm was derived. The paper also reports the findings of Balek (1971) who quoted an annual estimate of evapotranspiration from the Kafue Flats of 991 mm also based on a water balance calculation. No estimates of open water evaporation were stated explicitly, but the conclusion drawn in the Mumeka (1992) paper is that "the over-estimates of evaporative demand used in the design of the Itezhi-tezhi and Kafue Gorge reservoirs may have resulted in an unnecessary low flow of water released to the Kafue Flats". However, the years over which the calculations are based are not given (in particular it is not clear if the results are determined for the time before or after the closing of the Itezhi-tezhi reservoir), and it is not clear if account has been made for inflow into the Flats from rivers other than the Kafue. As DHV(1980) note "evaporation can only be determined from water balances of the Kafue Flats, once further insight is gained into the hydrology of the area".

SLHP (1990a) give no details of their analysis, but state that a water balance computation carried out on monthly data obtained from the operation of the Itezhi-tezhi Reservoir, for the period extending from May 1977 to September 1989, resulted in an annual open water evaporation of 1620 mm.

In the current study an attempt was also made to determine the open water evaporation directly from the water balance of the Itezhi-tezhi reservoir. The details of the approach used are given in section 6.6. Figure 17 shows the monthly evaporation figures derived from the water balance analysis. In some months the computed evaporation is negative, while in others it is far too high (e.g. greater than 1500 mm in a month). Possible reasons for these unrealistic results are given in section 6.5.2

6.3.3 Evaporation based on hydrometeorlogical data

DHV(1980) present results for open water evaporation determined using the Penman equation for the stations at Kafue Polder and Mount Makulu for the periods 1959 to 1968 and 1968 to 1977. These results converted from mmd^{-1} to mean monthly totals are given in Table 10. DHV (1980) concluded that there are no major differences between the stations and that the inter-annual variability at each station is relatively small. However, the values for the period 1968 to 1977 are consistently some 10% higher than for the period 1959 to 1968, and are more similar to the unadjusted pan data.

Sharma (1988) compared open water evaporation estimates determined using the Penman and Morton methods (both of which relate potential evaporation to meteorological factors) with the estimate obtained from a water balance calculation for the Lukanga swamp (see section 6.3.2). For both methods Sharma used meteorological data collected at Ndola airport. The local mean annual open water evaporation determined by the Penman method was 1790 mm, very similar to the value (1800 mm) he obtained from the water balance calculation. Monthly variations of open water evaporation determined by the Morton method followed a roughly parallel curve to the that produced by the Penman method, but yielded a mean annual open water evaporation of 1500 mm, about 15% less than that determined by the Penman method. Sharma concluded that the Penman method was to be preferred over the Morton method because it is based on fewer empirical relationships.

SLHP (1990a) published mean monthly open water evaporation estimates derived using the Penman equation and meteorological data from Kasaka, Namwala Pontoon and Mumbwa, collected between 1959 and 1968. These values are given in Table 10, and indicate that the mean open water evaporation is about 1770 mm annually. However, the mean net monthly open water evaporation data used in analysis in this study were the same as the values published in Watermeyer, Legge Piehold and Ulhmann (1972) corresponding to an annual figure of 1620 mm (confusingly exactly the same value that SLHP (1990a) obtained using the water-balance method). It could be argued that the use of this lower figure makes allowance for the possible effects of advection, although this is not explicitly stated. Advection may reduce evaporation by cooling air and increasing its humidity as it flows over the water. Since the basis of the Penman estimates are data obtained from meteorological stations located on land they may overestimate the open water evaporation from a large body of water.

Table 10 Mean monthly open water evaporation (mm) by the Penman method

	From SLHP (1990a)			From DHV (1980)			
	Kasaka	Namwala	Mumbwa	Kafue Polder		Mount Makulu	
	1959-1968	1959-1968	1959-1968	1959-1968	1968-1977	1959-1968	1968-1977
Jan	161	171	161	171	186	158	174
Feb	140	148	140	147	172	141	158
Mar	164	167	155	171	195	161	183
Apr	141	144	138	150	180	147	168
May	118	115	115	124	164	127	152
Jun	96	93	96	105	135	105	123
Jul	107	102	109	112	152	115	143
Aug	133	130	143	143	183	152	183
Sep	174	168	174	183	243	195	228
Oct	214	205	205	226	267	226	260
Nov	180	177	155	189	222	180	207
Dec	161	164	135	177	195	161	174
TOTAL	1784	1784	1746	1896	2294	1868	2152

6.3.4 Effect of vegetation

Aquatic vegetation effects the evapotranspiration from a water body in two opposing ways:

- the higher albedo (reflection) of vegetation may reduce evaporation.
- the increased turbulence over the rougher surface of the vegetation may increase evaporation.

From a review of swamp evaporation studies, DHV(1980) concluded that there is no simple answer to the question of how the growth of vegetation or its removal, would affect net evapotranspiration from a given body of water. What information is available on the transpiration of wetland species especially in tropical regions is well covered in the DHV report. However, it is clear that the amount of information, and the ability to draw consistent trends from it, is limited. The same can be said of the findings of a similar study conducted in Botswana (Snowy Mountains Engineering Corporation, 1987). The range of variation in evapotranspiration of wetland species is not well understood and, at present, the use of ratios of vegetation to open water evaporation is based on fragmentary evidence, with considerable extrapolation for plant species and locality required.

DHV (1980) rejected statements in earlier reports (e.g. White, 1968; SWECO, 1969,1971 and 1973) that evapotranspiration from inundated areas covered with plants may be 3 to 4 times open water evaporation, stating that these were excessively high. The considered conclusion of DHV was that, under most natural conditions, the ratio of transpiration from swamp plants to open water evaporation will vary between 0.6 and 1.5, depending on the species of plant. Particularly high values (1.45) are obtained for water hyacinth. For large water surface of which only a minor part is occupied by swamp vegetation, evapotranspiration losses should be equal to open water evaporation. DHV(1980) stated that this should apply to both the Itezhi-tezhi and Kafue Gorge reservoirs. However, at the time of the DHV(1980) report there had been no survey of vegetation in the Kafue Basin since the construction of the Itezhi-tezhi dam. Furthermore, since Itezhi-tezhi was not completed until 1978, it is unlikely that the ecology of the area would have changed significantly by 1980, as a consequence of the new aquatic regime caused by regulation of the river downstream of Itezhi-tezhi.

Snowy Mountains Engineering Corporation (1987) concluded that "the data available on the total evaporation losses from large swamps is very limited but the information that is available does tend to show that it is less than that from an equivalent area of open water".

SLHP (1990a) published open water flooded area results derived from a satellite interpretation study, carried out by Turner (1985) on LANDSAT observations of the Kafue Flats between 1981 and 1984. Using these data and the levels measured at Nyimba on the dates corresponding to the satellite observations, SLHP (1990a) concluded that a large part of the storage within the Kafue Flats is under vegetation cover. For example, in April 1984 it was estimated that approximately 64% of the flooded area was vegetation covered.

As a consequence of these results, SLHP (1990a), in their simulation of the Itezhi-tezhi and Kafue Gorge system, adjusted estimates of open water evaporation upwards for the Kafue Gorge reservoir because of the "weed covered nature of the water body". The factor applied to the open water evaporation was 1.2. This figure was determined by trial and error using a simple water balance procedure in which a crude estimate of tributary inflow to the Flats was determined. However, in SLHP (1990b) a factor of 1.3 was recommended.

6.3.5 Summary

Table 11 summarises the open water evaporation estimates obtained from the different authors by various methods.

DHV (1980) concluded that, on the basis of the most up to date information then available, open water evaporation is roughly equal to pan evaporation on an annual basis. However, over shorter periods, pan evaporation data are not as reliable as Penman calculated estimates of open water evaporation.

Table 11 Summary of annual open water evaporation estimates (mm) for the Kafue Basin

Method of Estimation							
Pan	**Water Balance**			**Morton**	**Penman**		
(All reliable data)	**Mumema**	**Sharma**	**SLHP**	**Sharma**	**Sharma**	**DHV**	**SLHP**
2030	??	1800	1620	1500	1790	2050	1770 or 1620

The exact origin of the monthly evaporation figures in SLHP (1990a) is unclear. The annual total of 1620 mm corresponds to the figure derived from a water balance. The figures quoted for the Penman equation result in an annual total of 1770 mm. However, the report states that the monthly values were derived using the Penman equation. Whatever the origin of these figures, no consideration is made of the more up to date Penman data published in DHV(1980). A factor of 1.2 was applied to evaporation from the Kafue Gorge reservoir to allow for vegetation growing in the reservoir. These same data were used in the more recent Shawinigan (1993a) study. In SLHP (1990b) a factor of 1.3 was assumed.

JICA (1992), in determining water balances for the Itezhi-tezhi and Kafue Gorge reservoirs, used the same mean monthly data as SLHP (1990a), but made no allowance for the aquatic vegetation in the Kafue Gorge reservoir.

6.3.6 Current study

Ideally the current study would have made use of what was considered to be the "best estimate" published evaporation series. However, as described in this section, there is some considerable variation in the estimates by different authors and methods. Of the three methods the water balance figures were rejected due to the inconclusive results given by the attempt to reproduce the published figures. Pan data are generally not considered to be as reliable as Penman data and so were also rejected. The Penman data were considered to be most reliable, and in using them in the current study, the authors wished to incorporate as wide a data set as possible. Penman figures were available from 5 sites: Kasaka, Namwala Pontoon, Mumbwa, Kafue Polder and Mount Makulu, the former three published in SLHP (1990a) with data from 1959 to 1968, and the latter two in DHV (1980) with data from 1959 to 1968 and from 1968 to 1977. An average of the 5 sites for the period 1959-68 would use the largest number of sites. However, as noted, the 1968-77 figures for Kafue Polder and Mount Makulu were some 10% higher then the 1959-68 figures, and it was considered important to use these higher values, which would unfortunately reduce the data set to only two sites.

Table 12 Correlation coefficients for monthly Penman evaporation estimates from different meteorological stations in the Kafue Basin

	Kasaka	**Namwala**	**Mumbwa**	**Kafue Polder**
Namwala	0.986			
Mumbwa	0.948	0.931		
Kafue Polder	0.998	0.983	0.939	
Mount Makulu	0.971	0.928	0.964	0.970

Correlation on mean monthly evaporations at the 5 sites for the period 1959-68 gave very strong relationships as shown in Table 12. Figures vary from 0.928 between Namwala Pontoon and Mount Makulu, to 0.998 between Kasaka and Kafue Polder. The average percentage increases in evaporation between the two periods 1959-68 and 1968-77 were calculated for Kafue Polder and Mount Makulu on a month-by-month basis. These increases were applied to the 1959-68 values at the other three sites to effectively generate mean monthly evaporation figures for these sites for the period 1968-77. The current study then uses an average of Penman open water evaporation estimates at 5 sites as the definitive evaporation series. This approach incorporates the maximum amount of reliable data from the maximum number of sites. Table 13 shows the derived mean monthly evaporation figures, summing to an annual total of 1980 mm. These values were used for both the Itezhi-tezhi and Kafue Gorge reservoirs, since the net affect of the vegetation on the evaporation from the Kafue Gorge reservoir is unresolved. However, as reported, the potential effect of vegetation could be quite significant, and a specific study to assess these effects might be worth considering.

Table 13 Mean monthly open water evaporation figures

	Eo mm
Jan	172
Feb	154
Mar	176
Apr	157
May	136
Jun	109
Jul	125
Aug	157
Sep	202
Oct	233
Nov	191
Dec	168
TOTAL	1980

6.4 RESERVOIR CHARACTERISTICS AND HYDROPOWER GENERATION DETAILS

The important physical features required to model the storage and releases from the Itezhi-tezhi and Kafue Gorge reservoirs were obtained from the various ZESCO reports.

6.4.1 Itezhi-tezhi Reservoir

The Itezhi-tezhi dam is a 65 m high earth-rockfill structure. A chute spillway fitted with three radial gates is used for flood control and regulated releases for reservoir elevations above 1018.7 masl. The spillway has a capacity of 2610 m^3s^{-1} with the reservoir at the full supply level. The value of 2610 m^3s^{-1} is equivalent to the 1:10,000 year flood peak after routing through the reservoir, as estimated in the Itezhi-tezhi feasibility study (Shawinigan, 1993a). One of two concrete diversion tunnels at the dam right abutment is fitted with a radial gate and is used for making regulated releases when reservoir elevations are below 1022.0 masl. Details of the computation of the discharge from the gated spillway and regulation gate at Itezhi-tezhi are given in Shawinigan (1993b).

The full supply level (FSL) is set at 1029.5 masl and the lower supply level (LSL) or minimum operating level is set at 1006.0 masl. These two limits provide a live storage of 4925 Mcm (SLHP, 1990a). Table B.10 (Appendix B) gives the volume and area corresponding to different elevations. The volumes are the revised volumes determined by SLHP(1990a); these differ slightly (but less than 2% as far as the live storage is concerned) from those determined in the feasibility studies.

SLHP (1990a) used HEC-3 to develop a lower rule curve for the Itezhi-tezhi reservoir. The aim of the curve is to reduce spillage and hence increase average and secondary energy generation, while maintaining the firm capability. The curve was refined slightly in the later Shawinigan (1993a) study. The rule, which is defined by a set of end-of-month levels or storages, is "a statistical one, based on the properties of the flow sequence used, and can be applied independently of flow factors. It is therefore of particular use when long-term planning is undertaken in the absence of reliable knowledge of the flows to come, especially the wet season flows. It can be considered as a conservative approach to efficient generation, i.e. one that minimises the risk of reservoir failure to meet the firm demand, while also reducing spillage" (Shawinigan, 1993a). Table 14 lists the end-of-month levels and storages, and the rule curve is shown graphically in Figure 15.

Table 14 Itezhi-tezhi Reservoir, lower operating rule curve

Month	End of month level m	End of month storage Mcm
Oct	1025.0	4118
Nov	1024.0	3827
Dec	1023.5	3689
Jan	1023.8	3772
Feb	1024.5	3973
Mar	1026.0	4424
Apr	1028.0	5084
May	1029.3	5550
Jun	1029.5	5624
Jul	1029.3	5550
Aug	1028.5	5262
Sep	1027.5	4915

Shawinigan (1993a) conducted a flood frequency analysis to assess the adequacy of the Itezhi-tezhi spillway and to evaluate the necessity for a flood rule curve. The study concluded that the spillway cannot, by itself, pass the 10,000 year flood without unacceptably high reservoir levels being reached. The emergency fuse spillway at Itezhi-tezhi is therefore an essential feature of the structure. Furthermore, the live storage of the reservoir, while providing significant seasonal regulation for generation purposes, is small compared to the total flood volume for an above average wet year. Therefore, it is not advantageous to lower the reservoir below the lower rule curve by spilling in anticipation of a flood. The lower rule curve should constitute the guide for operation during the wet season.

6.4.2 Kafue Gorge Reservoir

The Kafue Gorge dam raises the river some 45 m above its normal level. There is a single intake fitted with a wheel gate (sill elevation 958.3 masl). A 9.8 km headrace (mostly unlined with a cross sectional area of 117 m^2) leads to six vertical penstocks each 370 m long. An underground powerhouse is fitted with six francis turbines, each nominally rated at 150 MW and guaranteed to operate satisfactorily over a head range of 360 to 396 m (Shawinigan, 1993b). Shawinigan (1993b) also gives details of the turbine output and efficiency over a range of net heads.

There is a water surface slope observed from Kasaka to the Kafue Gorge Dam. The slope becomes more pronounced as the flow released from the reservoir through the turbines and spillway is increased. Since the greater part of the reservoir storage is upstream of Kasaka, the level at Kasaka gives a more accurate indication of the storage in the reservoir than the level measured at the dam (Shawinigan 1993a). The following figures therefore relate to the level measured at Kasaka.

The maximum storage level of the reservoir is set at 977.2 masl, but the normal maximum operating level is 976.6 masl. The normal minimum operating level is 975.4 masl with an extreme minimum level of 972.3 masl. The live storage at the maximum storage level is 785 Mcm. Table B.10 (Appendix B) gives the volume and area corresponding to different elevations. A chute spillway fitted with 4 radial gates has a maximum discharge capacity of 4,250 m^{3}s^{-1}, again the 1:10,000 year flood (Shawinigan, 1993b).

The normal operation rule curve for Kafue Gorge is shown in Figure 16, and the corresponding levels and storage values are given in Table 15. The main principle of operation is to keep the Kafue Gorge Reservoir elevation at the lowest possible level in order to minimise losses through evaporation. At the minimum level the reservoir has enough storage to meet the variation in power generation from day-to-day and week-to-week (SLHP, 1990b).

Table 15 Kafue Gorge Reservoir, operating rule curve

Month	End of month level masl	End of month storage Mcm
Oct	975.4	240
Nov	975.4	240
Dec	975.8	345
Jan	976.2	550
Feb	976.6	785
Mar	976.6	785
Apr	976.1	475
May	975.8	350
Jun	975.4	240
Jul	975.4	240
Aug	975.4	240
Sep	975.4	240

6.4.3 Historic reservoir data

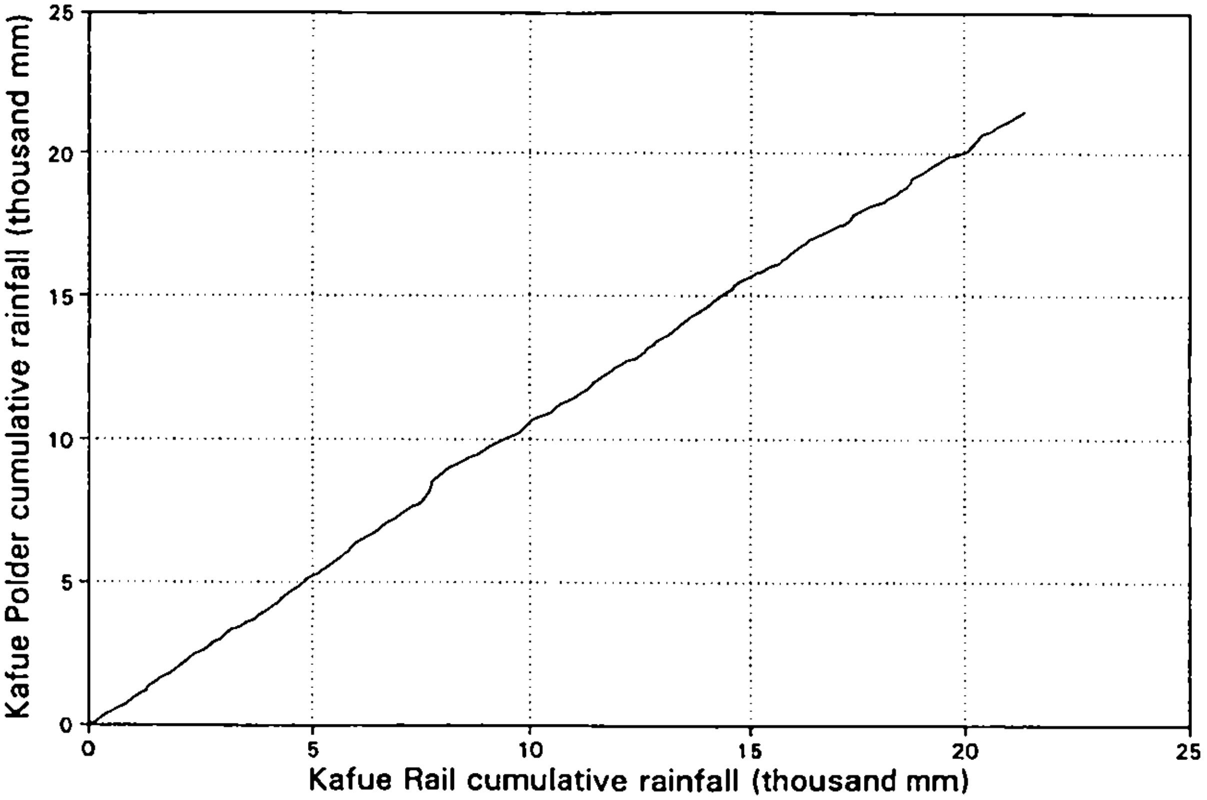
End of month water-levels and monthly releases and spills from both Itezhi-tezhi and Kafue Gorge reservoirs were provided by ZESCO. Details of the computation of discharge from both reservoirs are given in Shawinigan (1993b). Tables B.11 to B.16 (Appendix B) show the end of month water levels and releases for both reservoirs. The total discharge, as well as the flow passing through the turbines and the spill, are given for Kafue Gorge.

In the years preceding the completion of the Itezhi-tezhi dam, ZESCO was allowed to temporarily raise the Kafue Gorge reservoir level to 977.8 masl i.e. 1.2 m higher than the present maximum retention level. This increased the live storage to 2480 Mcm and was allowed because of the expected shortfall in energy arising as a consequence of the delay in commissioning the Kariba North power plant.

A catastrophic fire destroyed the power plant at Kafue Gorge on 26/03/89. It took several months of rehabilitation before the plant was once again operational. The data provided indicate that there was no flow through the turbines between April and November 1989, and it seems that there was also no measurement of spillway discharge for the period April to August 1989.

6.5 RESERVOIR WATER BALANCES

This section describes the water balance analyses conducted for both the Itezhi-tezhi and Kafue Gorge reservoirs. The water balance of Itezhi-tezhi was investigated for two purposes. In the first place, as noted in section 6.3.2, an attempt was made to determine an improved estimate of open water evaporation using an inflow series derived from the measured flow at Kafue Hook. Since this was unsuccessful the water balance was used to derive a reliable inflow series to the reservoir for the period of its operation. The water balance of the Kafue Gorge reservoir was used to derive an inflow series for this reservoir.



Double mass plot: Kafue Polder and Kafue Rail
Missing periods removed

Figure 11

Kafue at Hook Bridge
Gauging and rating equations

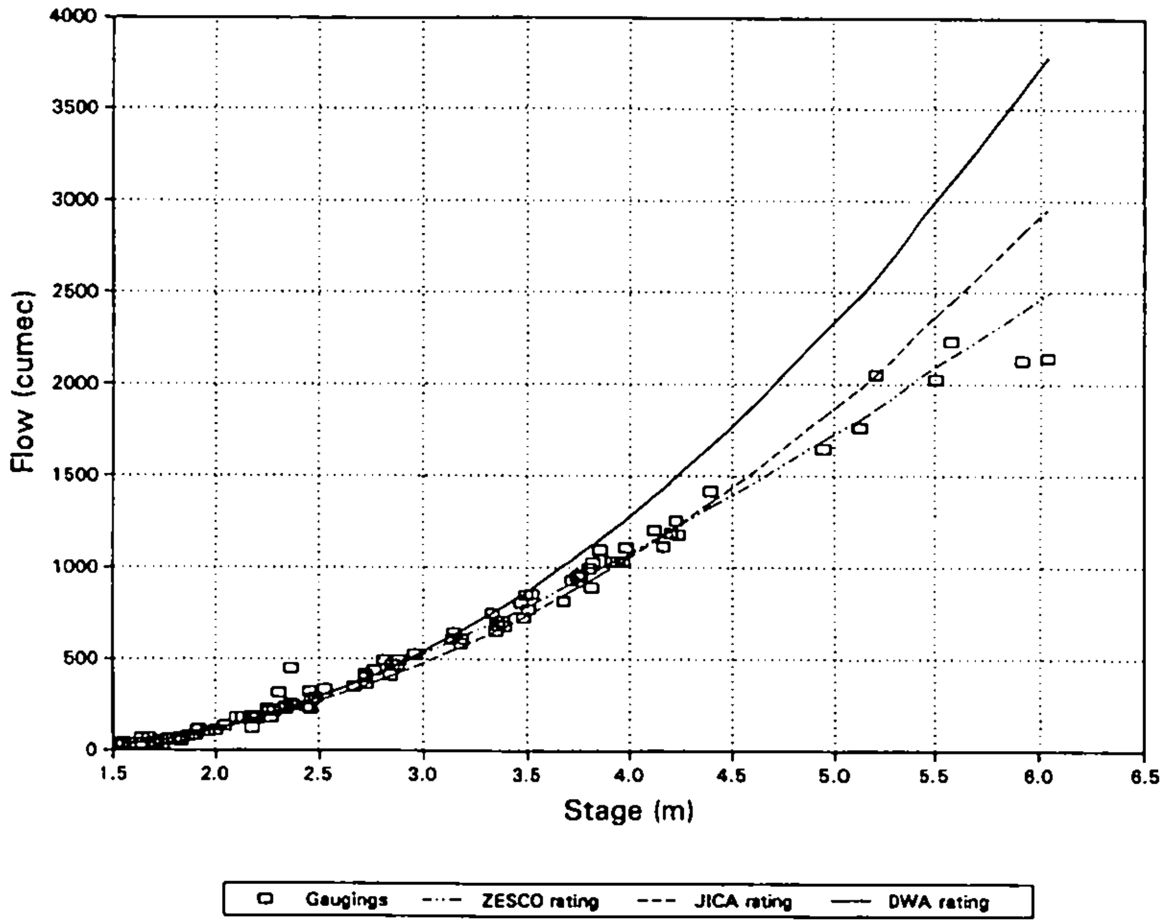


Figure 12

Comparison of flow series measured at Kafue Hook and Itezhi-tezhi

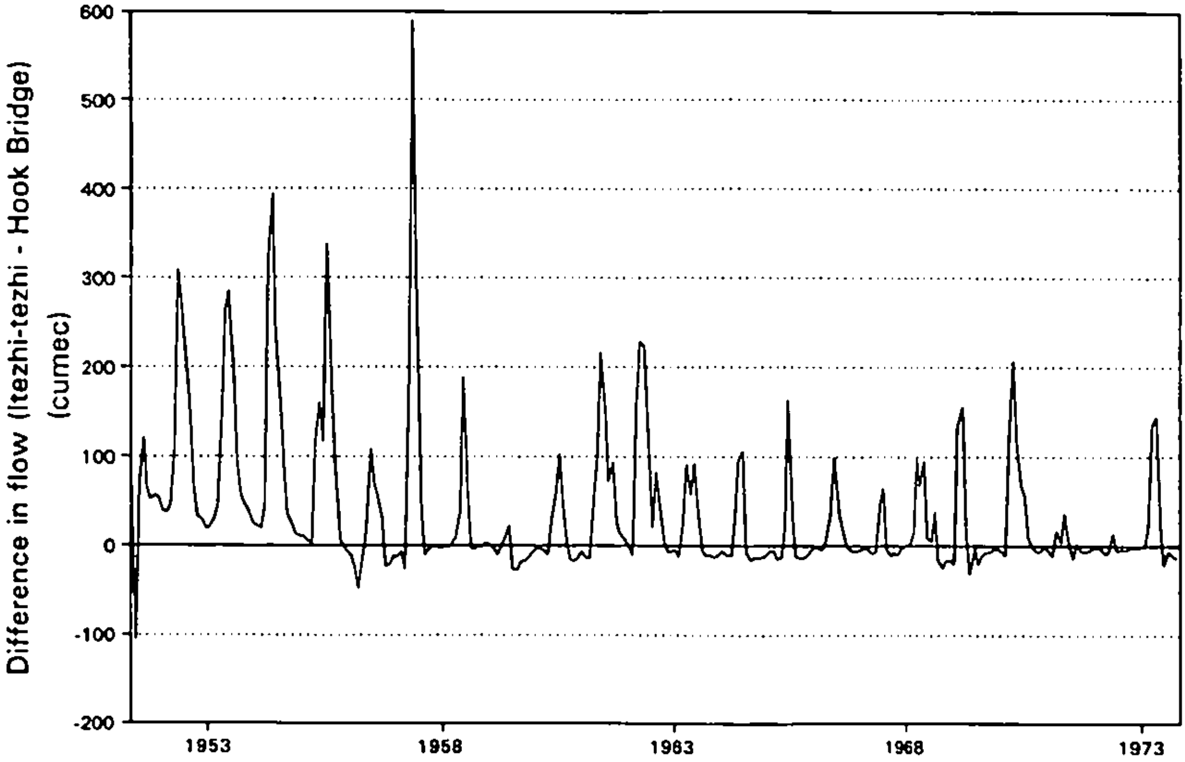


Figure 13

Comparison of flow series at Kafue Hook and Itezhi-tezhi

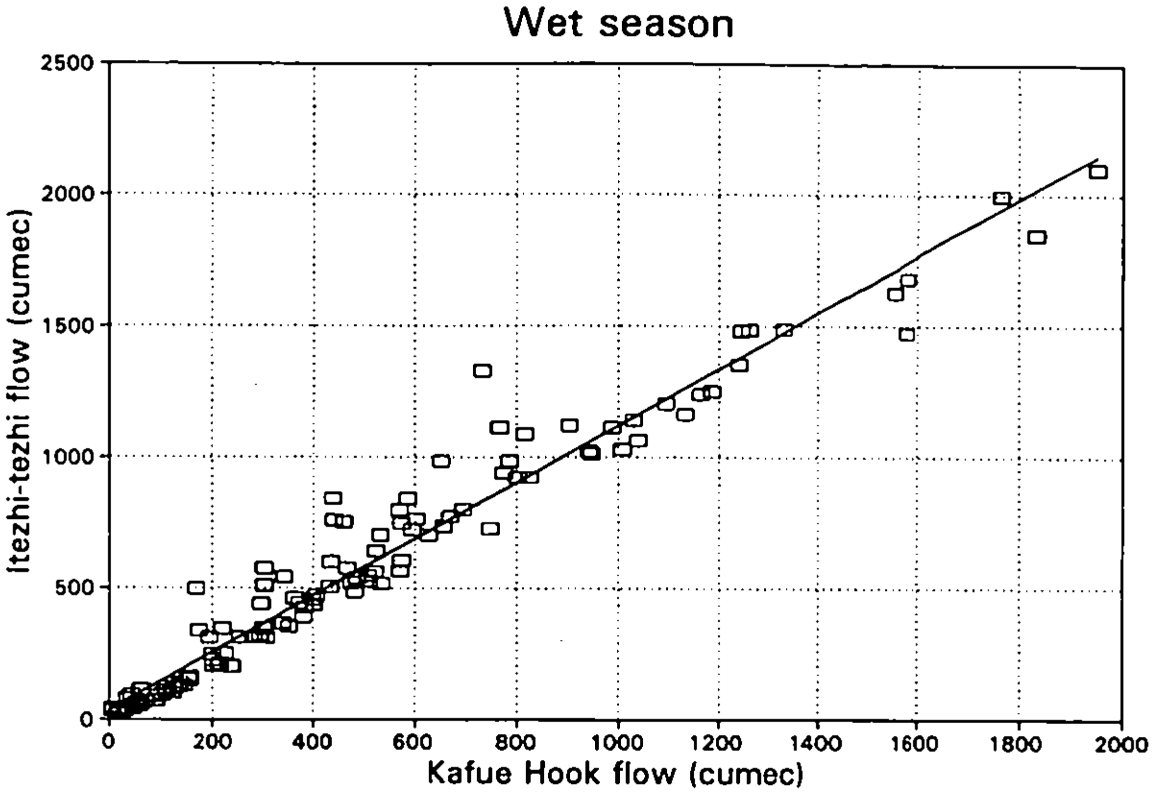


Figure 14a

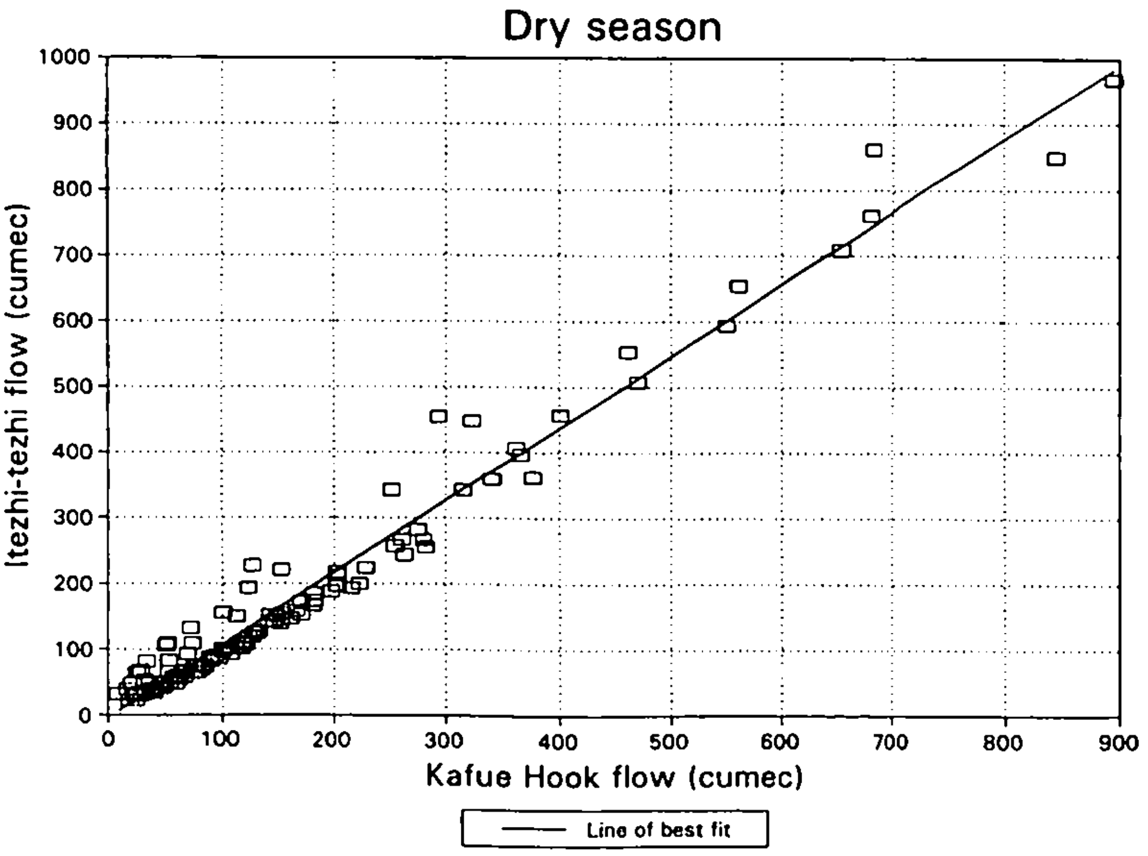


Figure 14b

Itezhi-tezhi Reservoir lower rule curve for firm target of 430MW

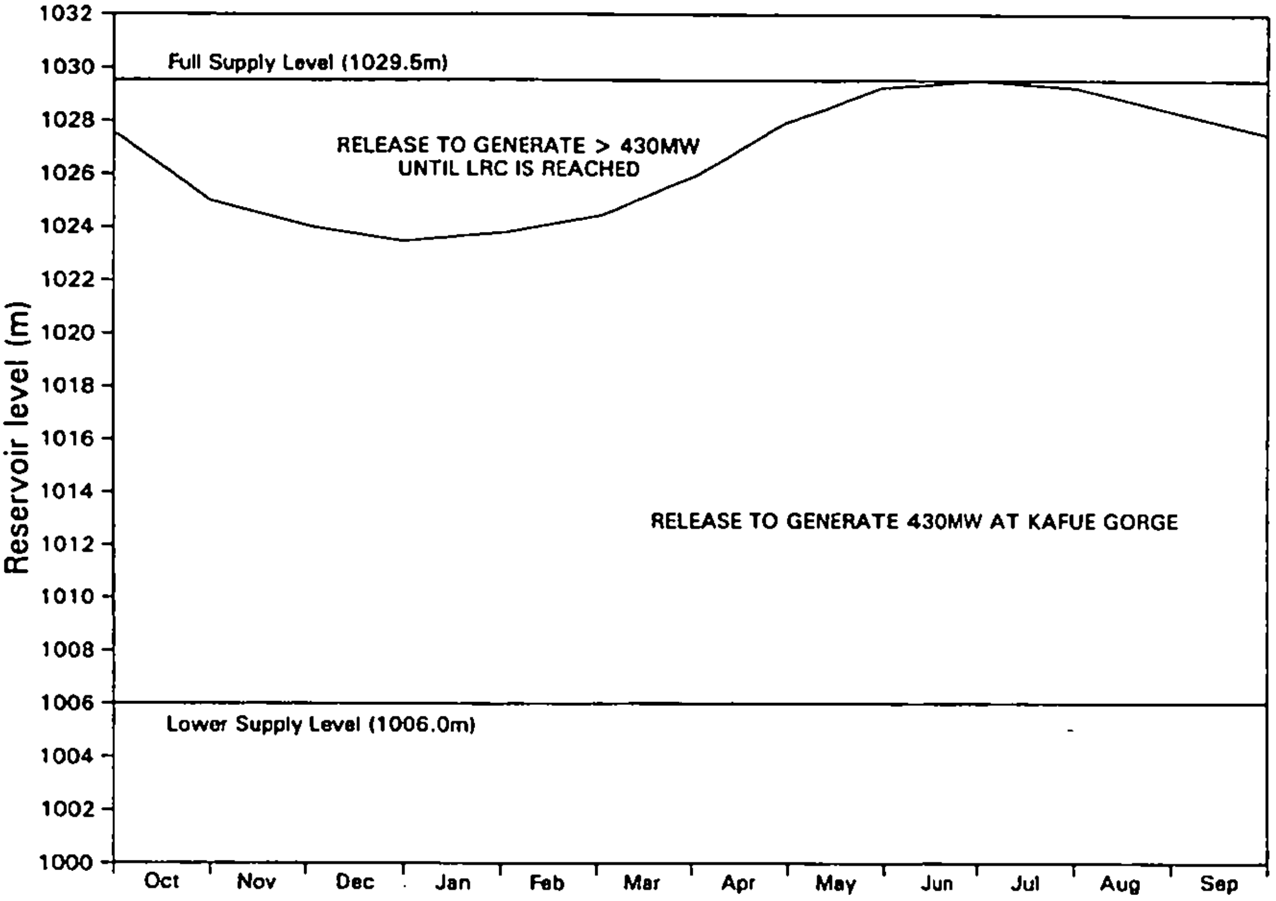


Figure 15

in the water balance is in the estimated inflow series; errors may arise both in volume and timing. Another possible error is the neglection of leakage. Any leakage which does occur will tend to make the evaporation estimate too high. However, the overall conclusion must be that no direct estimate can be made of reservoir evaporation at this site.

The water balance was reworked, substituting in the best estimate open water evaporation figures, in order to derive a corresponding inflow series, given the same changes in level, abstraction and spill. Figure 18 compares the best estimate Itezhi-tezhi inflow series (derived from Kafue Hook) and that derived from the water balance. It is clear that, whilst the timing is good and there is fairly good agreement during the dry season, during the wet season the best estimate inflow is significantly larger than the water balance inflow i.e. there is a possible volume error, but apparently not a timing error. To investigate this further, Figure 19 compares the flow at Kafue Hook with the water balance inflow series. Again the timing is good, indicating that there is a negligible lag between Kafue Hook and Itezhi-tezhi, but again whilst there is good agreement during the dry season, during the wet season the Kafue Hook flow is often larger than the water balance inflow. For completeness, the JICA (1992) inflow series derived from their water balance was also compared, and this was found to give similar results.

These results conflict with those presented in section 6.2.5 where the flow at Itezhi-tezhi was shown to be generally greater than or equal to that at Kafue Hook. Three possible conclusions can be drawn from this to explain why the water balance at Itezhi-tezhi failed to work satisfactorily. Firstly, the additional catchment area between Kafue Hook and Itezhi-tezhi appears to make a negligible contribution to the total flow, but this seems unlikely, particularly during the wet season. Secondly, perhaps seepage is more significant than previously thought, and water is being lost this way, which would reduce the evaporation. The final reason is that the observed flow series at Itezhi-tezhi could be erroneous, but again this seems unlikely in view of the past importance of this gauging station.

6.5.3 Kafue Gorge Reservoir

The water balance for Kafue Gorge Reservoir was used to derive an inflow series. The water balance was carried out for the period from June 1976 to January 1994, and was done on a monthly time step. End of month water levels as provided by ZESCO, and the elevation-area and elevation-volume relationships for the reservoir as given in SLHP (1990a) were used to determine the monthly changes in area and storage. The evaporation figures used were from the best estimate series described in section 6.3.6. The rainfall directly on to the reservoir surface was estimated from the depth recorded by the Kafue Polder raingauge applied over the average surface area for the month. The releases and spill were quantified by the outflow series provided by ZESCO. Leakage was assumed negligible. The abstraction record for PS1/PS11 was used and the abstractions for water supply were assumed to be at the water right levels at all times. These abstractions constitute the largest extraction from the Kafue Gorge Reservoir. The water rights relating to other abstractions are known, but as shown by the changing pattern in the cane irrigation requirements, the actual water use varies considerably from month to month. Consequently, no attempt was made to incorporate these directly into the water balance calculation. The inflow series thus derived represents the "true" inflow series minus the water abstracted for purposes other then municipal supply and sugar cane irrigation.

Figure 20 compares the inflow series derived in the current study with that obtained in a

6.5.1 Principle of reservoir water balances

If all except one term in a reservoir water balance are known, it is possible to calculate the only unknown value. For example, the evaporation from an open water body can be estimated from the water balance of the reservoir, if the inputs (i.e. inflow and rainfall), and the outputs (i.e. releases, spills, seepage and abstractions) are measured directly. In general the water balance of a reservoir is:

$$\Delta S = Q + R - E - L - A - Sp$$

where: ΔS = change in storage
Q = inflow
R = rainfall directly on the reservoir surface
E = evaporation from the reservoir surface (i.e. open water evaporation)
A = abstraction
L = leakage
Sp = spill

6.5.2 Itezhi-tezhi Reservoir

In the current study, an attempt was made to reproduce the water balance calculations for Itezhi-tezhi. These were mentioned, without any detail given, in SLHP (1990a) in order to determine the open water evaporation. Whilst the potential imprecision of this method is recognised, an evaporation estimate derived from the reservoir itself should be the best indicator of reservoir water losses. The water balance was carried out for the period from June 1978 to April 1994 i.e. the period for which Itezhi-tezhi has been operating and data were available. It was done on a monthly time step. End of month water levels as provided by ZESCO, and the elevation-area and elevation-volume relationships for the reservoir as given in SLHP (1990a) were used to determine the monthly changes in area and storage. The inflow to the reservoir was estimated from the flow at Hook Bridge using the relationship between the flow at Kafue Hook and that at Itezhi-tezhi developed for the period February 1952 to July 1973, as described in section 6.2.5. The rainfall directly on to the reservoir surface was estimated from the depth recorded by the Itezhi-tezhi raingauge applied over the average surface area for the month; The Itezhi-tezhi rainfall record was extended where necessary using the record from Kafue Rail as described in section 6.1.1. The abstractions and spill were quantified by the outflow series provided by ZESCO, and leakage was assumed negligible. Losses due to evaporation were estimated for each month from June 1978 to April 1994.

The water balance evaporation series is plotted in Figure 17, together with the best estimate figures derived as described in section 6.3.6. Two features are immediately apparent: firstly, the water balance series is in some cases negative, but in most months is unrealistically large (e.g. greater than 1500 mm in a month); secondly, there is a time lag between two evaporation series as characterised by the peaks and troughs of each yearly cycle. This is slightly greater than the typical lag of about one month found in reservoirs with large heat capacities. It is possible that there might be errors in the reservoir level, abstraction and spill records (e.g. if the spillway calibration is poor). However, this is unlikely as Shawinigan (1993b) conducted a very comprehensive study investigating the computation of releases and spills from both the Itezhi-tezhi and Kafue Gorge reservoirs. The most likely source of error similar manner by JICA (1992). The two series are nearly identical, despite the fact that different evaporation estimates were used, and that there was no attempt to simulate the abstractions directly in the JICA(1992) study.

Isohyets of mean annual precipitation over the Kafue Basin

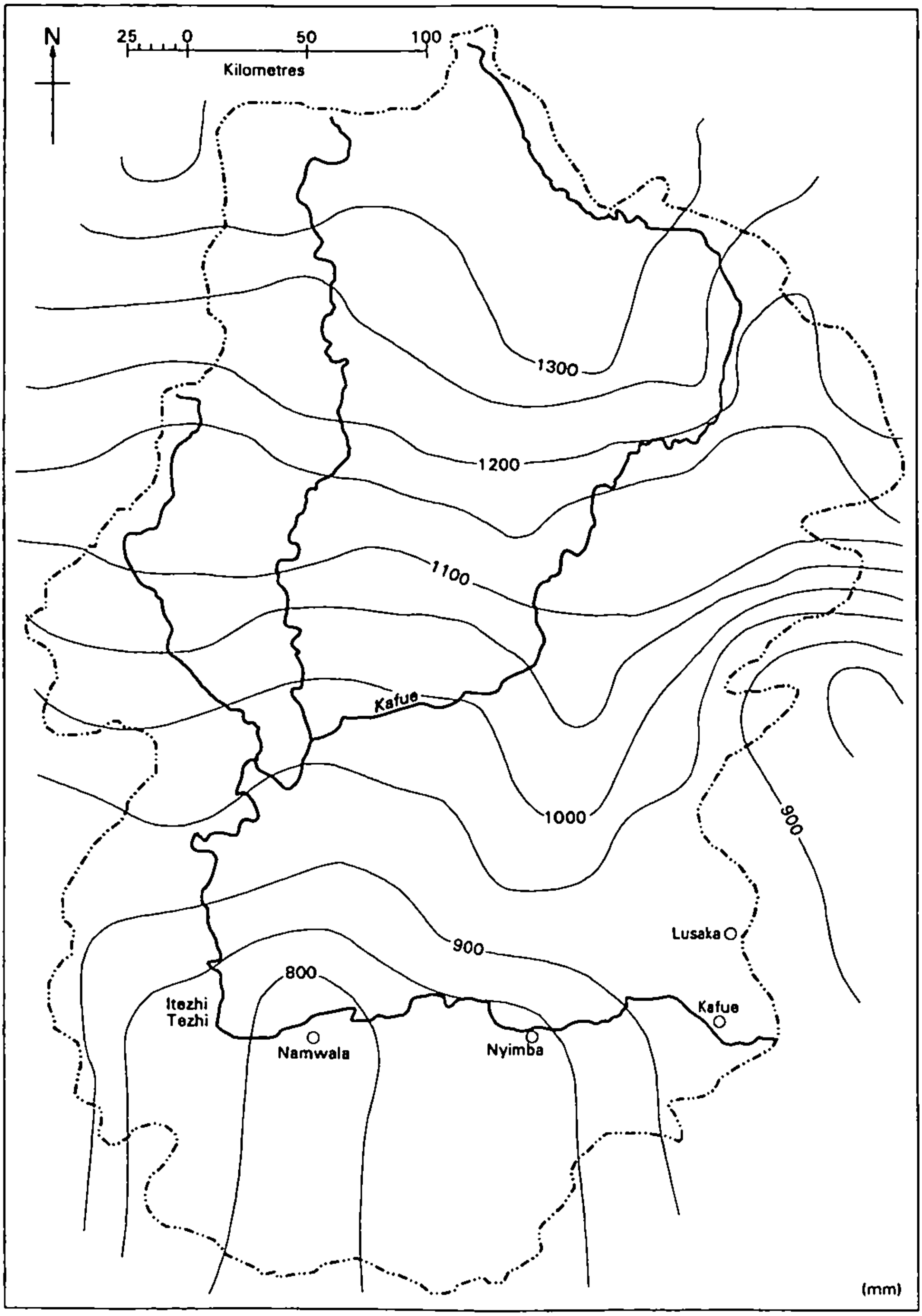
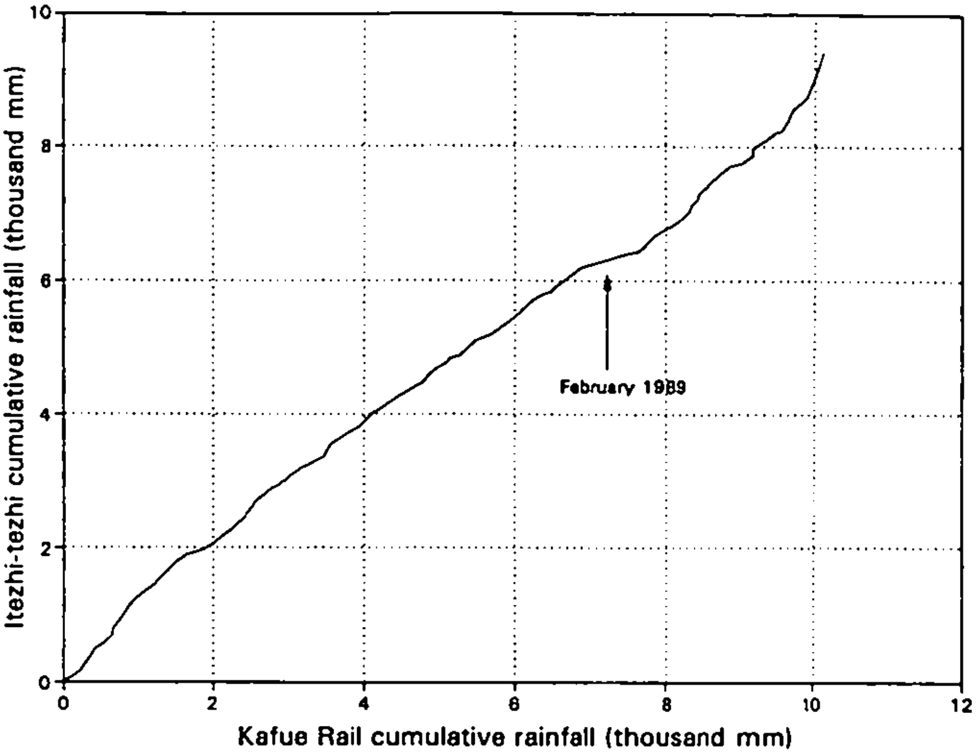
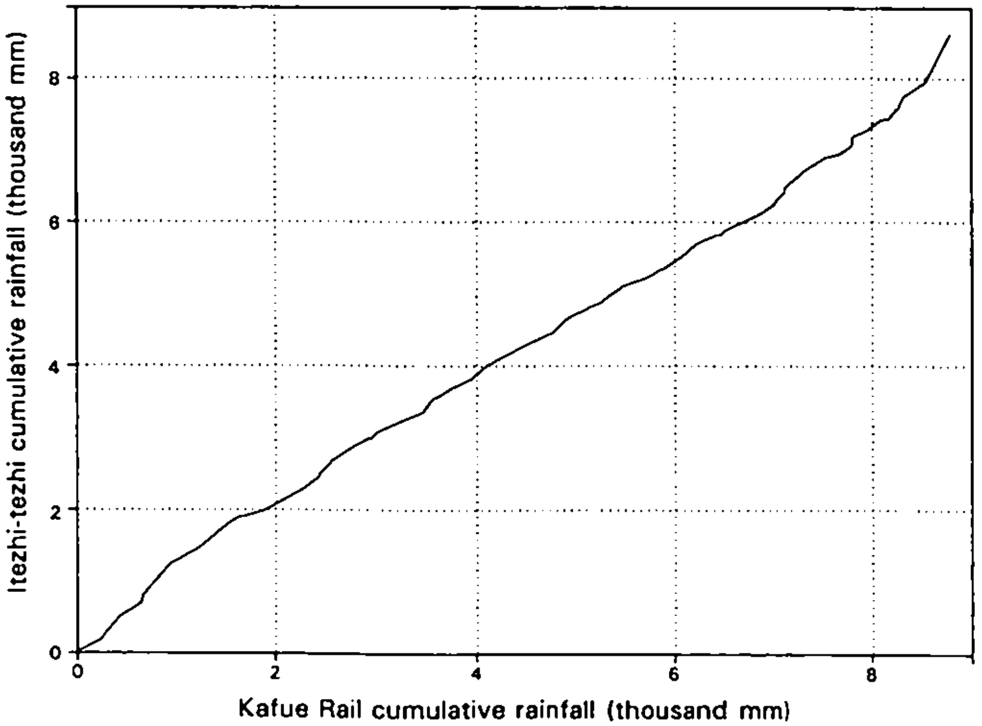


Figure 8



Double mass plot: Itezhi-tezhi and Kafue Rail
No missing periods

Figure 9a



Double mass plot: Itezhi-tezhi and Kafue Rail
1989 removed

Figure 9b

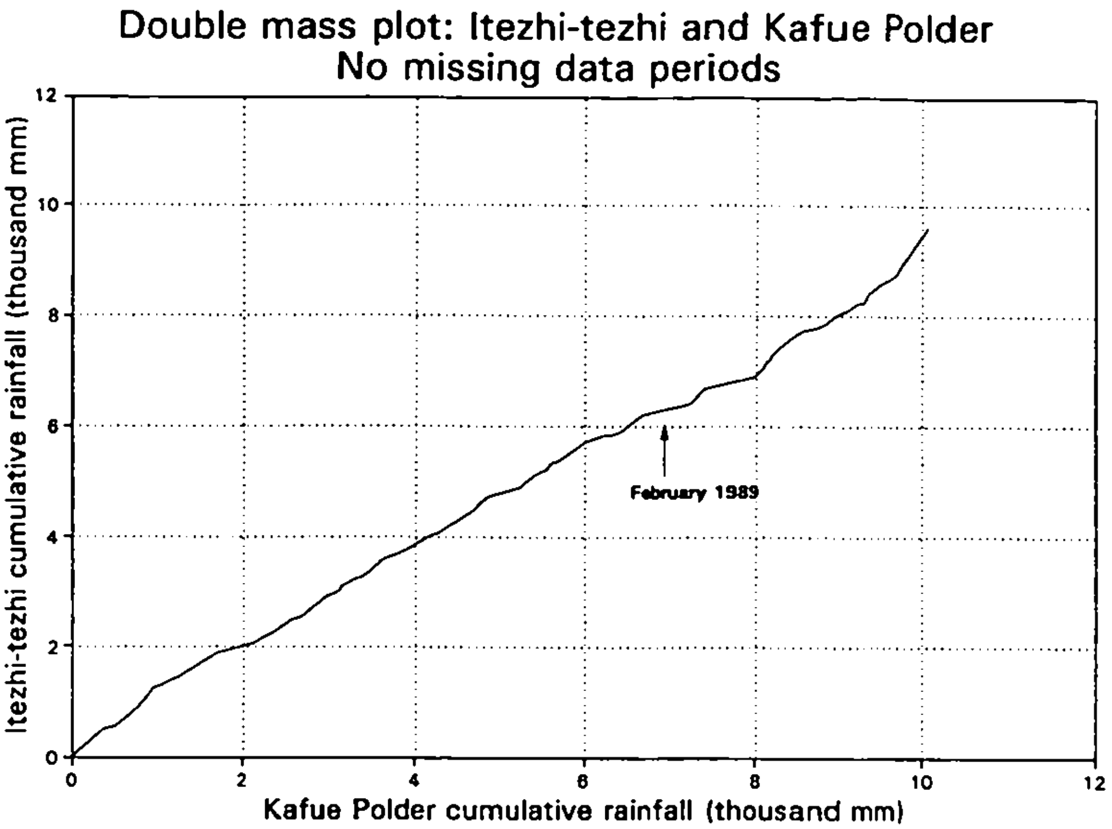

Double mass plot: Itezhi-tezhi and Kafue Polder
No missing data periods

Figure 10a

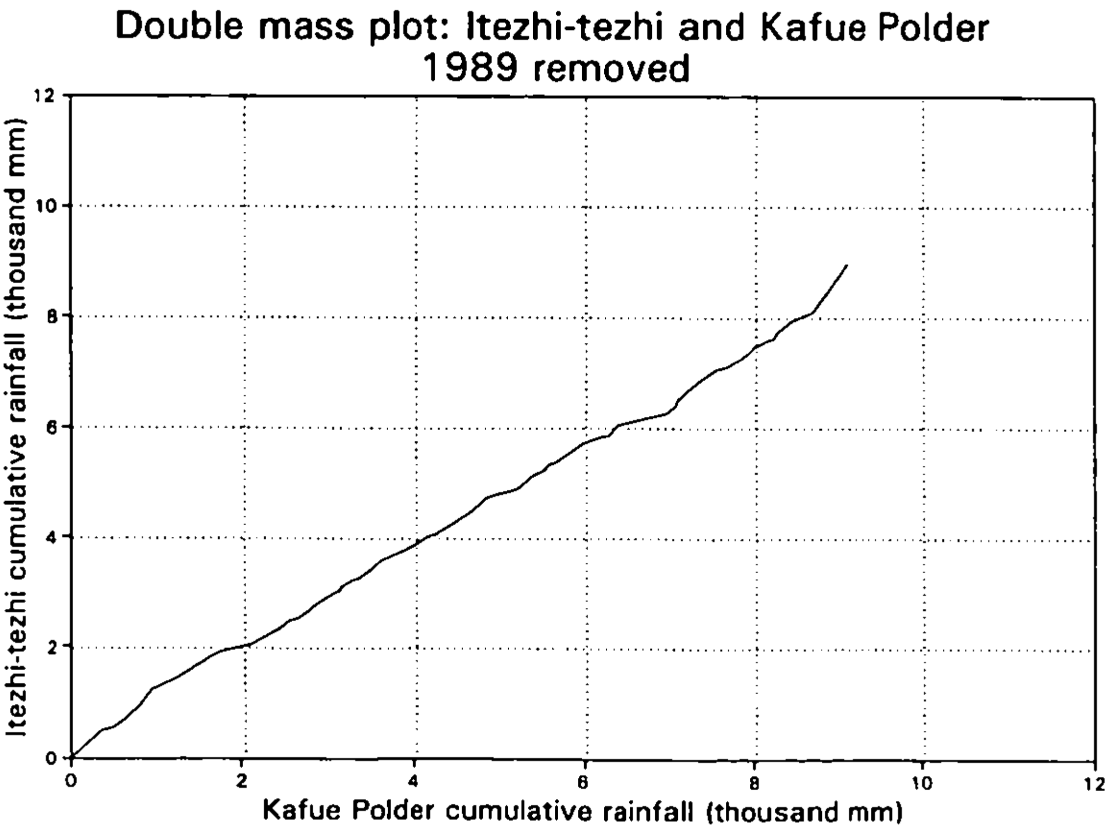

Double mass plot: Itezhi-tezhi and Kafue Polder
1989 removed

Figure 10b

Kafue Gorge Reservoir rule curve

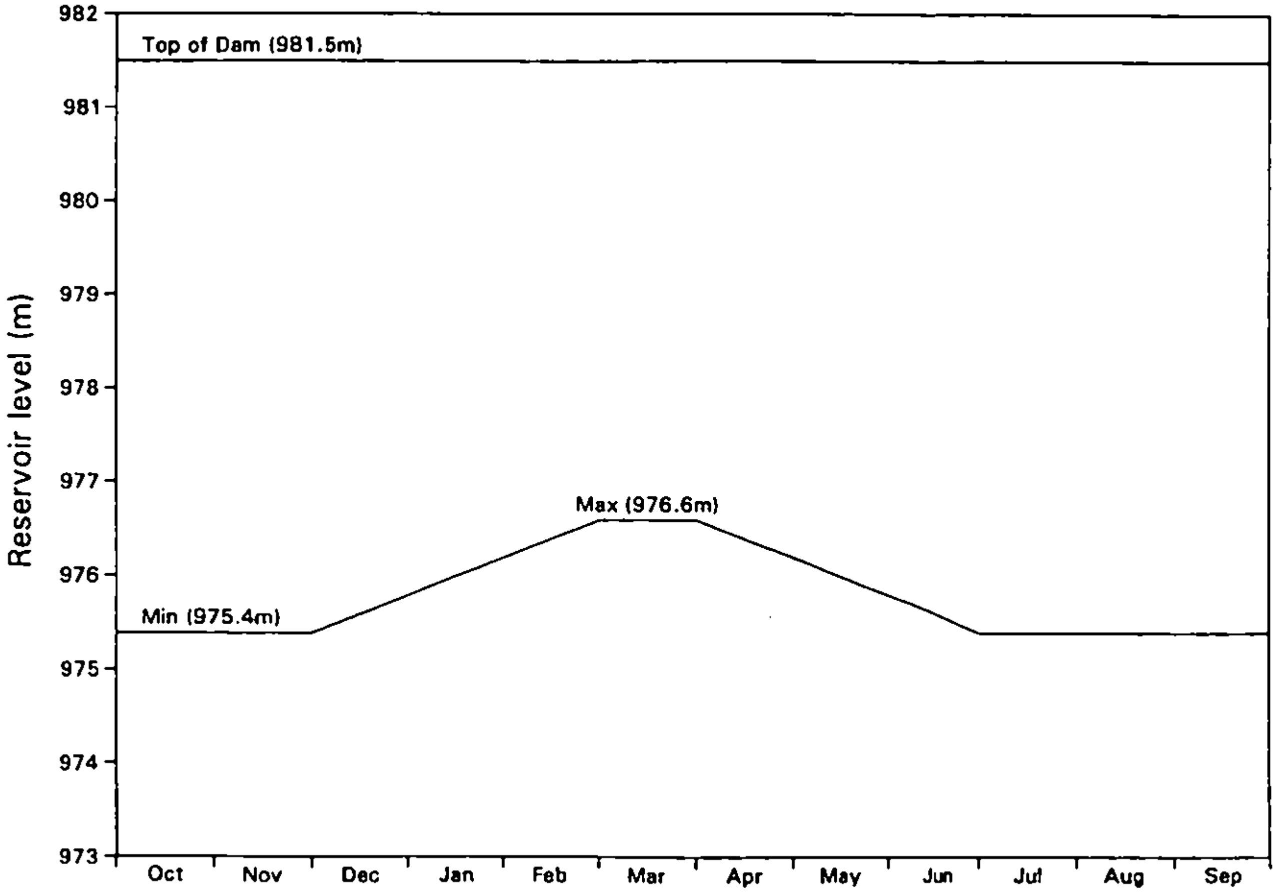


Figure 16

Itezhi-tezhi Reservoir
Comparison of evaporation series

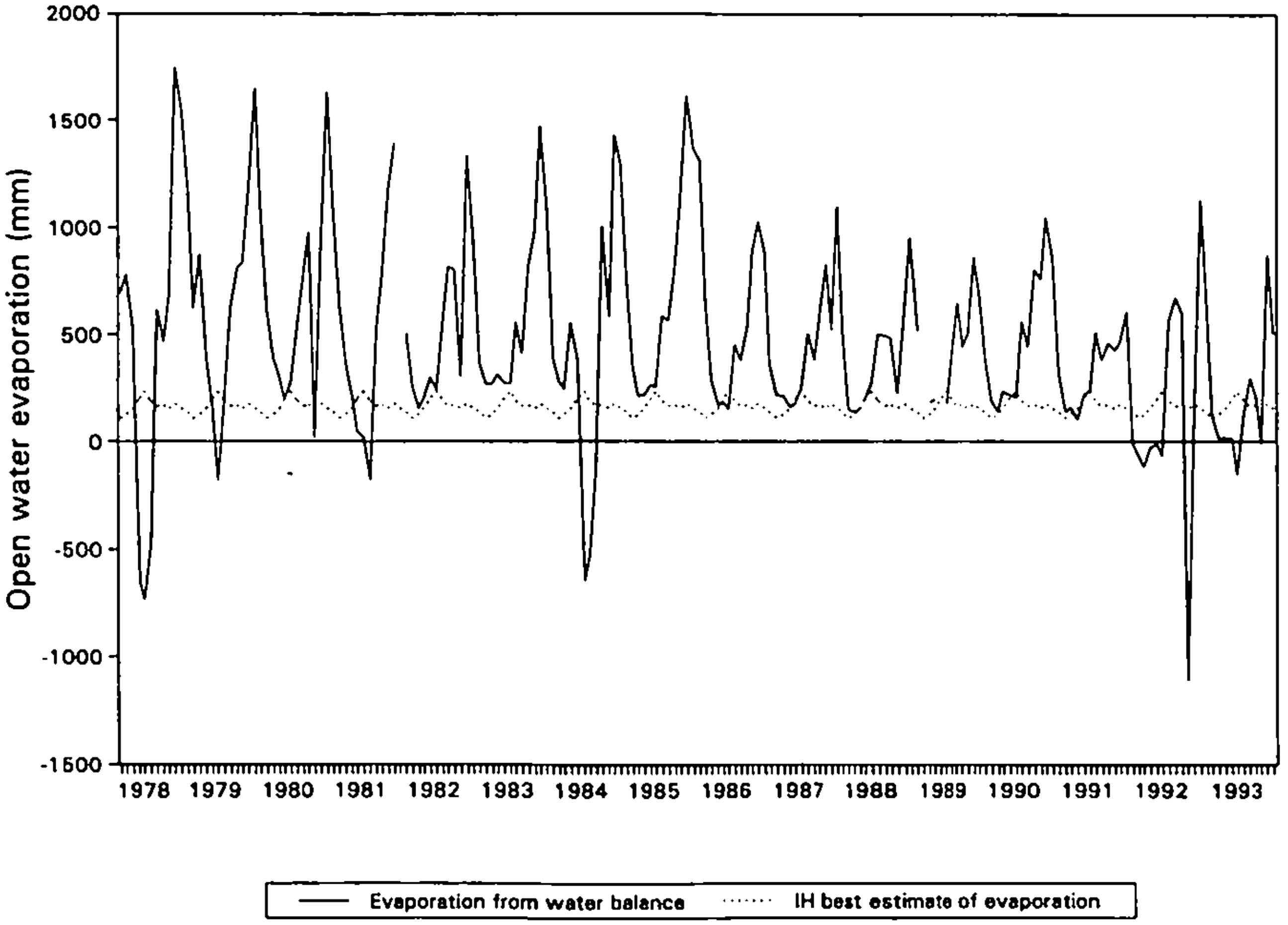


Figure 17

Itezhi-tezhi Reservoir
Comparison of inflow series

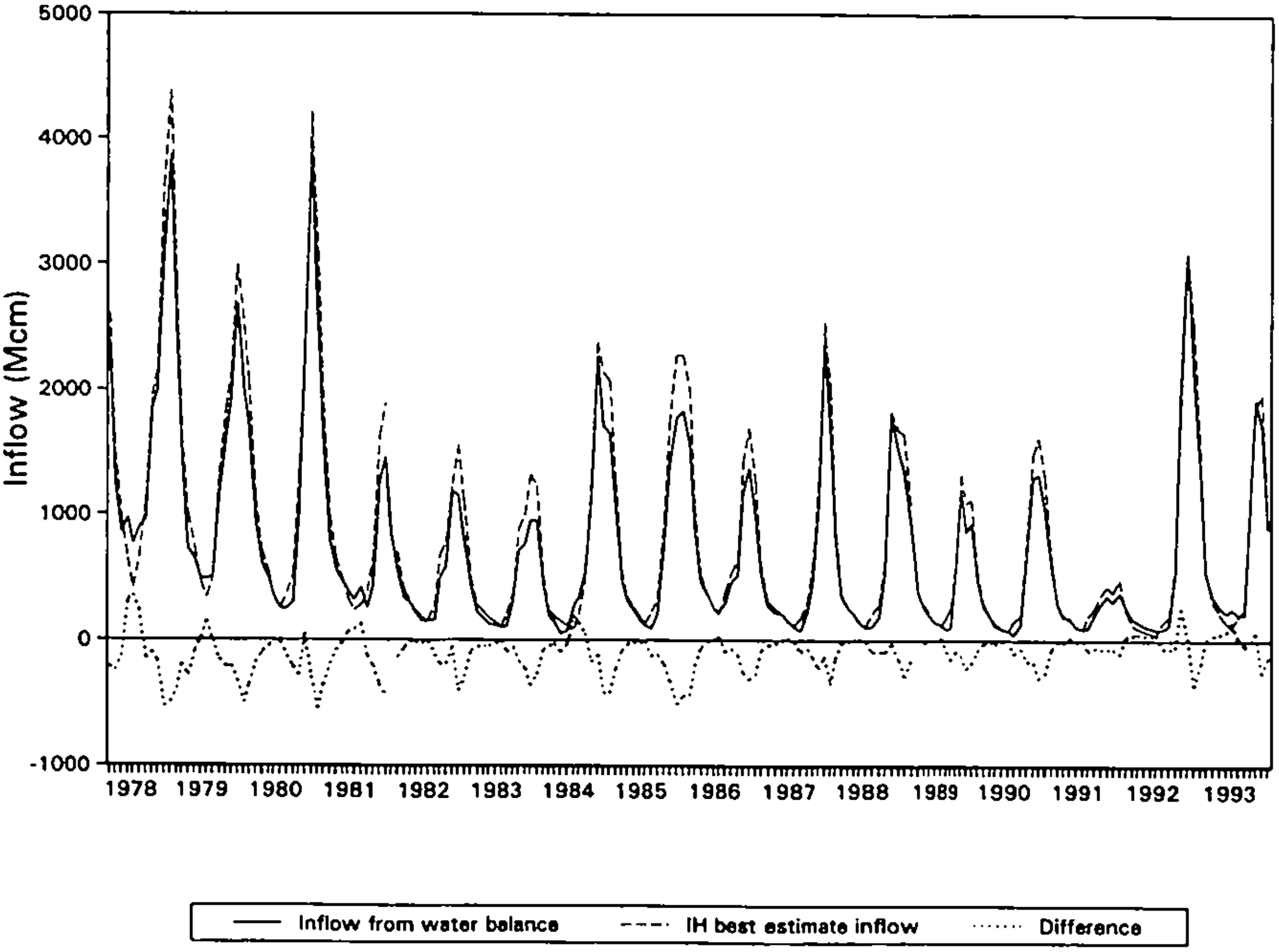


Figure 18

Itezhi-tezhi Reservoir
Comparison of flow series

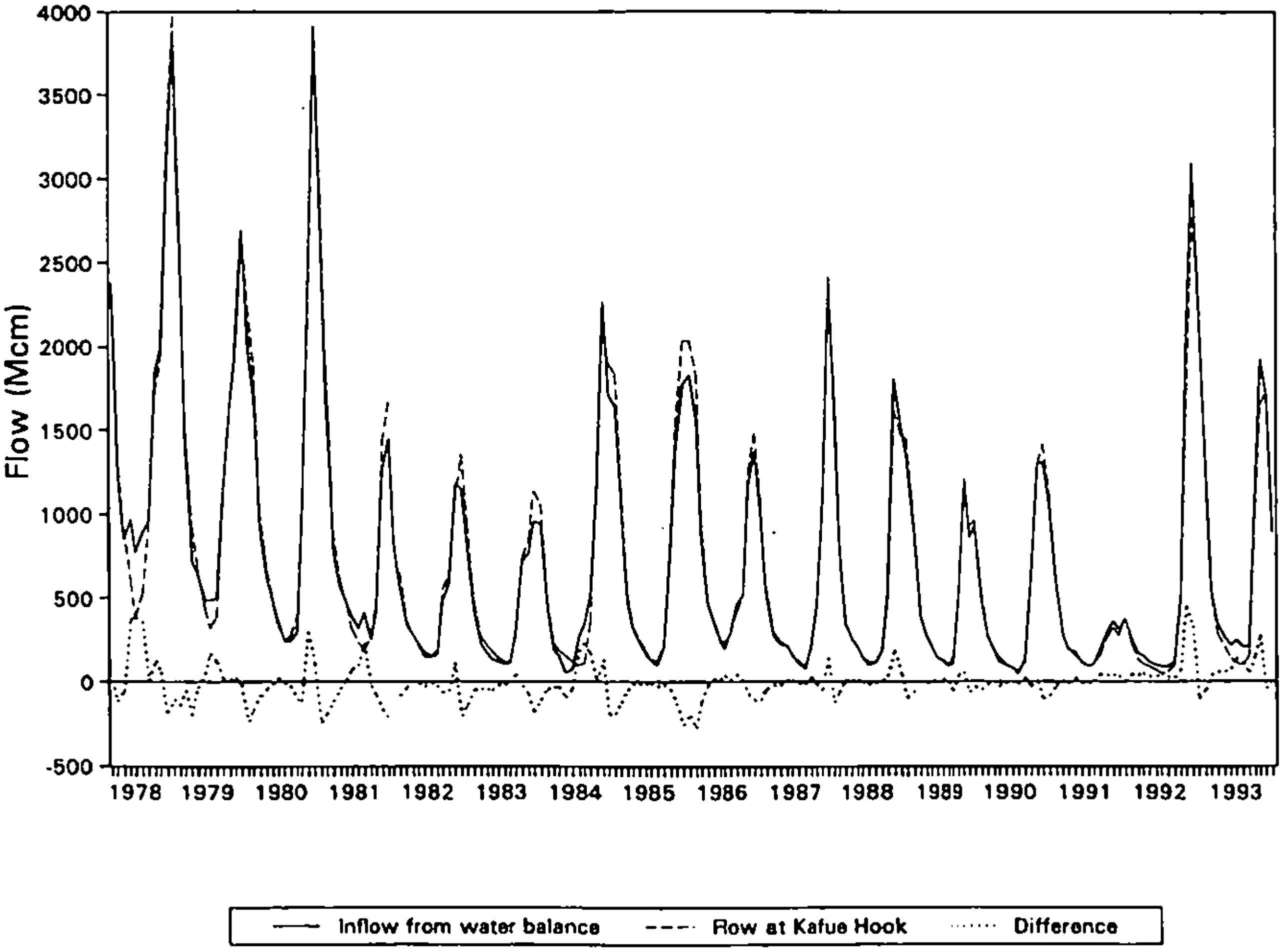


Figure 19

Kafue Gorge Reservoir
Comparison of inflow series

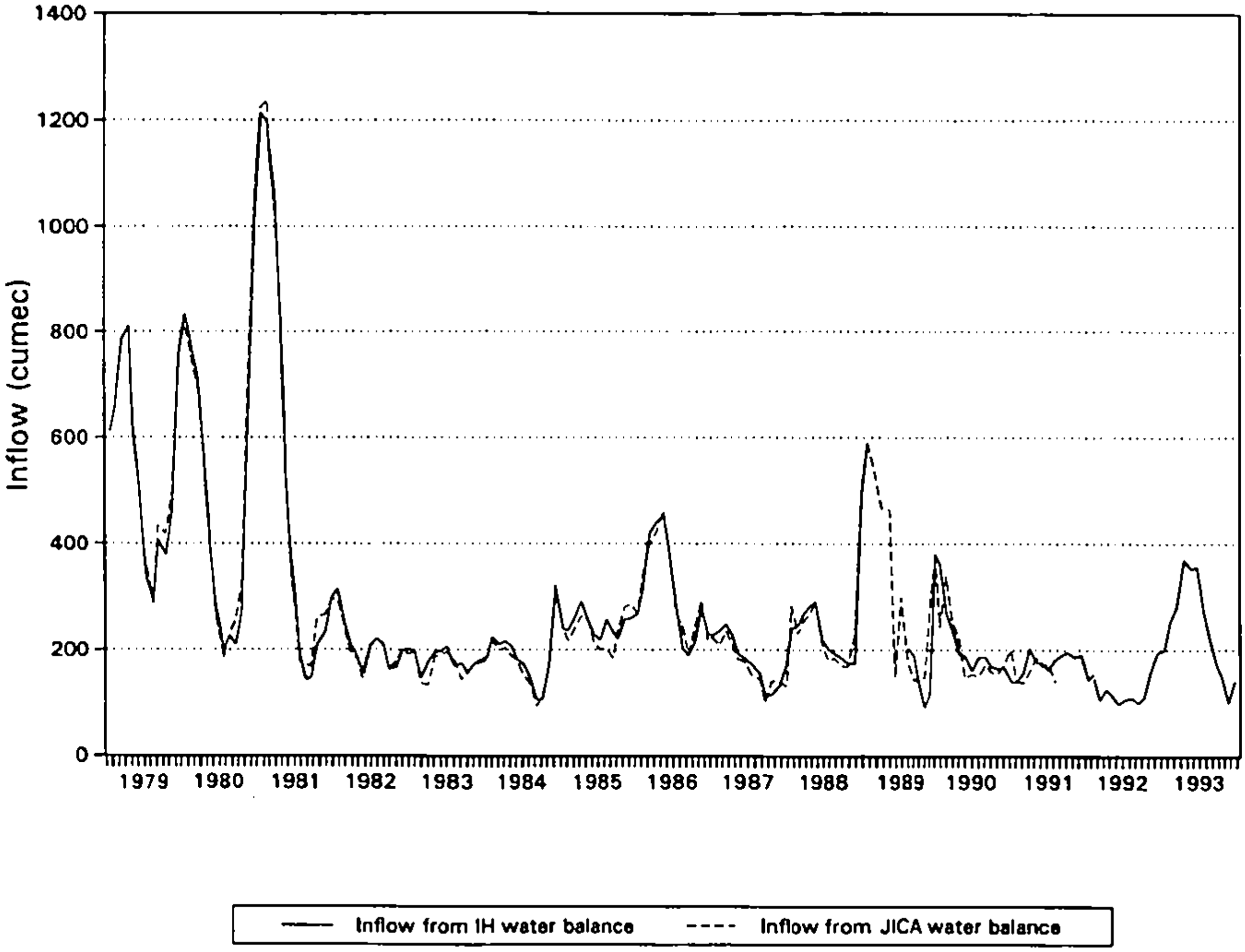


Figure 20

7. Simulation study

Having established the data requirements for simulation of the operation of both reservoirs, HYDRO-PC (Plinston, 1989) was run to produce results for existing conditions in the Kafue Basin. The simulation was done for the period October 1905 to September 1993. The generated inflow series to Itezhi-tezhi reservoir for this period is given in Table C.1 in Appendix C. Tables C.2 and C.3 show the long rainfall series for Itezhi-tezhi and Kafue Gorge, respectively. The effect of changing the sugar cane irrigation requirement was then investigated. Finally the simulation runs were repeated to investigate the effects of: firstly, not having the March freshet, and secondly, also increasing the full supply level of both the reservoirs. SLHP (1990a) state that since electricity generation in Zambia is predominantly hydropower, firm energy reliability estimates should be event-based i.e. firm energy has to be totally satisfied in a month or a failure is declared. This is the criterion used in the current study.

7.1 HYDRO-PC SIMULATION OF OPERATION OF ITEZHI-TEZHI

HYDRO-PC was set up to simulate the existing operating conditions at Itezhi-tezhi. The monthly releases necessary to maintain the firm energy requirement of 430 MW at Kafue Gorge were taken from Shawinigan (1993a) for the months April to November. The releases for December, January and February were obtained from SLHP(1990b) which has a table of minimum required releases for a very dry year (1972/73). The March release was set at 300 m^3s^{-1}, the stipulated requirement for the March freshet. Within HYDRO-PC, the flows were simulated as requirements for compensation flow. Table 16 gives the releases used.

Table 16 Releases from Itezhi-tezhi under existing conditions, including the March freshet

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
m^3s^{-1}	130	130	180	180	210	300	130	130	130	130	130	130
Mcm	348	337	482	482	513	804	337	348	337	348	348	337

Table C.4 (Appendix C) gives the input details for the simulation (run no. 1440) using inflow, rainfall and evaporation series as described in sections 6.2.5, 6.1.2 and 6.3.6, respectively. HYDRO-PC requires some input for hydroelectric generation even when a reservoir is simply used for regulation. Consequently Table C.4 contains some 'dummy' variables (e.g. for net head, peak capacity, efficiency at peak power and outflow and tailwater relationships). However, the file has been set up in such a way that these have no impact on the releases from the reservoir. Table 17 summarises the reservoir operation and performance for the entire period 1905-1993.

Table 17 *Summary of Itezhi-tezhi reservoir operation for the simulation period 1905-1993 (annual averages)*

Simulation run	Inflow	Rain	Evaporation loss	Compensation flow release	Spill	Total outflow	Compensation flow Months of shortfall	Compensation flow Seasons of shortfall
No.	Mcm	Mcm	Mcm	Mcm	Mcm	Mcm		
1440	9170.8	187.5	595.2	5001.1	3740.8	8741.8	5	2
1450	9170.8	189.1	600.7	4558.2	4179.9	8738.1	2	1
1460	9170.8	200.1	632.8	4561.5	4151.5	8712.9	2	1

These data show that there would have been a shortfall in flow releases in 5 months in 2 years. In fact, in order to maintain the volume in the reservoir at the minimum operating level of 1006.0 m, it would have been necessary to cutback releases made between November 1922 and January 1923 and in November and December 1924. Other near critical periods were October 1973 to January 1974 and October 1992 to January 1993. Figure 21a shows the variation in Itezhi-tezhi water level elevation during the simulation. Figure 21b is the same result obtained by Shawinigan (1993b) using HEC-3. The results are very similar, but not identical. The differences probably arise because of slight dissimilarities in the ZESCO rainfall and evaporation series, compared to those used in the current study. The difference in the evaporation series has been dicussed in section 6.3. ZESCO also used a "net rainfall" series i.e. the long-term mean rainfall in each month minus the long-term mean evaporation. In the current study actual rainfall determined through correlation with the long-term raingauges at Kafue Rail and Kafue Polder was used (section 6.1.1). The latter method, although of limited accuracy, does incorporate some of the annual variation in the rainfall to the reservoir. The results obtained in the current study are similar enough to the Shawinigan (1993a) figures for confidence to be placed in them, and were therefore judged to be acceptable.

Figure 22 shows the time series of the monthly total outflows from the reservoir. The average annual outflow from the reservoir is 8742 Mcm of which 3741 Mcm (43%) is spill. Table C.5 (Appendix C) is a breakdown of the annual results for this simulation run.

7.2 ROUTING FLOWS FROM ITEZHI-TEZHI TO KAFUE GORGE

Given a long generated outflow series from Itezhi-tezhi, it is necessary to derive some method of routing these flows 450 km downstream to generate a long inflow series to Kafue Gorge. Ideally, if data were available at stations between Itezhi-tezhi and Kafue Gorge, water balance calculations to enable routing would have been attempted. However, since this was not possible, a simple statistical approach was used. The relationship between the outflow at Itezhi-tezhi and the inflow at Kafue Gorge was investigated for the period of overlap of the outflow records from Itezhi-tezhi as provided by ZESCO, and the inflow to Kafue Gorge as derived by the water balance. As described in section 6.5.3, the water balance inflow to Kafue Gorge is the true inflow minus miscellaneous unquantified abstractions, but including the water abstracted for municipal supply and for sugar cane irrigation. It should be noted that the period from April to November in 1989, when the fire occurred at Kafue Gorge power station, is infilled from JICA (1992) estimates. Figure 23 compares the outflow from Itezhi-tezhi with the inflow to Kafue Gorge, and it is clear that there is both lag and attenuation. The relationship investigated was of the form:

$$\mathrm{KGin}_t \quad = \quad f(\,\mathrm{ITTout}_t,\ \mathrm{ITTout}_{t-1},\ \mathrm{ITTout}_{t-2}\ldots\ldots)$$

where: KGin is the inflow to Kafue Gorge
ITTout is the outflow from Itezhi-tezhi
t, t-1, t-2 etc refer to the present and lagged previous months respectively

Such a relationship allows for time-lag in the flow between the two sites. Rainfall and evaporation data series were also considered, but were found not to significantly affect the large flows being modelled. Using the complete flow series an "all-year" relationship was derived, given by the following equation:

$\text{KGin}_t = 0.387\ \text{ITTout}_t + 0.045\ \text{ITTout}_{t-1} + 0.607\ \text{ITTout}_{t-2} + 20.861 \quad R^2 = 0.75$

Seasonal relationships were then investigated in order to try and improve the fit. The seasons were taken as in section 6.2.5 i.e. the wet season from November to April, and the dry season from May to October. The derived relationships were given by the following equations:

Wet season:
$\text{KGin}_t = 0.353\ \text{ITTout}_t + 0.276\ \text{ITTout}_{t-1} + 0.290\ \text{ITTout}_{t-2} + 26.445 \quad R^2 = 0.80$

Dry season:
$\text{KGin}_t = 0.378\ \text{ITTout}_{t-1} + 0.125\ \text{ITTout}_{t-2} + 0.494\ \text{ITTout}_{t-3} + 8.107 \quad R^2 = 0.88$

Although the improvement in fit in the wet season is slight, the improvement in the dry season is significant. Figure 24 presents a time series plot of the water balance and simulated inflows. This simulation was judged to be acceptable. A further indication of the fit of the model is given in Figure 25 which is a plot of simulated against water balance mean monthly flows. Again the overall fit is reasonable. There are a few outliers, but most points cluster about the 1:1 line. To investigate the quality of the simulation further, Figures 26a and 26b compare the seasonal distribution of flows through the mean monthly flows and standard deviations of the two series. The means agree very well, with just a little overestimation in June and July and a little underestimation in September, October and February. The standard deviations also agree well, but show that the simulated series does not have quite as much variation as the water balance inflow series. These results show that the seasonal model gives an adequate simulation of the water balance inflow series.

7.3 HYDRO-PC SIMULATION OF OPERATION OF KAFUE GORGE

HYDRO-PC was set up to simulate the existing operating conditions at Kafue Gorge. Abstractions for water supply and cane irrigation were taken from the reservoir. The water supply abstractions were assumed to be constant and were taken as the full water right value. The cane irrigation abstractions were set as the mean monthly figures, determined from the abstraction record provided by ZSC for the period April 1979 to March 1994. A small amount was added on each month for the two farmers (Cantlay and Cowley) who also abstract water from the Kafue, but not through pumping stations PSI/PSII. This addition was determined for each month separately. The assumption was made that the farmers would abstract the same proportion of their total water right as that pumped in the month by ZSC. Table 18 shows the abstractions required for irrigation and water supply, as well as the firm energy demand (430 MW converted to GWh) in each month. The demands were prioritised with water supply being given the highest, then energy and irrigation the lowest priority. This order reflects the authors perception of the relative importance placed on these water uses in the Kafue Basin. There is no allowance for compensation flow from the reservoir since it is beieved that at present there is no requirement for ZESCO to make such releases. Table C.6 (Appendix C) gives the input details for the simulation (run no. 1350) using inflow, rainfall and evaporation series as described in sections 7.2, 6.1.3 and 6.3.6, respectively.

Table 18 Existing demands from Kafue Gorge Reservoir

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Water supply (Mcm)	6.1	5.9	6.1	6.1	5.6	6.1	5.9	6.1	5.9	6.1	6.1	5.9
Compensation (Mcm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irrigation (Mcm)	18.6	16.0	8.5	5.1	4.7	8.0	14.9	17.0	15.4	15.1	16.5	17.4
Firm energy (GWh)	319.9	309.6	319.9	319.9	291.5	391.9	309.6	319.9	309.6	319.9	319.9	309.6
Peak power (MW)	900.0	900.0	900.0	900.0	900.0	900.0	900.0	900.0	900.0	900.0	900.0	900.0

A summary of the reservoir operation is given in Table 19, which also contains summary information relating to the other scenarios discussed later in this chapter. Table 20 summarises the reservoir performance for this simulation. Table 20 shows that there would have been a shortfall in releases for firm energy in 4 months in two years. These occur in December 1922 and January 1923, and in December 1924 and January 1925 i.e. the months corresponding to the periods when flows from Itezhi-tezhi were cutback (section 7.1). During these months, there would also been insufficient water for cane irrigation, because energy generation has priority. In addition there would have been one other month (February, 1923) when the irrigation demand would not quite have been met.

The failure to meet the firm energy demand in 4 months out of a total of 1096, is equivalent to a 99.5% reliability (i.e 0.5% risk of failure). The mean yearly output of 5773 GWh is within 3% of the value (5900 GWh) obtained by SLHP (1990a) for the simulation period 1905 to 1989. This enables confidence to be placed in the simulation.

Table 20 Summary of Kafue Gorge Reservoir performance (1905-1993) - simulation run no. 1350

	Water supply Mcm	Compensation flow Mcm	Irrigation Mcm	Energy Gwh
Annual demand	71.9	0.0	157.2	3769.2
Mean annual supply	71.9	0.0	156.9	3754.7
Mean annual shortfall	0.0	0.0	0.3	14.5
Months of shortfall	0	0	5	4
Seasons of shortfall	0	0	2	2

One significant difference that there is between the simulation of the current study and that of SLHP (1990a) is in the amount of spill. SLHP (1990a) derived a mean annual spill of 53 m^3s^{-1}, which is considerably less than that obtained in the current study. The simulated mean annual spill of 5386.4 Mcm is equivalent to 171 m^3s^{-1} i.e. more than 3 times the value obtained by SLHP (1990a). There was insufficient data given in SLHP (1990a) to investigate this inconsistency in detail, but the following are three reasons why the discrepancy may occur:

Table 19 Summary of Kafue Gorge Reservoir operation for the simulation period 1905-1993 (annual averages)

Simulation run	Inflow	Rain	Evaporation loss	Water supply release	Irrigation release	Energy release	Spill	Total outflow	Total d/s flow	Firm energy	Secondary energy	Total energy
No	Mcm	Mcm	Mcm	Mcm	Mcm	Mcm	Mcm	Mcm	Mcm	GWh	GWh	GWh
1350	9911.2	324.9	684.5	71.9	156.9	3936.2	5386.4	9551.3	9322.6	3754.7	2018.1	5772.8
1360	9911.2	307.9	657.4	71.9	262.0	3935.4	5292.1	9561.4	9227.5	3754.7	1967.4	5722.1
1370	9906.4	312.2	659.3	71.9	262.5	3941.2	5283.4	9559.0	9224.6	3769.2	1933.3	5702.5
1380	9847.4	444.9	957.7	71.9	262.5	3935.9	5062.8	9333.1	8998.7	3769.2	1771.6	5540.8

- Differences in the inflow series used. SLHP (1990a) inflow series is based on a water balance of the Kafue Flats, with estimates of the inflow from tributaries. The current study derives the inflow series from a simple statistical relationship (section 7.2).

- Differences in the amounts of water taken from the reservoir for non-energy purposes. In SLHP (1990a) abstractions were assumed to equal the water rights allocation, although it is acknowledged that the amount actually withdrawn may differ considerably from this value. In the current study an attempt has been made to estimate the average actual amount diverted for non-energy purposes in each month. Although the potential inaccuracy in the method used is recognised, this is felt to be a more realistic approach than simply assuming that water is removed at the maximum rate specified in the water rights.

- Errors in evaporation and rainfall estimates. These errors are difficult to quantify, but are common to both studies. However, the consequences of inaccuracies are likely to be small in comparison to the two reasons given above, and certainly not of sufficient magnitude to explain the difference in spill on their own.

Figure 27 shows the variation in Kafue Gorge water level elevation during the simulation. Table C.7 (Appendix C) is a breakdown of the annual results for this simulation run.

7.4 EFFECT OF POTENTIAL FUTURE ABSTRACTION SCENARIO

HYDRO-PC was set up to simulate the existing operation but with the abstractions changed to reflect the projected requirement for irrigation of 17,400 ha of sugar cane. These are listed as the "maximum" values in Table 6 (section 5.2). The input file for this simulation (run no. 1360) is given in Table C.8 (Appendix C). Table 21 is a summary of the reservoir performance for this simulation run. This shows that if the irrigation abstractions were increased to the amounts required to irrigate 17,400 ha, failure to meet the firm energy demand would still only occur in 4 months, i.e. the 0.5 % risk of failure is not increased by the additional abstraction. The number of months where the irrigation demand would fail to be met would remain at 5, although obviously the shortfall in the months of failure is increased. As before, the critical periods in the simulation are the end of 1922 and 1924. Table C.9 (Appendix C) is a breakdown of the annual results for this simulation run.

A summary of the reservoir operation for run 1360 is given in Table 18. By comparison with the results from run 1350 it can be seen that the increased abstraction for sugar cane causes a reduction in the average total energy from 5773 GWh to 5722 GWh annually (a reduction of less than 1 %). Figure 28 is a comparison of the energy duration curves for scenarios 1350 and 1360. This emphasises the very small difference that the proposed future irrigation abstraction would have on the total energy production at Kafue Gorge.

Table 21 Summary of Kafue Gorge Reservoir performance (1905-1993) - simulation run no. 1360

	Water supply Mcm	Compensation flow Mcm	Irrigation Mcm	Energy Gwh
Annual demand	71.9	0.0	262.5	3769.2
Mean annual supply	71.9	0.0	262.0	3754.7
Mean annual shortfall	0.0	0.0	0.5	14.5
Months of shortfall	0	0	5	4
Seasons of shortfall	0	0	2	2

7.5 EFFECT OF CHANGING THE RULE CURVES AND OPERATION AT ITEZHI-TEZHI AND KAFUE GORGE

As noted in section 3, the Shawingan (1993a) simulation study of the Lower Kafue Basin found that 430 MW can be considered the firm energy of the Itezhi-tezhi/Kafue Gorge system with 100 % reliability, providing the requirement for the March freshet is removed. The point is made that the March freshet taxes Itezhi-tezhi during low flow years, to the point of affecting the firm flow from the reservoir. The removal of the freshet results in higher guaranteed flows, and hence higher firm energy generation at Kafue Gorge.

It has also been suggested that the full supply level in Itezhi-tezhi could be raised by 1.0 m, and that in Kafue Gorge by 0.4 m (Mr. Mwasile, SADC Project Manager, ZESCO, personal communication). This would have the effect of providing greater storage in both reservoirs, and so would also increase the firm energy of the system. SWECO have confirmed with ZESCO that increasing the full supply level of Itezhi-tezhi by 1.0 m is a viable option (SWECO, 1993 - letter to ZESCO). As noted in section 6.4.3, there already exists a precedent for raising the level of Kafue Gorge.

In the current study two scenarios have been run to simulate possible future operating procedures. In the first case (simulation run nos. 1450 and 1370 for Itezhi-tezhi and Kafue Gorge, respectively) the necessity for the March freshet was removed, but the operating curves for both reservoirs were left unchanged. In the second (simulation run no. 1460 and 1380 for Itezhi-tezhi and Kafue Gorge, respectively) the March freshet was removed and the operating curves were raised in each month, by 1.0 m at Itezhi-tezhi and by 0.4 m at Kafue Gorge. In both cases, the outflows generated in the simulation of the Itezhi-tezhi operation were routed downstream to Kafue Gorge as described in section 7.2. Also in both cases, the irrigation abstraction requirement was taken from the Kafue Gorge reservoir and was set in each month at the requirement to irrigate 17,400 ha of cane (Table 6). The results of these simulations are discussed below. It should be noted that failure to meet the compensation flow demand at Itezhi-tezhi in any one month does not automatically result in failure to meet either the firm energy demand or the irrigation demand at Kafue Gorge. This is because as shown in section 7.2, the inflow into Kafue Gorge is dependent on previous months outflow from Itezhi-tezhi as well as the month in which failure to meet the compensation flow demand occurred.

7.5.1 Removal of the March freshet

The effect of removing the requirement for the March freshet on the operation and performance of Itezhi-tezhi is given in Table 17. There would be 4 months of shortfall in 2 seasons. This compares with 7 months in 2 seasons when the March freshet was required (i.e. simulation run no. 1450, section 7.1). It should be noted that although the risk of failure to meet the required releases is reduced slightly, there is a small increase in losses through evaporation (because more water is stored and consequently there is a slight increase in the reservoirs surface area), and consequently a slight reduction in the average annual total released from the reservoir.

At Kafue Gorge the removal of the March freshet, results in no failures to meet either the firm energy or the irrigation demand (Table 22). This confirms the Shawinigan (1993a) finding and furthermore shows that 100% reliability could be maintained even with the irrigation requirement for 17,400 ha.

Table 22 Summary of Kafue Gorge Reservoir performance (1905-1993) - simulation run no. 1370

	Water supply Mcm	Compensation flow Mcm	Irrigation Mcm	Energy Gwh
Annual demand	71.9	0.0	262.5	3769.2
Mean annual supply	71.9	0.0	262.5	3769.2
Mean annual shortfall	0.0	0.0	0.0	0.0
Months of shortfall	0	0	0	0
Seasons of shortfall	0	0	0	0

7.5.2 Raising the full supply level of both reservoirs

The effect of raising the full supply level at Itezhi-tezhi by 1.0 m is shown in Table 17. In this case the number of failures to meet compensation flow requirements is again just 2 months; December 1922 and January 1923. However, it should be noted that in this case there is an even greater loss through evaporation (a 6% increase over that in simulation run no. 1450), and as a consequence total releases from the reservoir are slightly reduced (by 3%).

At Kafue Gorge this scenario again resulted in no failures to meet either the firm energy or the irrigation demand in the whole 88 year period of record i.e. an absolute reliability of 100 % (Table 23). However, as shown in Table 19, the increase in water level causes a very significant increase in the amount of water lost through evaporation from the Kafue Gorge reservoir. This is a consequence of the greatly enlarged surface area of the reservoir that occurs when the water level is raised. The loss is 957.7 Mcm which compares to 684.5 Mcm under present operating conditions i.e. a 40 % increase. The increased evaporation loss results in a decrease in the secondary energy produced which declines from an average of 2018.1 GWh annually to 1771.6 GWh annually. This is a 12 % decrease. It is beyond the scope of the current study to determine the increase in firm energy that would arise from the increase in the full supply level.

Table 23 Summary of Kafue Gorge Reservoir performance (1905-1993) - simulation run no. 1380

	Water supply Mcm	Compensation flow Mcm	Irrigation Mcm	Energy Gwh
Annual demand	71.9	0.0	262.5	3769.2
Mean annual supply	71.9	0.0	262.5	3769.2
Mean annual shortfall	0.0	0.0	0.0	0.0
Months of shortfall	0	0	0	0
Seasons of shortfall	0	0	0	0

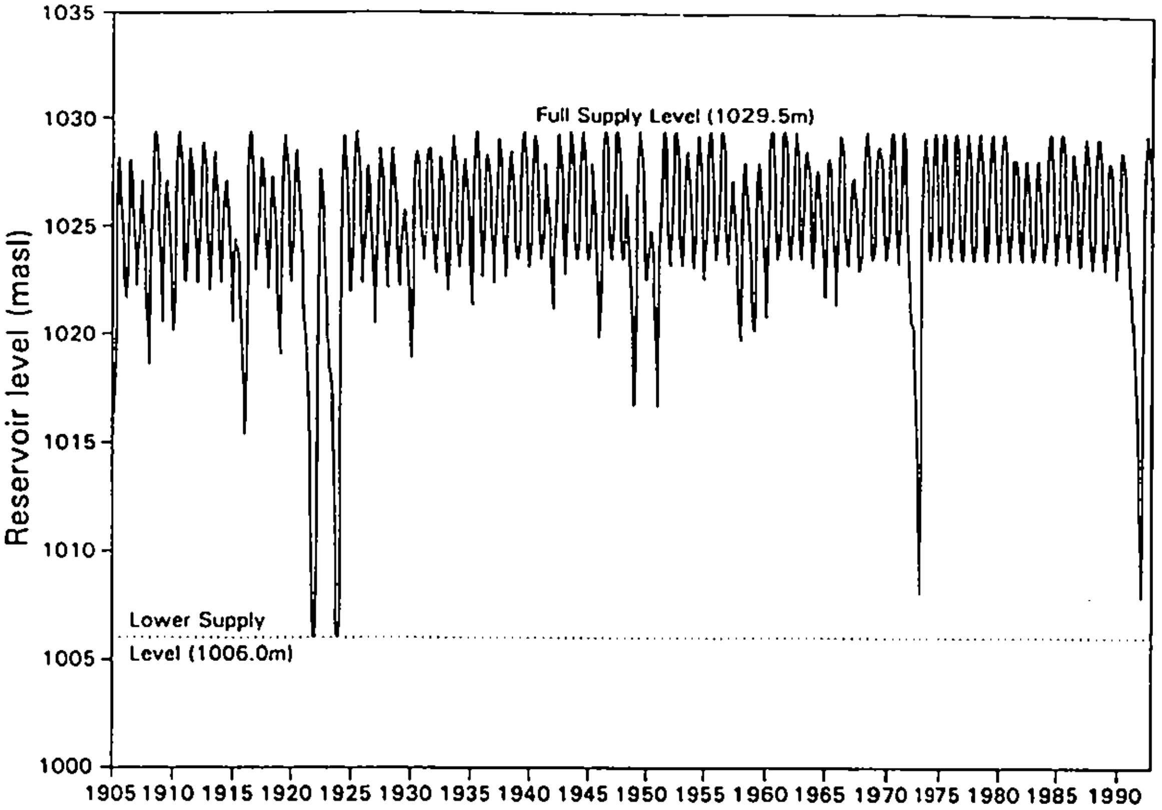
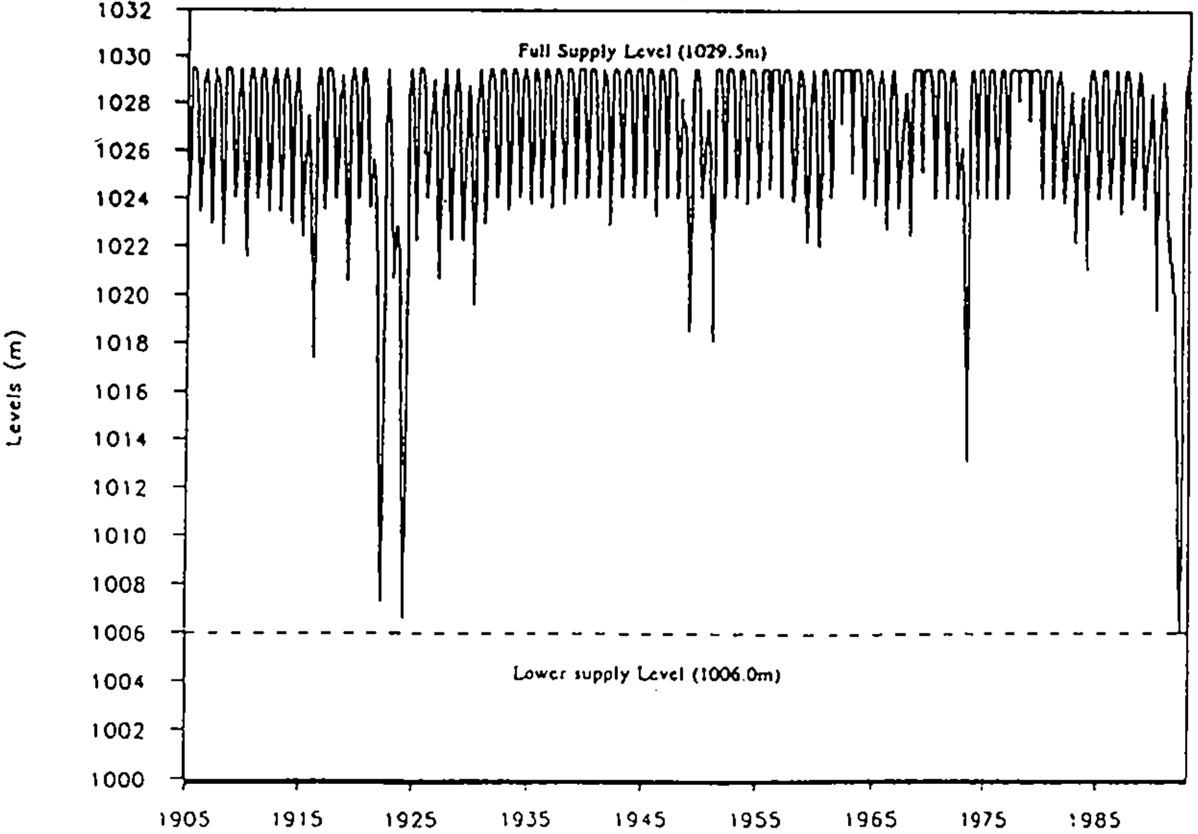

Itezhi-tezhi reservoir operation
Simulation run no. 1440

Figure 21a


Itezhi-tezhi reservoir operation
Simulation results from Shawinigan (1993a)

End-Of-Month Levels (1905-92). Target Firm=429MW with Lower Rule Curve.

Figure 21b

Itezhi-tezhi reservoir operation
Simulation run no. 1440

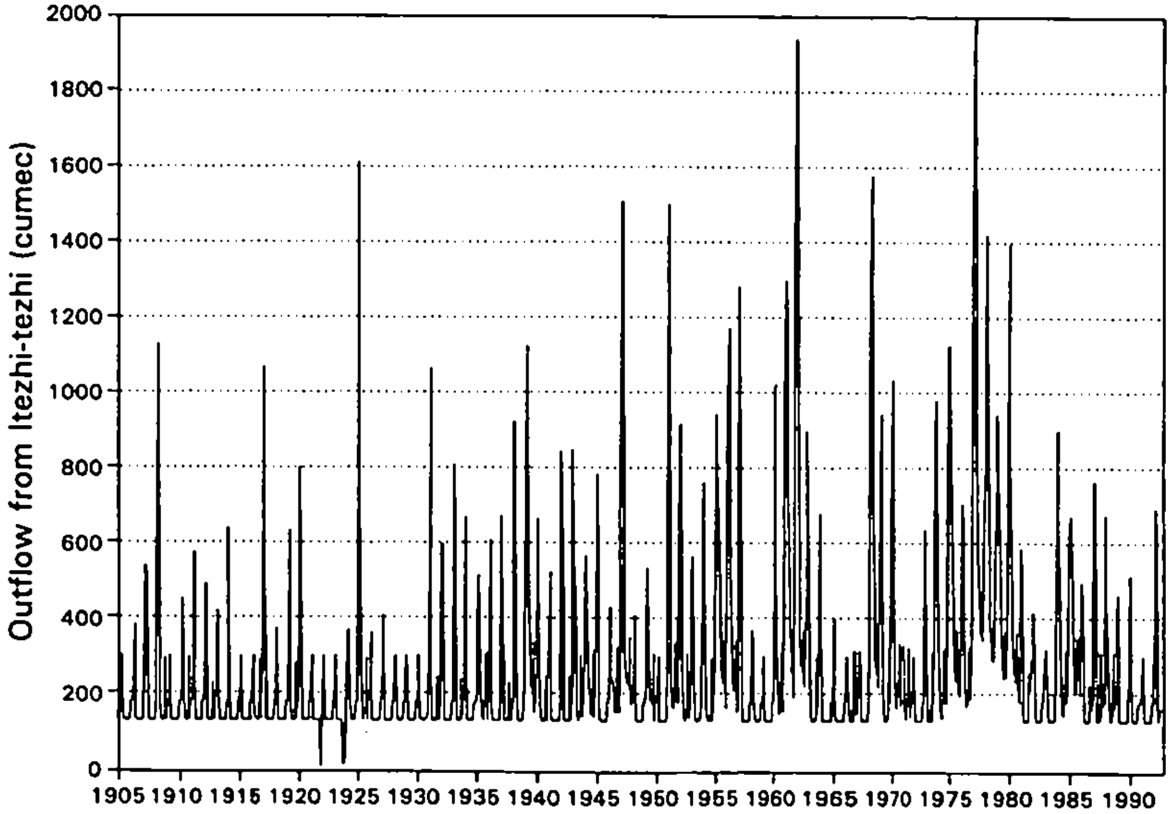


Figure 22

Comparison of Itezhi-tezhi outflow and Kafue Gorge inflow

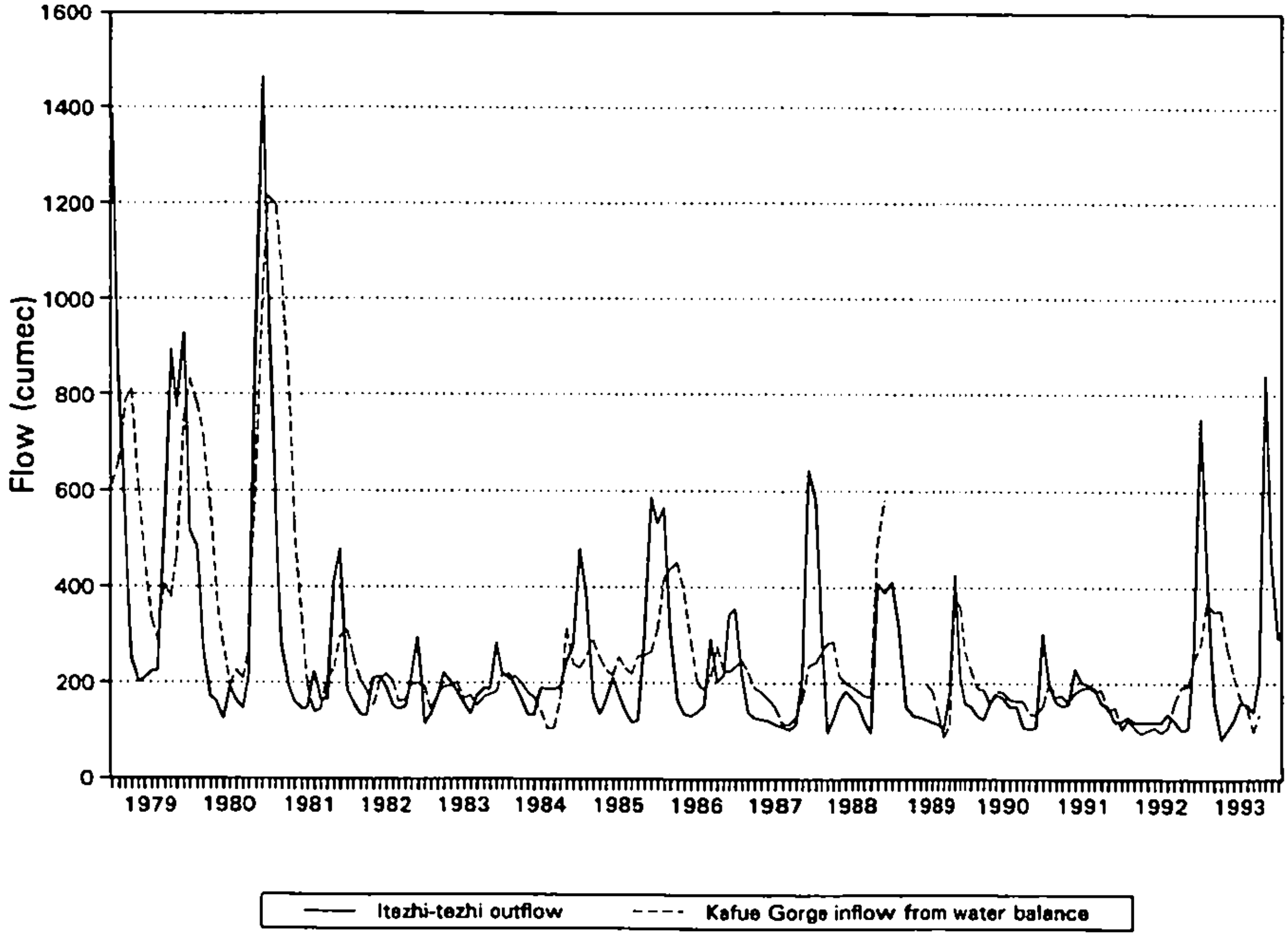
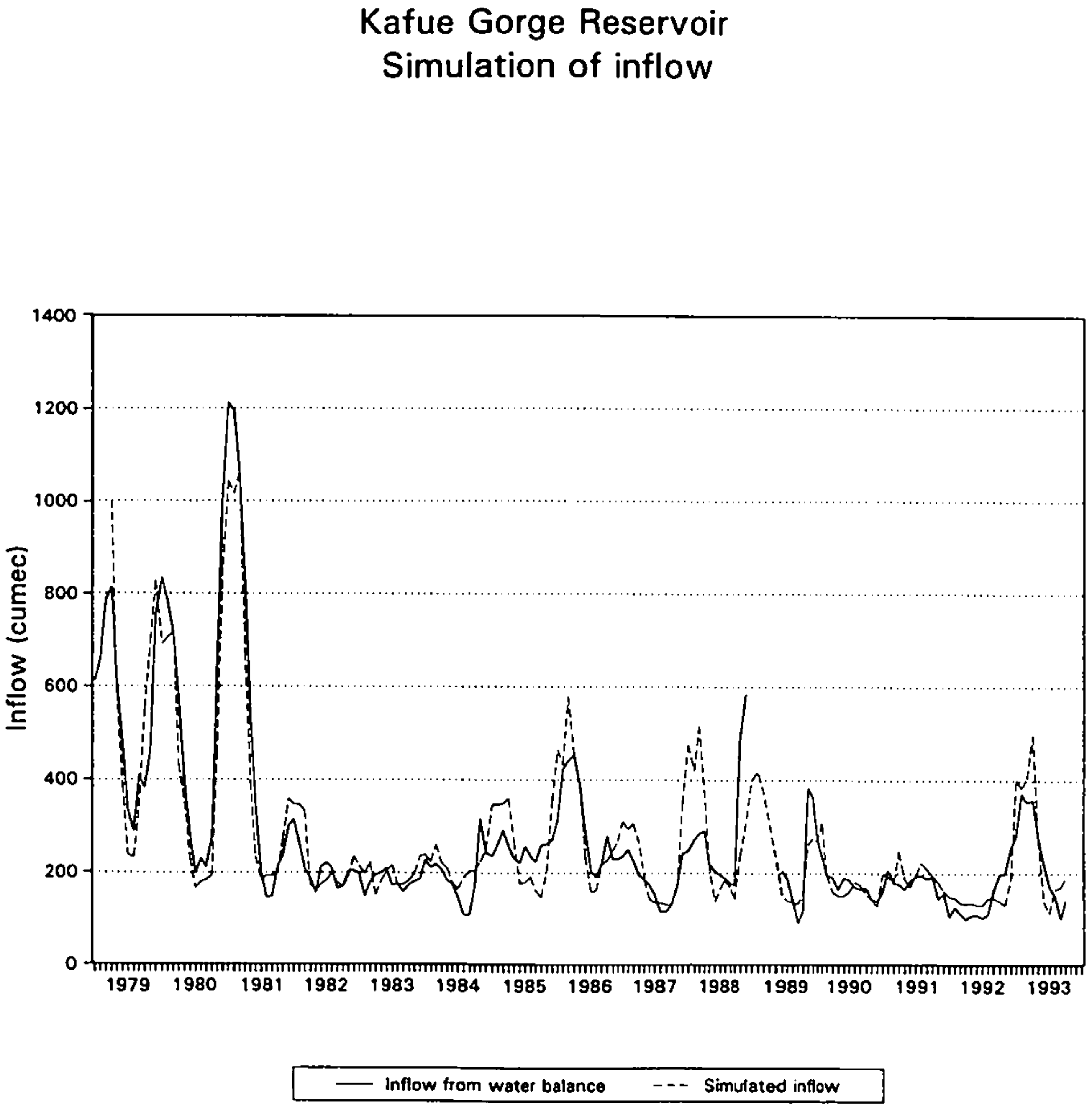


Figure 23



Kafue Gorge Reservoir
Simulation of inflow

Figure 24

Kafue Gorge Reservoir
Simulation of inflow

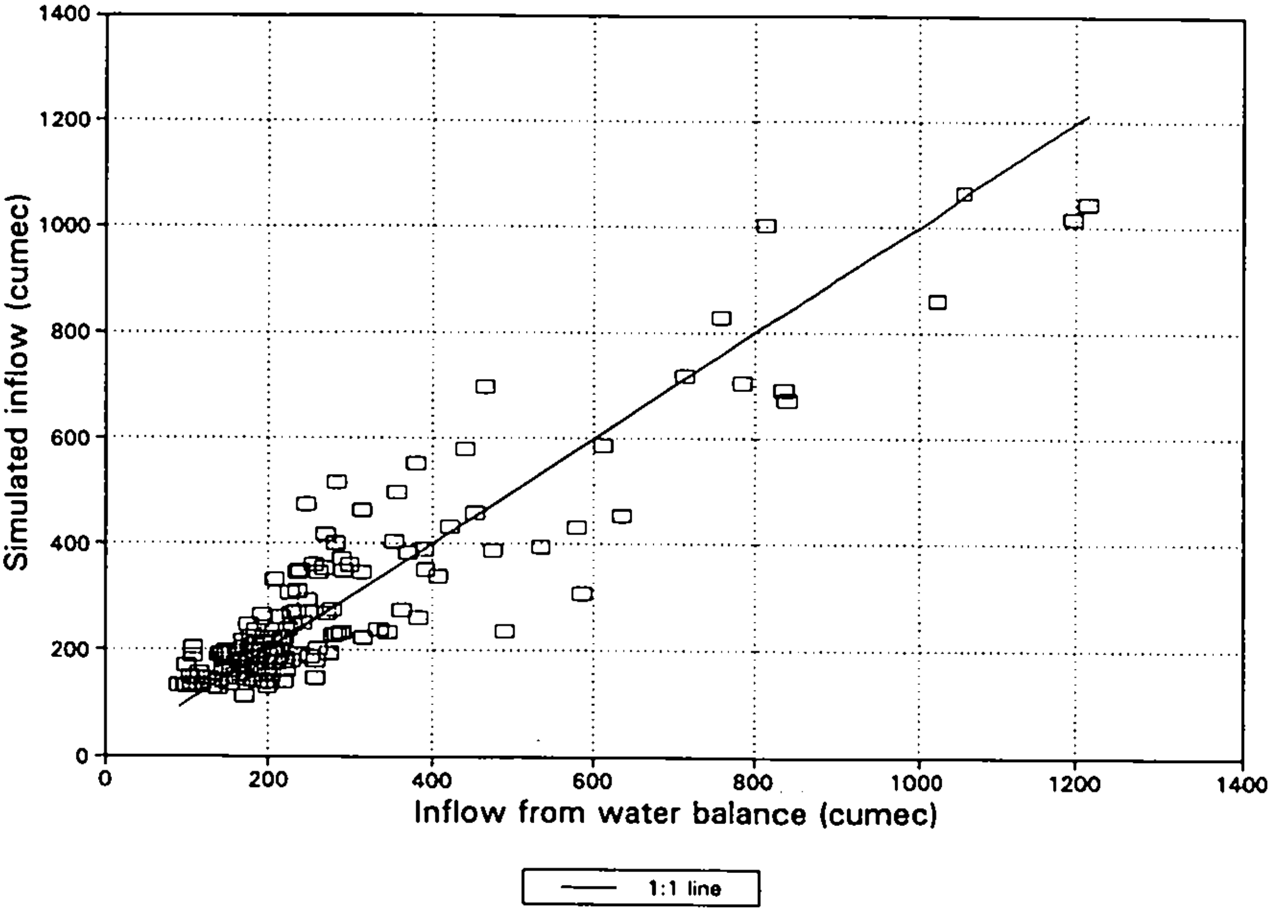


Figure 25

Kafue Gorge Reservoir
Simulation of inflow

Comparison of mean monthly inflows

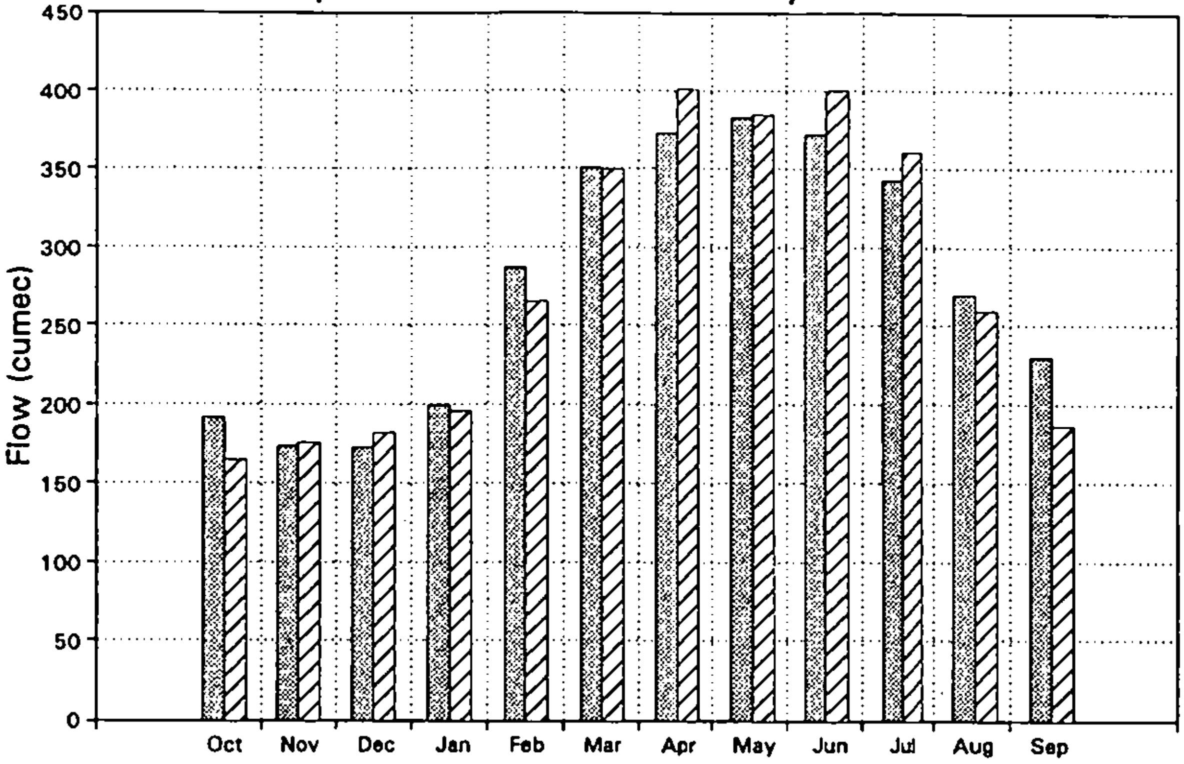


Figure 26a

Comparison of mean monthly standard deviations

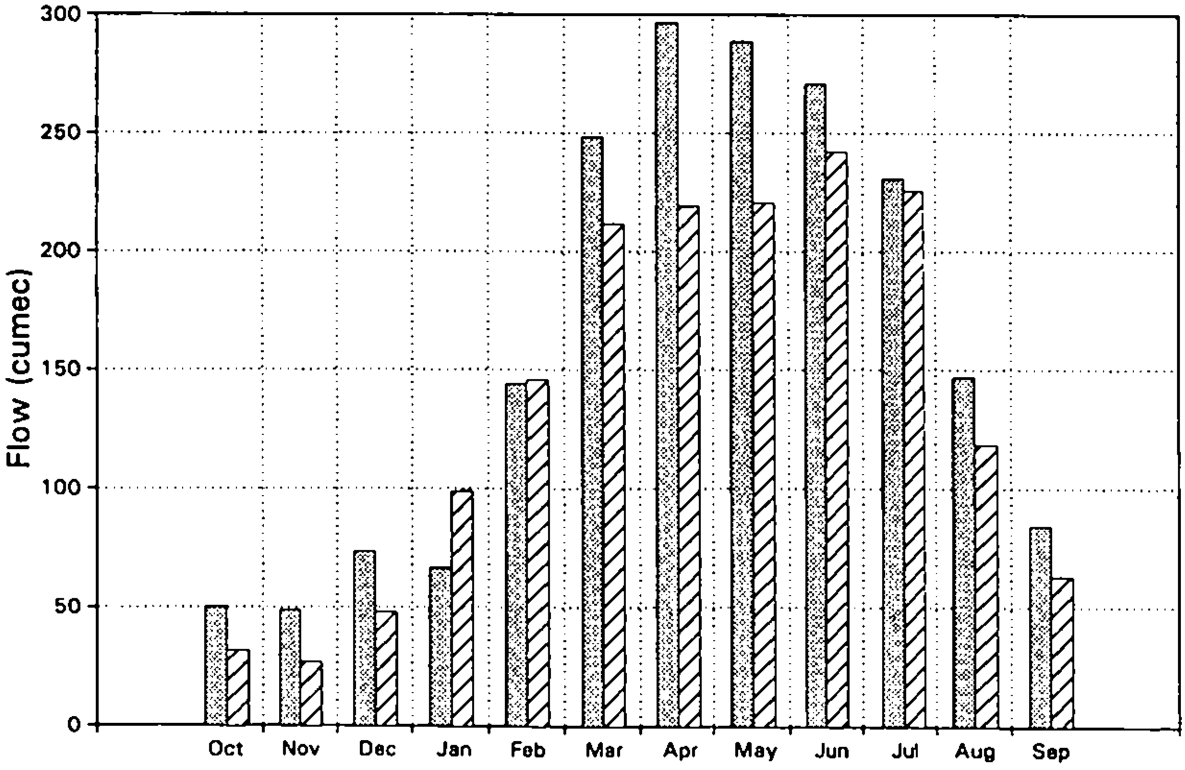


Figure 26b

▒ Inflow from water balance ▨ Simulated inflow

Kafue Gorge reservoir operation
Simulation run no. 1350

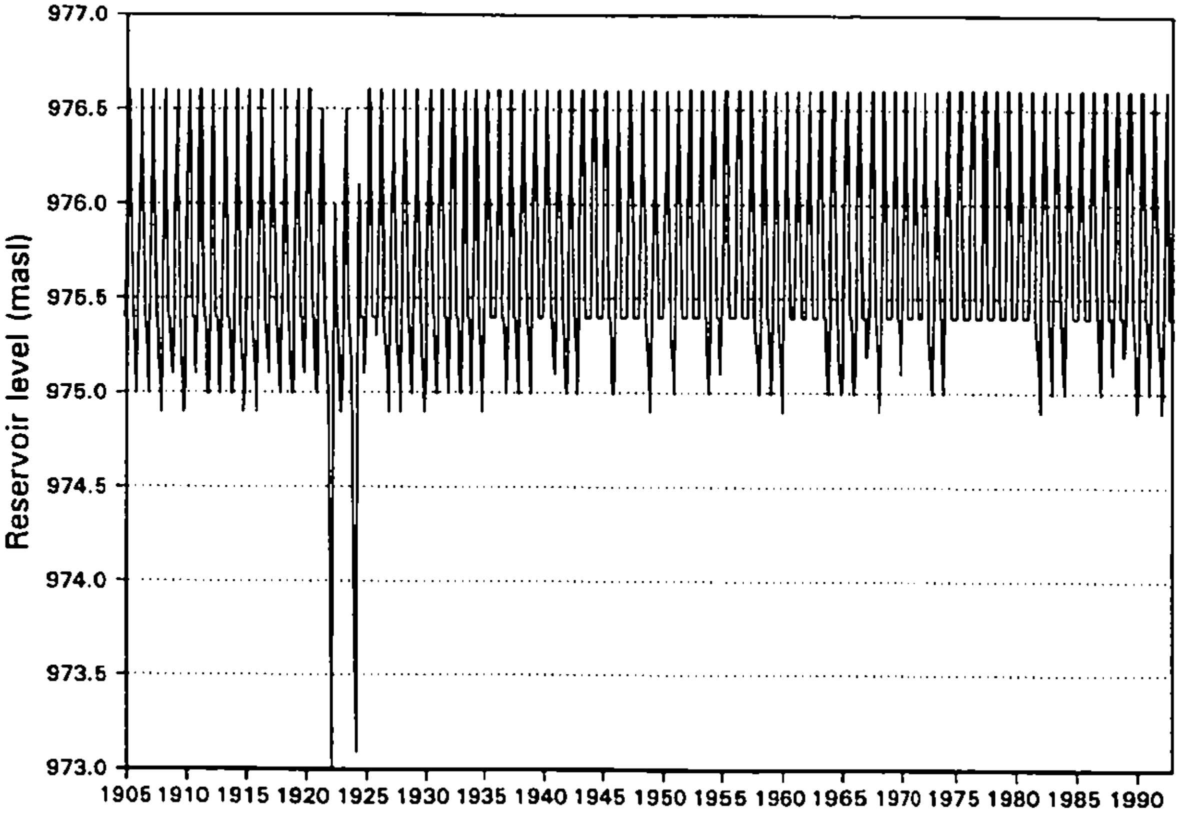


Figure 27

Kafue Gorge reservoir operation
Comparison of energy duration curves from run nos. 1350 and 1360

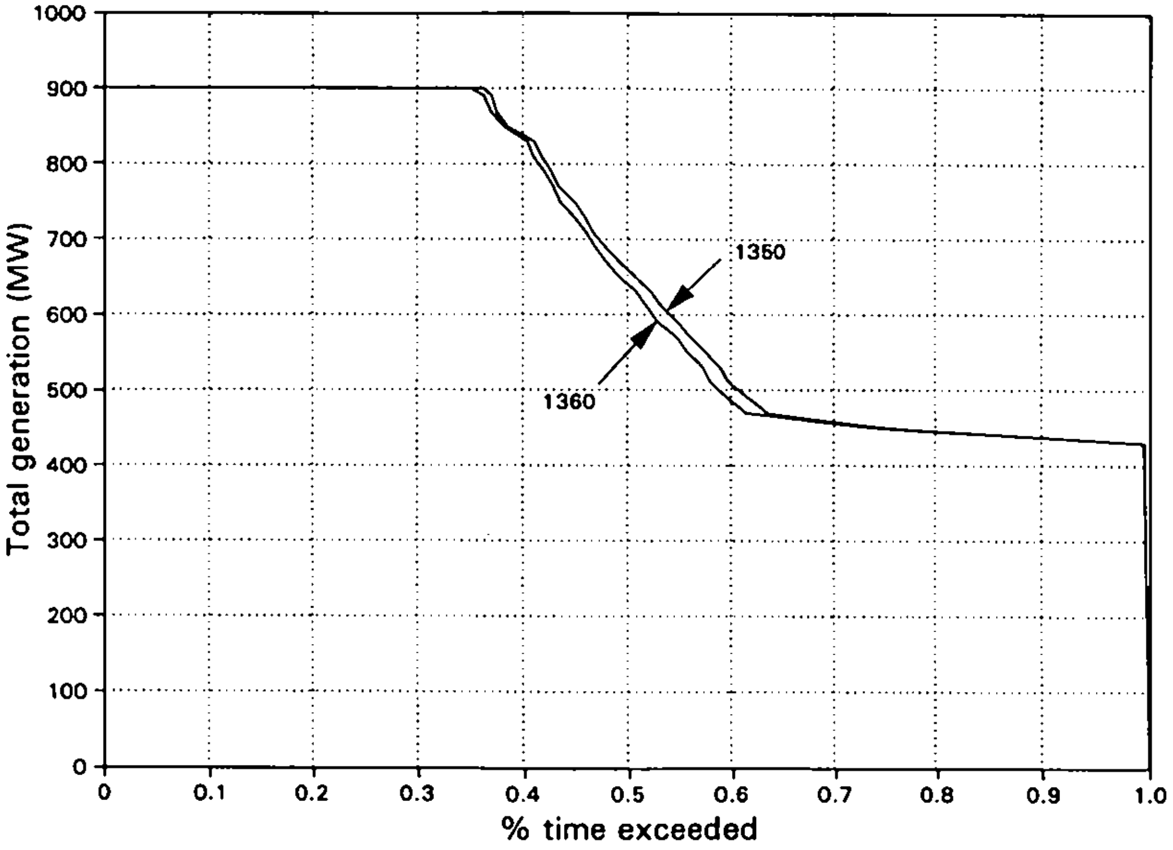


Figure 28

8. Discussion

The results of the simulations conducted in the current study are consistent with those reported by SLHP (1990a) and Shawinigan (1993a). The results presented in section 7 clearly demonstrate that the quantities of water removed for sugar cane irrigation have only a minor impact on the production of hydro-electricity at Kafue Gorge. This is primarily because the quantities involved are very small relative to the total flow in the Kafue. There is no doubt that regulating the flow between Itezhi-tezhi and Kafue Gorge benefits the sugar industry as well as ZESCO, by ensuring the flow is maintained throughout even the driest years.

The water rights granted for irrigation of sugar cane are rarely, if ever, fully utilised. They correspond to the peak quantities that can be taken on any day. However seasonal variations in crop water requirements means that the water rights are not fully used. In 1992 the Water Board attempted to restate the agricultural water rights in a manner reflecting more closely the actual water usage of the sugar industry. However, the amended water rights failed to adequately cover the crop water requirement (particularly in the months of June and July); determined by ZSC using long-term climate data and a calculation that is standard in the Sugar Industry in Southern Africa. Nevertheless there is no disagreement on the principle of basing future water rights on monthly figures rather than a single value.

By comparison with the actual amounts taken historically, the crop water requirement calculated on the basis of long-term average climatic data, appears to underestimate the water needed during the wet season. It is surmised that this is a consequence of the temporal variability of rainfall that occurs in the wet season; something that is not taken into consideration when using mean-monthly data to calculate the crop water requirement (section 5.2). In the current study the highest value determined in any month from either the mean-monthly climatic data or the historic abstraction data was assumed to reflect the true crop water requirement in that month.

The irrigation demand for the proposed future area of 17,400 ha under cane was determined simply by scaling up each month's requirement for 10,000 ha (section 5.2). On this basis the annual total requirement for 17,400 ha is 266 Mcm. This is 22% less than is granted under existing water rights. However, the peak demand in September (1,220,000 m^3d^{-1}) exceeds the present water right limit of 925,000 m^3d^{-1}.

The simulations conducted in the current study indicate that under present operating conditions the firm energy (430 MW) of the Itezhi-tezhi/Kafue Gorge system is 99.5% reliable. This reliability would not be altered if the irrigation demand was changed to that required to irrigate 17,400 ha. There would however, be a very small decrease in the total (firm plus secondary) energy that could be produced. This would be a reduction in the average annual total energy produced of less than 1%. It is beyond the scope of the current study to investigate the relative socio-economic consequences of a slight reduction in secondary energy generation as compared to the increase in sugar production that would result; however, it is suggested that such a study would be desirable.

The simulations conducted in the current study confirm the results of Shawinigan (1993a) that if the March freshet is not released, the firm energy of 430 MW can be considered 100% reliable. Again this would not be altered if the irrigation demand was changed to that required to irrigate 17,400 ha. The suggestion that the full supply level in Itezhi-tezhi and Kafue Gorge be raised by 1.0 m and 0.4 m respectively would increase the firm energy of the system, but would significantly increase the losses through evaporation. At Kafue Gorge the average annual loss would increase by nearly 40 %. The consequence of this would be that the annual secondary energy production would be reduced from the present 2018 GWh to 1772 GWh, a drop of 12 %.

8.1 A PROPOSAL FOR WATER-USE DURING EXCEPTIONALLY DRY YEARS

There can be no doubt that during the drought of 1991/92 the water resources of the Kafue Basin were severely stressed. During this year ZSC and the other cane growers made significant attempts to reduce water use. It has been suggested (Spitteler, General Manager, Nakambala Sugar Estate, personal communication) that ZSC would make similar attempts to save water during periods of extreme water shortage in the future. However, this would be a lot easier if ZSC are given advanced (i.e several months) warning of the need to reduce the application of irrigation water.

Shawinigan (1993a) demonstrated that the flow in the Kafue at Hook Bridge is extremely predictable through the dry season (April to October). This is because during this period the flow in the river arises predominantly from depletion of groundwater storage. Shawinigan (1993a) showed that the consequence of this is that from mid-April until the end of September, the flow recession can be modelled simply using two exponential decay functions; one for the period April 15 to June 15 and one for the period June 16 to September 30. Since the state of the storage in both the Kafue Gorge and the Itezhi-tezhi reservoirs are known at all times it is therefore possible to budget and plan water use for several months in advance. Indeed this is the basis of the KAFGEN operation program developed by Shawinigan (1993a). It would therefore be possible to give several months warning to agricultural users of the need to cutback on irrigation water use.

It is therefore recommended that a system is established whereby ZSC and the other agricultural users in the basin are given two to three months warning of the need to reduce water-use following a failure of the rains. If warned in mid-April, ZSC and the other cane growers could reduce water abstractions during say, July to October, the period of peak water requirement for the cane industry. This would assist in safeguarding both the municipal supplies and the firm energy of Kafue Gorge power station. It should be remembered that the cane growers are dependent on electricity to pump the irrigation water from the river and so it is in their own self-interest to safeguard energy production.

8.2 CONCLUSIONS

The following conclusions can be drawn from this study:

1. At Nakambala, the rate of abstraction only approaches the existing water right value on a few days of peak demand in each year.

2. The Water Board suggestion to change existing water-rights from a single annual value (that must necessarily match the peak irrigation demand) to monthly values that reflect seasonal changes in crop water requirements is sensible and is accepted by the Zambian Sugar Industry.

3. Using crop water requirements to determine the water needed for irrigation of the proposed 17,400 ha of cane, the current study has demonstrated that in total 22 % less water is required than the present water-rights allow for the sugar industry. However, the peak requirement during the growing season will exceed the amount allowed by the existing water right.

4. The water taken from the Kafue by the sugar industry does not reduce the firm energy of the Kafue Gorge/Itezhi-tezhi system, because the firm energy has been fixed assuming a full uptake of some 15 m^3s^{-1} by non-ZESCO water users at all times. This is the legal right of the other users, but because of the nature of crop water requirements is rarely, if ever, actually taken.

5. On the basis of the simulations conducted in the current study, the present operating rules for Itezhi-tezhi and Kafue Gorge reservoirs ensure that the firm energy target of 430 MW has a reliability of 99.5 %.

6. The simulations conducted in the current study show that under present operating conditions the proposed future irrigation requirement for 17,400 ha would not result in any increase in the failure of Kafue Gorge hydropower station to meet its firm energy target of 430 MW. The firm energy target of 430 MW would still be met 99.5 % of the time.

7. Under present operating conditions the proposed future irrigation requirement for 17,400 ha would reduce the total energy (i.e. firm plus secondary) produced by Kafue Gorge by less than 1 %.

8. If in future the March freshet is not released from Itezhi-tezhi, this study confirms the findings of Shawinigan (1993a) that 430 MW can then be regarded as firm energy that can be met continuously (i.e. 100 % reliability). This will not be affected by the proposed irrigation demand for 17,400 ha.

9. The proposal to raise the full supply level by 1.0 m at Itezhi-tezhi and by 0.4 m at Kafue Gorge is questioned. Although this would result in an increase in the firm energy of the system, the increased surface area of both reservoirs, but particularly at Kafue Gorge, results in a significant increase in losses through evaporation. Consequently there is a reduction in the secondary energy that can be produced by the system. The simulations conducted for this study suggest that the reduction would be of the order of 12% when compared to that produced under present conditions. The advantages of a slight increase in firm energy production must be weighed against the losses in secondary energy production that will occur.

10. It is believed that ZSC and other cane growers are willing to reduce irrigation during periods of extreme drought in order to safeguard the municipal supplies taken from the Kafue River as well as the firm energy of the Kafue Gorge hydropower station. Using the KAFGEN model to plan future operation of the Itezhi-tezhi/Kafue Gorge system, ZESCO could warn ZSC and other agricultural users of the need for reduction in the application of irrigation water several months in advance. This advance warning would enable all parties to develop plans to utilise the limited resources in the best way possible.

11. Given its important role in the economy of Zambia, IH strongly supports the

recommendation of Burke *et al.* (1994) that an integrated water resources management strategy is developed for the whole of the Kafue Basin.

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References

Balek, J. 1971. Water balance of the Zambezi Basin. NCSR TR 15/WR8, Lusaka.

Booker Tate Ltd. 1990. Visit report - irrigation and drainage.

Burke, J.J., Jones, M.J. & Kasimona, V. 1994. Approaches to integrated resource development and management of the Kafue basin, Zambia. Integrated River Basin Development (editors Kirby, C. & White, W.R.). John Wiley & Sons, Chichester.

DHV Consulting Engineers. 1980. Kafue Flats Hydrological Studies. Final Report.

JICA. 1992. Final report supporting the master plan study on hydrologic observation systems of the major river basins in Zambia.

Mumeka, A. 1992. The water resources of the Kafue Flats and Bangweulu Basin. Proceedings of the WWF - Zambia Wetlands Project Workshop (November 1986). Managing the wetlands of Kafue Flats and Bangweulu Basin (editors Jeffrey, R.C.V., Chabmela, H.N., Howard, G. & Dugan, P.J.).

Njobvu, S.L. 1990. The problems of running an efficient irrigation system on a small holder project. Agricultural Water Management, 17 319-321.

Obrdlik, P., Mumeka, A. & Kasonde J.M. 1989. Regulated Rivers in Zambia - the case study of the Kafue River. Regulated Rivers: Research & Management, 3, 371-380.

Plinston, D. 1989. User Notes: Multipurpose reservoir simulation program (HYDRO-PC).

Sharma, T.C. 1988. An evaluation of evapotranspiration in tropical central Africa. Hydrological Sciences Journal 33, 31- 40.

Shawinigan-Lavalin & Hidrotechnica Portuguesa. 1990a. Simulation of the Kafue Gorge power plant operation. SADCC 3.0.4 Hydroelectric Hydrological Assistance Project - Phase 1.

Shawinigan-Lavalin & Hidrotechnica Portuguesa. 1990b. Review of river basin models in use in the SADCC region and recommendations for models and studies appropriate to the Zambezi River Basin - Draft Report. SADCC 3.0.4 Hydroelectric Hydrological Assistance Project - Phase 1.

Shawinigan. 1992. Reservoir operation studies with HEC-3. Training Manual. SADC AAA.3.4 Hydroelectric Hydrological Assistance Project - Phase 2.

Shawinigan. 1993a. Itezhi-tezhi/Kafue Gorge operating procedure. Draft final report. SADC AAA.3.4 Hydroelectric Hydrological Assistance Project - Phase 2.

Shawinigan. 1993b. Computation of discharge from hydrualic structures and powerplant at Itezhi-tezhi/Kafue Gorge - Draft report. SADC AAA.3.4 Hydroelectric Hydrological Assistance Project - Phase 2.

Snowy Mountains Engineering Corporation. 1987. Study of open water evaporation in Botswana - Final report.

SWECO. 1969. Kafue River regulation, water management, stage 1.

SWECO. 1971. Kafue River hydro-electric power development, stage 2.

SWECO. 1973. Kafue River regulation. Memo 12404-310-03, 7th November 1973.

SWECO. 1993. Preliminary Consideration of Itezhi-tezhi and Kafue Gorge Maximum Storage Levels. Letter to ZESCO.

Turner, B. 1983. Bibliography of the Kafue Flats. Kafue Basin Research Committee of the University of Zambia.

Turner, B. 1985. Flooded areas compiled from Landsat imagery. Map published by the Kafue Basin Research Project in conjunction with the Survey Department, Lusaka, Zambia.

Watermeyer, Legge Piesold & Uhlmann. 1972. Kafue River hydro-electric power development Itezhi-tezhi dam. Review of pre-investment study by SWECO.

White, E. 1968. Kafue Hydro-electric scheme, Zambia. Artificial lakes and its consequences.

Zambian Sugar Company Ltd. 1994. Information Pack.

Appendix A

GLOSSARY OF TERMS

Average energy: the sum of firm and secondary energy expressed as an average (monthly or annual) amount available considering a range of inflow conditions.

Demand: the output or level of benefit sought under normal operating conditions.

Energy units: The normal usage is kWh, MWh or GWh. Because of the difficulty in using this for variable periods e.g. GWh/month often use MW with a clear reference to the applicable period (month/year). Note a MW-year = 8.76 GWh.

Firm energy: amount that can be guaranteed (subject to the accuracy of the analysis) with a specified degree of reliability and for a specified time period.

Gross Head: elevation difference between the upstream reservoir and the downstream tailwater level.

Head Loss: the friction and other losses in the penstock and turbine system, expressed in terms of head.

Installed Capacity: The rated output of the plant generators, expressed in MW.

Machine efficiency: the term required to convert net head and turbine flow into power/capacity. Normally covers turbine efficiency and generator efficiency.

Maximum Plant Capacity: Total (all units) output under best conditions i.e. normally with maximum flow (all units at full gate) with the upstream reservoir full, just prior to spilling and no flooding downstream to raise tailwater levels.

Minimum Plant Capacity: The total plant output under worst conditions (but with all units running at full gate), typically with the upstream reservoir at minimum level i.e. minimum available head.

Net Head: gross head reduced by head loss; the effective head across the turbines.

Operating rule curve: any set of rules defining an operating strategy which can be expressed or defined by a series of monthly reservoir levels.

Secondary energy: amount generated in excess of firm energy. Obviously the amount is variable and unpredictable - zero at times, large during well above average flow conditions.

Tailwater level: the water level below the dam at the point where the flow from the turbines is discharged.

Appendix B

DATA SERIES USED IN THIS STUDY

Table B.1

NAKAMBALA SUGAR ESTATE
HISTORIC RECORD OF WATER ABSTRACTION - WATER SUPPLIED TO MAZABUKA TOWN

MCM

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total Mcm
1979/80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980/81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981/82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.14	0.12	0.14	0.50
1982/83	0.17	0.14	0.13	0.16	0.18	0.17	0.14	0.12	0.16	0.15	0.12	0.13	1.77
1983/84	0.14	0.16	0.12	0.14	0.14	0.19	0.13	0.16	0.14	0.14	0.13	0.14	1.73
1984/85	0.13	0.12	0.12	0.13	0.15	0.12	0.11	0.16	0.11	0.15	0.11	0.12	1.53
1985/86	0.11	0.13	0.11	0.12	0.16	0.11	0.13	0.12	0.13	0.15	0.12	0.13	1.52
1986/87	0.14	0.16	0.13	0.18	0.15	0.14	0.17	0.15	0.15	0.16	0.18	0.14	1.85
1987/88	0.14	0.13	0.17	0.14	0.14	0.17	0.14	0.12	0.19	0.10	0.13	0.11	1.68
1988/89	0.14	0.13	0.17	0.14	0.14	0.18	0.19	0.18	0.19	0.19	0.17	0.19	2.01
1989/90	0.18	0.19	0.18	0.19	0.19	0.18	0.19	0.18	0.19	0.19	0.17	0.19	2.22
1990/91	0.18	0.19	0.18	0.19	0.19	0.18	0.19	0.18	0.19	0.19	0.17	0.19	2.22
1991/92	0.14	0.19	0.18	0.19	0.19	0.18	0.19	0.18	0.19	0.19	0.18	0.19	2.19
1992/93	0.18	0.19	0.18	0.19	0.19	0.18	0.19	0.18	0.18	0.22	0.17	0.19	2.24
1993/94	0.18	0.19	0.18	0.19	0.19	0.18	0.19	0.14	0.19	0.19	0.17	0.19	2.18

Table B.2

NAKAMBALA SUGAR ESTATE
HISTORIC RECORD OF WATER ABSTRACTION
(includes domestic and factory requirement, but excludes outgrowers and Mazabuka supply)

MCM

	Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total Mcm	Total m3/s	Area of cane ha
	1979/80	12.42	15.07	12.48	12.88	16.26	11.62	13.24	7.33	0.59	5.91	9.55	5.78	123.13	3.90	9707
	1980/81	10.95	14.08	10.59	12.92	15.66	12.92	19.33	10.52	0.00	0.00	0.00	0.00	106.97	3.39	9853
	1981/82	1.62	15.53	10.54	11.47	15.50	11.66	17.99	15.96	11.51	2.25	2.40	3.70	120.13	3.80	9821
	1982/83	18.35	10.26	7.73	9.79	9.71	9.58	12.11	10.17	8.13	11.01	1.35	5.40	113.59	3.60	9940
	1983/84	10.76	10.40	9.16	10.71	9.28	13.21	10.99	13.16	11.52	6.32	4.99	6.68	117.18	3.71	9920
	1984/85	10.74	12.10	14.56	12.24	15.29	14.68	13.33	11.23	1.38	1.29	1.86	5.91	114.61	3.63	9929
	1985/86	10.79	17.80	12.16	14.73	11.99	14.02	18.87	12.68	4.14	1.19	2.24	8.92	129.53	4.10	9943
	1986/87	7.97	10.04	14.35	14.70	12.51	14.49	11.50	8.31	4.27	9.40	4.79	7.07	119.40	3.78	9943
	1987/88	18.98	15.61	17.30	12.89	14.50	19.17	14.86	16.82	4.50	9.45	5.90	7.55	157.53	4.99	10168
	1988/89	16.54	15.64	18.66	14.40	15.34	20.12	16.02	20.62	10.81	2.45	0.67	3.56	154.83	4.90	10132
	1989/90	12.80	15.52	12.77	13.13	15.24	13.85	15.67	18.01	13.92	0.91	2.12	15.87	149.81	4.74	10068
	1990/91	14.73	19.04	12.28	12.82	16.77	16.35	20.56	17.51	11.23	1.03	1.94	8.39	152.65	4.83	10113
	1991/92	11.82	19.79	15.48	13.52	15.27	14.71	18.93	9.43	10.27	6.86	15.26	12.63	163.97	5.19	10093
	1992/93	14.95	13.89	13.07	13.84	11.24	17.26	13.59	13.17	4.61	1.22	1.21	1.27	119.32	3.78	10109
	1993/94	12.50	12.56	13.71	10.82	11.76	16.30	14.33	13.10	5.06	2.99	1.41	7.87	122.41	3.87	10432
Average	Mm3	12.39	14.49	12.99	12.72	13.90	14.55	15.50	13.21	6.92	4.24	3.88	6.62	131.40		
	000's m3/d	413.16	467.38	432.98	410.45	448.29	484.86	499.98	440.29	223.23	136.61	137.24	213.66	359.76		
	cumecs	4.78	5.41	5.01	4.75	5.19	5.61	5.79	5.10	2.58	1.58	1.59	2.47	4.16		
	% annual	0.09	0.11	0.10	0.10	0.11	0.11	0.12	0.10	0.05	0.03	0.03	0.05	1.00		
	Maximum	18.98	19.79	18.66	14.73	16.77	20.12	20.56	20.62	13.92	11.01	15.26	15.87	163.97		
	Minimum	1.62	10.04	7.73	9.79	9.28	9.58	10.99	7.33	0	0	0	0	106.97		
	CV	0.33	0.20	0.22	0.11	0.17	0.19	0.19	0.28	0.63	0.84	1.01	0.59	0.14		
Existing	Mcm	21.51	22.23	21.51	22.23	22.23	21.51	22.23	21.51	22.23	22.23	20.26	22.23	261.88		
water right	000'm3/d	717	717	717	717	717	717	717	717	717	717	717	717			

Table B.3

NAKAMBALA SUGAR ESTATE
HISTORIC RECORD OF WATER ABSTRACTION INCLUDING WATER SUPPLIED TO THE OUTGROWERS
(includes domestic and factory requirement, Mazabuka town supply)

MCM

	Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total Mcm	Total m3/s	Area of cane ha
	1979/80	13.05	15.70	12.83	13.36	17.04	12.30	13.95	7.55	0.59	6.20	9.68	5.98	128.23	4.06	10339
	1980/81	11.42	14.68	10.99	13.29	16.06	13.40	20.13	10.82	0.00	0.00	0.00	0.00	110.79	3.51	10485
	1981/82	1.67	16.00	10.94	11.80	16.18	12.34	18.76	16.49	11.87	2.29	2.42	4.07	124.83	3.95	10513
	1982/83	19.24	11.01	8.38	10.51	10.38	10.36	13.19	11.15	8.96	11.98	1.38	7.19	123.73	3.92	11185
	1983/84	12.71	12.34	10.95	12.47	11.02	15.88	13.56	16.29	15.02	7.66	6.72	7.81	142.43	4.51	11940
	1984/85	12.51	13.75	16.77	13.99	17.97	17.45	16.56	13.63	1.54	1.47	2.06	6.54	134.24	4.25	12269
	1985/86	12.74	20.42	13.80	17.06	14.06	16.45	22.65	15.76	5.14	1.19	3.03	11.60	153.90	4.87	12473
	1986/87	9.78	11.86	16.05	16.85	14.99	17.38	13.77	10.20	5.39	11.83	6.82	9.83	144.75	4.58	12473
	1987/88	22.91	18.79	20.58	15.09	17.06	22.97	17.91	20.43	5.00	11.75	7.18	8.40	188.07	5.95	12698
	1988/89	20.30	18.29	22.08	17.20	18.59	24.58	19.56	25.29	13.66	2.45	0.67	3.94	186.61	5.91	12663
	1989/90	15.10	19.68	15.17	15.60	18.69	16.60	18.91	21.06	15.81	0.90	2.29	18.77	178.58	5.65	12532
	1990/91	17.68	22.51	15.53	15.32	19.88	19.51	24.78	21.21	13.49	1.03	2.09	10.06	183.09	5.80	12577
	1991/92	14.33	21.46	17.81	15.93	18.11	17.21	21.55	10.76	11.76	8.18	18.00	14.49	189.59	6.00	12557
	1992/93	18.08	15.92	15.45	16.44	13.35	20.13	16.52	15.66	7.05	1.22	1.38	1.30	142.50	4.51	12632
	1993/94	14.92	15.43	16.57	13.27	14.10	19.19	16.88	15.68	5.86	3.48	2.26	10.21	147.85	4.68	12956
Average	Mcm	14.43	16.52	14.93	14.55	15.96	16.90	17.99	15.45	8.23	4.87	4.55	7.86	152.22		
	000's m3/d	480.98	532.99	497.56	469.20	514.70	563.24	580.18	515.00	265.62	157.03	161.11	253.41	416.76		
	cumecs	5.57	6.17	5.76	5.43	5.96	6.52	6.72	5.96	3.07	1.82	1.86	2.93	4.82		
	% annual	0.09	0.11	0.10	0.10	0.10	0.11	0.12	0.10	0.05	0.03	0.03	0.05	1.00		
	Maximum	22.91	22.51	22.08	17.2	19.88	24.58	24.78	25.29	15.81	11.98	18	18.77	189.59		
	Minimum	1.67	11.01	8.38	10.51	10.38	10.36	13.19	7.55	0	0	0	0	110.79		
	CV	0.34	0.21	0.24	0.14	0.17	0.23	0.19	0.31	0.62	0.88	1.00	0.60	0.17		

Table B.4

Institute of Hydrology
Summary of monthly data - Rainfall

Station number : 2305 Name : Kafue Rail

Basin no. : 0 Latitude : 15:45: 0 S Longitude : 28:10: 0 E Altitude : .0

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Total
1909/10	-	-	-	46.	85.	188	41	0.	0.	0.	0.	0.	-
1910/11	10.	159.	139.	193.	266.	118.	3	40.	0.	0	0	0	928.
1911/12	3.	42	85.	268.	161.	0.	0.	0.	0.	0	0.	0.	559.
1912/13	0.	5.	178.	114.	210.	142.	43.	32.	0.	0.	0.	0.	724.
1913/14	2.	76.	70.	183.	216.	27.	29.	0.	0.	1.	0.	0.	604.
1914/15	0.	149.	160.	209.	273.	54.	9.	0.	0.	0.	0.	0.	854.
1915/16	5.	63.	165.	232.	85.	39.	0.	0.	0.	0.	0.	0.	589.
1916/17	0.	113.	290.	120.	54.	91.	13.	0.	0.	0.	0.	0.	681.
1917/18	7.	125.	274.	256.	275.	107.	22.	0.	0.	0.	0.	0.	1066.
1918/19	2.	191	78.	246.	288.	34.	0.	0.	0.	0.	0.	0.	839.
1919/20	64.	63.	255.	210.	276.	141.	2.	2.	0.	0	0.	0.	1013.
1920/21	16.	29.	146.	336.	129.	75	4.	0.	0.	0	0.	0.	735.
1921/22	20.	77.	141.	45.	158.	7.	21.	0.	0.	0	0.	0.	469.
1922/23	27.	93.	197.	162.	129.	208.	0.	0.	0.	0.	0.	0.	816.
1923/24	0.	52.	125.	55.	102.	48.	0.	0.	0.	0.	0.	0.	382.
1924/25	6.	130.	228.	400.	230.	124.	17.	18.	0.	0.	0.	25.	1178.
1925/26	36.	28.	96.	349.	222.	180.	0.	0.	0.	0.	0.	1.	912.
1926/27	0.	51.	242.	80.	95.	27.	0.	0.	0.	0.	0.	0	495.
1927/28	6.	146.	156.	230.	66.	101.	4.	0.	0.	0.	0.	0.	709.
1928/29	0.	201.	261.	449.	48.	194.	0.	0.	0.	0.	0.	0.	1153.
1929/30	1.	82.	212.	55.	30.	132.	17.	0.	0.	0.	0.	0.	529.
1930/31	0.	178.	302.	136.	84.	89.	3.	0.	0.	0.	0.	0.	792.
1931/32	0.	186.	180.	212.	209.	191.	28.	0.	0.	0.	0.	0.	1006.
1932/33	0.	67.	401.	329.	237.	0.	0.	0.	0.	0.	0.	0.	1034.
1933/34	0.	55.	104.	91.	192.	47.	22.	0.	0.	0.	0.	0.	511.
1934/35	35.	245.	287.	211.	69.	57.	5.	7.	0.	0.	0.	0.	936.
1935/36	3.	40.	144.	152.	215.	205.	18.	0.	0.	0.	0.	0.	777.
1936/37	48.	24.	175.	137.	154.	66.	0.	0.	0.	0.	0.	0.	604.
1937/38	0.	57.	175.	238.	99.	35.	28.	0.	0.	0.	0.	0.	632.
1938/39	10.	80.	200.	312.	333.	160.	1.	0.	0.	0	0.	0.	1096.
1939/40	0.	168.	286.	60.	226.	164.	43	0.	0	0.	0.	0.	947.
1940/41	57.	86.	174	357.	149.	113.	0	0.	0	0.	0.	0	936.
1941/42	50.	83.	277.	267.	41.	41.	0.	0.	0	0	0.	0.	759.
1942/43	72	45.	208.	256.	148.	165.	33.	0.	0.	0	0.	0.	927.
1943/44	0.	131.	218.	200.	490.	139.	0.	0.	11.	0.	0.	0.	1189.
1944/45	4.	115.	74.	130.	111.	189.	7.	0.	0.	0	0.	0.	630.
1945/46	13.	53.	119.	303.	207.	128.	0.	0.	0.	0	0.	0.	823.
1946/47	0.	34.	169.	73.	52.	64.	38.	0.	0.	0	0.	0.	430.
1947/48	13.	71.	254.	114.	127.	261.	3.	0.	0.	0	0.	0.	843.
1948/49	62.	169.	35.	146	58.	4.	11.	0.	0.	0	0.	0.	485.
1949/50	0.	76.	202.	136.	166.	35.	13	0.	0.	0.	0.	0.	628.
1950/51	0.	64.	141.	177.	63.	22.	0.	0.	0.	0.	0	0	467.
1951/52	37	52.	288.	412.	162.	38.	1.	0.	0	0	0.	0.	990.
1952/53	8.	124.	184.	277.	224.	194.	17.	0.	– 0.	0.	0.	0.	1028.
1953/54	0.	72.	168.	223.	199.	58.	0.	0.	0.	0	0.	0.	720.
1954/55	1.	179.	241.	297.	198.	66.	0.	0.	0.	0	0.	0.	982.
1955/56	5.	38	143.	191.	347.	230.	0	0.	0.	0	0.	0.	954.
1956/57	0.	72.	204.	78.	176.	65.	4	0	0.	0	0.	7.	606
1957/58	11.	42	370.	367.	408.	71.	0	0.	0.	0	0.	12.	1281.
1958/59	23.	38	247.	161	208.	51.	3.	0	0	0.	0	0.	731.
1959/60	10	61	234.	228.	177.	28.	0.	0.	0	0.	0	0	738.
1960/61	3.	106.	112	219.	188.	147.	0.	0.	0.	0.	0	0	775.
1961/62	0.	155.	170.	198.	160.	53.	28.	0.	0.	0	0.	0.	764.
1962/63	0	143	390.	80.	260.	38.	0.	0.	0.	0	0.	0.	911
1963/64	4.	45	158.	226.	117.	18.	0.	0.	0.	-	-	-	-
1964/65	-	-	-	-	-	-	-	-	-	-	-	-	-
1965/66	-	-	-	-	-	-	-	-	-	-	-	-	-
1966/67	0	51.	-	-	-	-	-	-	-		-	-	-
1967/68	-	-	-	-	-	-	-	-	-	-	-	-	-
1968/69	-	-	-	-	-	-	-	-	-	-	-	-	-

Table B.4 continued

Institute of Hydrology
Summary of monthly data - Rainfall

Station number : 2305 Name : Kafue Rail

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Total
1969/70	-	-	-	-	-	-	-	-	-	-		-	-
1970/71	-	-	-	-	-	-	-	-	-	0	0.	0.	-
1971/72	0.	90.	163.	359	150	33.	51.	0.	0	0	0.	0.	846.
1972/73	5.	25.	198.	222.	190.	119.	1.	0	0.	0	0.	0.	760.
1973/74	11.	22.	118.	110	71.	3.	0.	0	0	0	0.	0.	337.
1974/75	0	155.	215.	361.	153.	63.	0.	0.	0.	0	0.	0.	947.
1975/76	0.	101.	260.	163.	158.	356.	48.	10	0.	0	0.	6.	1102.
1976/77	17.	25.	126.	62.	128.	152.	0.	0	0.	0.	0	0.	510.
1977/78	0.	140.	256.	287.	105.	254.	49	0	0.	0	0.	0.	1091.
1978/79	0	19.	424.	126.	135	58	0	0	0	0.	0.	0.	762.
1979/80	31.	211.	184	68.	158	19	6.	0	0.	0.	0	0.	677.
1980/81	0	66.	206.	286.	208.	114.	68.	0	0.	0	0.	0.	1028.
1981/82	-	179.	92.	290.	163.	-	-	0.	0.	0.	0.	0.	-
1982/83	0.	90.	42.	230.	89.	37.	50.	0.	0.	0.	0.	0.	538.
1983/84	0.	57.	153.	89.	197.	79.	11.	0	0	0.	0.	0.	586.
1984/85	0.	69.	119.	204.	145.	38.	0.	0	0.	0.	0.	0.	575.
1985/86	16.	54.	282.	298.	88.	102.	117.	0.	0.	0.	0.	0.	957.
1986/87	45.	107.	211.	217.	98.	52.	0.	0	0.	0.	0.	5.	755.
1987/88	4.	28.	207.	153.	149.	54.	16.	0.	0.	0.	0.	0.	611.
1988/89	0	15.	51.	360.	581.	195.	0.	0	0.	0.	0.	0.	1202.
1989/90	0	41.	191.	318.	138.	43.	68.	0	0.	0.	0.	0.	799.
1990/91	0	15	187.	267.	135.	99.	14.	0	0.	0.	0.	0.	717.
1991/92	16	0.	153.	131.	77.	77.	13.	4	0.	0.	0.	0.	471.
1992/93	0.	53.	208.	89.	164.	-	-	-	-	-	-	-	-
1993/94	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	11.	86.	192.	207.	172.	96.	14.	1.	0.	0.	0.	1.	780.
Median	2.	71.	184.	210.	158.	71.	3.	0.	0.	0.	0.	0.	
Maximum	72.	245.	424.	449.	581.	356.	117.	10.	11.	1.	0.	25.	
Minimum	0.	0	35.	45.	30.	0.	0.	0.	0.	0.	0.	0.	
St. dev.	18.	56.	80.	100.	97.	73.	21.	6.	1.	0.	0	3.	
CV	1.64	.65	.42	.48	.56	.76	1.53	4.22	8.72	8.72	00	4.54	

Total monthly rainfall in millimetres

Data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

Printed on 28/10/1994

Table B.5

Institute of Hydrology
Summary of monthly data - Rainfall

Station number : 2400   Name : Kafue Polder Agromet. Stn.

Basin no. : 0   Latitude : 15:46: 0 S   Longitude : 27:55: 0 E   Altitude : 978.0

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Total
1956/57	-	-	-	-	-	-	-	-	0.	0.	0.	0.	-
1957/58	0.	27.	375.	285.	436.	52.	8.	0	0.	0.	0.	9.	1192.
1958/59	22.	90.	329.	132.	243.	19.	0.	5.	0.	0.	0.	0.	840.
1959/60	1.	73.	320.	202.	132.	32.	10.	29	1.	0.	0.	0.	800.
1960/61	5.	86.	87.	334.	93.	114.	41.	0	0.	0.	0.	0.	760.
1961/62	0.	108.	189.	210.	170.	32.	101.	0	0.	0.	0.	0.	810.
1962/63	0.	170.	420.	149.	203.	31.	6	0	0.	0.	0.	0.	979.
1963/64	19.	59.	143.	259.	166.	13.	0	0	0.	0.	0.	0.	659.
1964/65	3	81.	255.	138.	72.	71.	0	0	0.	0.	0.	9.	629.
1965/66	19	80.	43.	254.	273.	53.	6	9	1	0.	0.	0	738
1966/67	3	17.	250.	160.	154	42.	26	13	0.	0.	0.	0.	665
1967/68	71	78.	180.	194.	114.	16.	10	2.	0.	0.	0.	0.	665.
1968/69	0	121.	204.	133.	88.	212.	24.	0.	0.	0.	0.	0.	782.
1969/70	42.	21.	382.	86.	76.	26.	6.	0.	0	0.	0.	0.	639.
1970/71	5	285.	161.	234.	98.	21.	18.	3.	0.	0.	0.	6.	831.
1971/72	1.	108.	278.	274.	191.	74.	39.	0.	0.	0.	0.	1.	966.
1972/73	30.	13.	157.	238.	219.	33.	0	0.	0.	0.	0.	0.	690.
1973/74	0.	48.	203.	216.	255.	68.	8.	5.	0.	0.	0	0.	803.
1974/75	1.	210.	300.	237.	117.	37.	0	0	0.	0.	0.	0.	902.
1975/76	6.	50.	297.	117.	113.	193.	106.	23	0.	0.	0.	5.	909.
1976/77	16.	14.	230.	126.	60.	81.	0.	0.	0.	0.	0.	2.	529.
1977/78	0.	112.	304.	208.	136.	208.	101.	10.	0	0.	0.	0.	1079.
1978/79	4.	54.	419.	123.	114.	75.	0	0.	0.	0.	0.	0.	789.
1979/80	26.	106	235.	126.	127.	67.	7	0.	0	0.	0.	0.	694
1980/81	5	71.	174.	305.	348.	101.	44.	0	0.	0.	0	0.	1048.
1981/82	0.	283.	159.	208.	158.	7.	2.	1	0.	0.	0.	7.	825.
1982/83	72	113.	51.	173.	83.	19.	32.	0	0.	0.	0.	0.	543.
1983/84	17.	6.	135.	83.	109.	104.	8.	0	0.	0.	0.	0.	462.
1984/85	0.	58.	169.	177.	172.	64.	0.	0.	0.	0.	0.	0.	640.
1985/86	18.	44.	223.	182.	84.	70.	144.	0.	0.	0.	0.	0.	765.
1986/87	166.	73	171.	147.	43.	44.	0.	0.	0.	0	0.	0	644.
1987/88	25.	23.	177.	147.	133.	80.	2.	0	0.	0.	0.	0.	587.
1988/89	23.	43.	126.	268.	516.	69.	0.	0.	0.	0.	0.	0.	1045.
1989/90	1.	27.	114.	579.	106.	25.	53.	0.	0.	0.	0.	0.	905.
1990/91	0.	33.	149	201.	127.	119.	9.	0	0.	0.	0.	0.	638.
1991/92	35	96.	88.	135.	81.	60.	10.	3.	0	0.	0.	0.	508.
1992/93	19.	98.	253.	92.	213.	64.	10.	0	0.	0.	0.	0.	749.
1993/94	0.	149.	78.	172.	137.	20.	31.	0.	-	-	-	-	-
Mean	18.	62.	212.	200.	161.	65.	23.	3.	0.	0.	0.	1.	765.
Median	5.	73.	189.	182.	132.	60.	8.	0.	0.	0.	0.	0.	
Maximum	166.	285.	420.	579.	516.	212.	144.	29.	1.	0.	0.	9.	
Minimum	0.	6.	43.	83.	43.	7.	0.	0.	0	0.	0.	0.	
St. dev.	31.	61.	99.	91.	101.	51.	35.	6.	0.	0.	0.	3.	
CV	1.75	.74	.47	.46	.63	.78	1.51	2.32	4.24	.00	.00	2.43	

Total monthly rainfall in millimetres

Data flags

Missing - flag '-'   Original - no flag set   Estimate - flag 'e'

Printed on 26/10/1994

Table B.6

Institute of Hydrology
Summary of monthly data - Rainfall

Station number : 2800 Name : NAMWALA

Basin no. : 0 Latitude : 15:45: 0 S Longitude : 26:27: 0 E Altitude : 1000 6

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Total
1919/20	-	-	-	-	-	-	-	-	-	0.	0.	0	-
1920/21	16	38.	211.	290.	263.	95	0	0	0.	0.	0	0.	913.
1921/22	47.	81.	94.	55.	149.	48.	4	1	0.	0.	0.	0.	479.
1922/23	61.	86.	155.	165.	255.	384	1.	0	0.	0.	0	0.	1107.
1923/24	12.	31.	136.	66.	65.	123.	0.	0.	0.	0.	0.	0.	433.
1924/25	20.	80.	206.	305.	175.	236.	133	5.	0.	0.	0.	24	1184.
1925/26	8.	28	99.	326.	280.	154.	0.	0.	0.	0.	0	6.	901.
1926/27	2.	36	234.	104.	208.	96.	8	0	0.	0.	0	0.	688.
1927/28	20.	48.	120.	170.	107.	134.	1	0	0.	0.	0.	0.	600.
1928/29	1.	37.	200.	327.	41.	122.	0.	0.	0.	0.	0	0.	728.
1929/30	0.	63.	223.	178.	120.	99.	47.	0.	0.	0.	0.	0.	730.
1930/31	0.	34.	228.	111.	87.	46.	8.	0.	0.	0.	0.	0.	514.
1931/32	5.	65	264.	186.	196.	189	71.	0.	0.	0.	0.	0.	976.
1932/33	0.	92.	189.	201.	135.	0	1.	0.	0.	0.	0.	0.	618.
1933/34	0.	176.	132.	146.	98.	86.	2.	0.	0.	0.	6.	5.	651.
1934/35	31.	143.	101.	225.	155.	56.	0.	0.	0.	0.	0.	0.	711.
1935/36	2.	13.	199.	176.	190.	361.	0.	0.	0.	0.	0.	0.	941.
1936/37	12	80	85.	215.	137.	54.	1.	1.	0.	0.	0	0.	585.
1937/38	10.	16.	185.	245.	227.	52.	8.	0.	0.	0.	0	0.	743.
1938/39	34	61.	157.	256.	147.	202.	0.	0.	6.	0.	0	35.	898.
1939/40	53.	290.	269.	88.	245.	168.	21.	0.	2.	0.	0.	0.	1136.
1940/41	13.	48.	91.	360.	180.	53.	34.	0.	0.	0.	0.	0.	779.
1941/42	18.	54.	76.	174.	35.	34.	3.	0.	0.	0.	0.	0.	394.
1942/43	24.	44.	152.	413.	236.	317.	15.	1.	0.	0.	0.	0.	1202.
1943/44	0.	41.	137.	133.	313.	82.	21.	0.	1.	0	0.	0.	728.
1944/45	37.	50.	99.	180.	216.	153.	8.	0.	0.	0.	0.	0.	743.
1945/46	0.	197.	145.	461.	202.	176.	0.	0.	0.	0.	0.	0.	1181.
1946/47	6.	99.	144.	98.	115.	132.	0.	0.	0.	0.	0.	0.	594.
1947/48	13.	22.	205.	244.	186.	447.	9.	2.	0.	0.	0.	0.	1128.
1948/49	22.	156.	23.	79.	55.	98.	0.	0.	0.	0.	0.	0.	433.
1949/50	2.	133.	278.	109.	195.	156.	50.	0.	0	0.	0.	0.	923.
1950/51	8.	139.	104.	136.	57.	49.	17	0.	0.	0.	13.	0.	593.
1951/52	69.	50.	181.	466.	247.	16.	1.	0	0.	0.	0.	1	1031.
1952/53	1	78.	113.	305.	215.	199.	27.	0.	0	0.	0.	6	944.
1953/54	4.	152.	280.	214.	184.	32.	0	0.	0	0	0.	0	866.
1954/55	2.	42.	311.	234.	190.	60.	31.	0.	0.	0	0.	0	870.
1955/56	0.	98.	126.	113.	233.	99.	28.	0.	0.	0.	0.	0	697.
1956/57	2.	94.	80.	187.	85.	75.	8	0	0.	0.	0.	0.	531.
1957/58	44.	65.	271.	320.	469.	13.	9.	0	0.	0.	0.	0.	1191.
1958/59	23.	116.	294.	178.	228.	35.	0.	14	0.	0.	0.	0	888.
1959/60	4.	24.	217.	183.	167.	60.	36.	6.	0.	0.	0.	0.	697.
1960/61	9.	149.	176.	225.	193.	81.	175.	0.	0.	0.	0.	0.	1008.
1961/62	0.	96.	175.	207.	143.	40.	13.	0.	0.	0.	0.	0.	674.
1962/63	0.	102.	383.	137.	238.	122.	21.	0	0.	0.	0	0.	1003.
1963/64	14.	134.	164.	91.	173.	3.	0.	0.	0.	0.	0	0	579.
1964/65	1.	71.	232.	172.	66.	15.	0.	0.	0.	0.	0.	5.	562.
1965/66	9.	111.	84.	191.	179.	105.	26.	37.	7.	0.	0.	0	749.
1966/67	0.	21.	168.	306.	149.	90.	6.	0.	0.	0.	0.	0	740.
1967/68	36.	56.	247.	172.	111.	117	0.	0.	0.	0.	0.	0.	739.
1968/69	3.	185.	450.	103.	84.	283.	0.	0	0	0.	0.	0.	1108.
1969/70	116.	80.	403	151.	107.	5.	5.	0.	0.	0.	0.	0.	867.
1970/71	4.	92.	211	271.	45.	59.	-	-	-	0.	0.	0	-
1971/72	4.	53.	188.	229.	54.	118.	16.	-	-	0.	0.	7	-
1972/73	46.	28.	58.	128.	106.	13.	35.	-	-	0.	0	14.	-
1973/74	23.	126.	289.	313.	285	48.	66.	50	-	0.	0	0.	
1974/75	1.	74.	230.	250.	309	23.	25.	-	-	0.	0	0	-
1975/76	15	66.	444.	232.	236	200	133	14	-	0	0.	2.	
1976/77	22.	104.	214.	126.	145.	156.	11.	-	-	0.	0.	5.	-
1977/78	-	45.	334.	288.	185.	367.	103.	18	-	-	-	-	-
1978/79	-	-	-	-	-	-	-	-	-	0.	0.	0.	-

Table B.6 continued

Institute of Hydrology
Summary of monthly data - Rainfall

Station number : 2800 Name : NAMWALA

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Total
1979/80	14.	202.	203.	39.	280.	103.	15.	-	-	0	0	2	-
1980/81	21.	59.	198.	313	246	178.	1.	-	-	-	-	-	-
1981/82	-	-	-	-	-	-	-	-	-	0.	0.	6	-
1982/83	24.	94	33.	218.	76.	65.	8.	-	-	0.	0	0	-
1983/84	16	34.	237.	103.	208	98.	8.	-	-	0.	0.	0.	-
1984/85	8	54.	160.	209.	182.	-	-	-	-	-	-		-
1985/86	-	-	-	-	-	-	-	-	-	-	-		-
1986/87	-	-	-	-	-	-	-	-	-	0	0.	1	-
1987/88	40.	33.	177	67.	86.	131.	24.	-	-	0.	0	0	-
1988/89	9.	29.	131.	154.	213.	61	11.	-	-	0.	0	0	-
1989/90	8.	37.	147.	158.	159.	34.	50.	0.	0.	0.	0.	0.	593
1990/91	6	14.	-	101.	76.	82	0.	0	0.	0.	0.	0.	-
1991/92	0.	8.	111.	72.	32.	190.	1.	14	0	0.	0.	0	420.
1992/93	0	157.	248.	43.	-	-	-	-	-	-	-	-	-
1993/94	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	16.	79.	195.	196.	166.	116.	20.	3.	0.	0.	0.	2.	793.
Median	9.	65.	185.	183.	173.	96	8.	0.	0.	0.	0.	0.	
Maximum	116.	298.	450.	466.	469.	447.	175.	50.	7.	0.	13.	35.	
Minimum	0.	8.	23.	39.	33.	8.	0.	0.	0.	0.	0.	0.	
St dev.	20.	55.	91.	96.	81.	97	34.	8	1.	0.	2.	5	
CV	1.28	.69	.47	.49	.49	.83	1.70	3.04	4.24	.00	4.22	3.17	

Total monthly rainfall in millimetres

Data flags

Missing - flag "-"   Original - no flag set   Estimate - flag "e"

Printed on 28/10/1994

Table B.7

Institute of Hydrology
Summary of monthly data - Rainfall

Station number : 2402 Name : Nakambala Sugar Estate, Rainfall

Basin no. : 0 Latitude : 0: 0: 0 N Longitude : 0: 0: 0 E Altitude : .0

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Total
1964/65	-	-	-	-	-	-	-	-	-	0.	0.	3	-
1965/66	11.	54.	50	225.	277.	54.	17.	7	2	0.	0.	0.	699
1966/67	0.	9.	229.	163.	109.	44.	60.	6	0.	0.	0.	0.	620.
1967/68	75.	69.	112	145.	92.	46.	30.	13.	0.	0.	0.	0.	582
1968/69	0.	154.	184	156.	53	140	7.	0	0.	0	0.	0	694
1969/70	46.	67.	340	102	58.	42	17.	0	0.	0	0.	0	672.
1970/71	15.	123	160	218.	96.	17.	83.	0	0.	0	0.	11.	731.
1971/72	2.	163.	207.	226.	121.	80.	8.	0	0.	0.	0.	15.	822.
1972/73	0.	16.	98	161.	188.	7.	7.	0.	0.	0.	0.	5	482
1973/74	28.	100.	225	266.	328.	78	13.	0	0	0	0.	0.	1049
1974/75	0.	137.	265	98.	127.	52	6.	0	0	0	0.	0.	685
1975/76	6.	20.	182	134	132.	307.	109.	3.	0.	0	0.	10.	903
1976/77	11.	17.	162	87.	50.	137.	13.	0.	0.	0.	0.	22.	499.
1977/78	0.	140.	254.	130.	191	159.	61.	15.	0.	0.	0.	0.	950.
1978/79	10.	66.	377.	57.	118	55.	0.	0.	0	0.	0.	0	683.
1979/80	27.	87.	300.	65.	195.	43	31.	0.	0.	0.	0.	0.	748.
1980/81	0.	90.	203.	272.	406.	179.	12.	0.	0.	0.	0.	0.	1162.
1981/82	0.	61.	81.	244.	201.	2.	3.	0	0.	0.	0.	9.	601.
1982/83	37.	130.	25.	175.	76.	84.	36.	0	0	0	0.	0.	563
1983/84	28.	35.	70	126.	82	79.	14.	0.	1.	0.	0.	0.	435.
1984/85	0.	125.	172.	115.	156.	89.	0.	0.	0.	0.	0.	0.	657.
1985/86	20.	54.	263.	183.	132.	92.	105.	0.	0.	0.	0.	0.	849.
1986/87	130.	35.	183.	67.	129.	30.	0.	41.	0.	0.	0.	4.	619.
1987/88	43.	14.	126	86.	111.	116.	1.	0.	6.	0	0.	0.	503.
1988/89	12.	42.	71	290.	390	78.	0.	0.	0.	0	0.	0.	883.
1989/90	6.	35.	116	433.	86	34.	39.	0.	0.	0	0.	0.	749.
1990/91	2.	21.	185.	153.	117.	143.	0.	0.	0.	0.	0.	0.	621.
1991/92	49.	121.	129.	77.	59.	115.	23.	5.	0	0.	0.	0.	578.
1992/93	0.	36.	349.	79.	181.	119.	43.	0.	0	0.	0.	1	808.
1993/94	1.	133.	132.	153.	147.	2.	-	-	-	-	-	-	-
Mean	19.	74.	181.	162.	153.	84.	26.	3.	0.	0.	0.	3.	705.
Median	10.	66.	182.	153	127.	78.	13.	0.	0.	0.	0.	0.	
Maximum	130.	163.	377.	433.	406.	307.	109.	41.	6.	0.	0.	22.	
Minimum	0.	9.	25.	57.	50.	2.	0.	0.	0.	0.	0.	0.	
St. dev.	29.	49.	91.	85.	93.	64.	31.	8.	1.	0.	0.	5.	
CV	1.50	.65	50	.53	.61	.77	1.18	2.61	3 70	.00	.00	1.99	

Total monthly rainfall in millimetres

Data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

Printed on 28/10/1994

Table B.8

Institute of Hydrology
Summary of monthly data - Rainfall

Station number : 460990 Name : Itezhi-tezhi ZESCO Met. Stn-Rain

Basin no. : 0 Latitude : 15:45:30 S Longitude : 26: 1:12 E Altitude : .0

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Total
1979/80	21.	146	330	56.	141.	104.	12.	0.	0	0	0	0.	810
1980/81	2.	105.	329.	228.	335.	92.	15.	0.	0	0.	0.	0.	1106.
1981/82	18.	72.	55.	251.	177.	1.	3.	0.	0	0.	0.	5.	582.
1982/83	34	115.	81	195.	58.	38.	1.	5.	0.	0	0.	0.	527.
1983/84	16	60	118.	49.	122.	161.	0	0.	0.	0	0.	0.	526
1984/85	16.	45	100	140.	155.	46.	6.	0.	0.	0	0.	0.	508.
1985/86	0.	35	209	197.	133.	86.	83.	0.	0.	0.	0.	0.	743.
1986/87	59	43.	225.	105.	80.	41.	0.	0.	0	0	0	0.	553.
1987/88	12.	13	178.	173.	84.	39.	0.	0	0.	0.	0.	0.	499.
1988/89	0.	0	60	304.	189.	46.	7.	0.	0.	0	0.	0.	606
1989/90	11.	40.	193.	222.	133.	97.	76.	0.	0.	0.	0.	0.	772.
1990/91	0.	87.	197	223.	42.	91.	0.	0.	0.	0.	0.	0.	640.
1991/92	47.	96.	104	127.	18.	146.	4.	23.	0.	0	0.	0.	565.
1992/93	15.	128.	107.	232.	450.	135.	40.	0.	0.	0.	0.	0.	1107.
1993/94	0.	140.	85.	208.	161.	10.	0	0	-	-	-	-	-
Mean	17.	75.	163	181.	152.	76.	16.	2.	0.	0	0.	0.	682.
Median	15.	72.	178.	197.	133.	86.	4.	0.	0	0.	0.	0.	
Maximum	59.	146.	330.	304.	450.	161.	83.	23	0.	0.	0.	5.	
Minimum	0.	0.	55	49.	18.	1.	0.	0.	0.	0.	0.	0.	
St. dev.	18.	46.	88.	72.	112.	49.	26.	6.	0.	0.	0.	1.	
CV	1.06	.61	.54	.40	.74	.64	1.60	3.21	.00	00	.00	3.74	

Total monthly rainfall in millimetres

Data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

Printed on 28/10/1994

Table B.9

Institute of Hydrology
Summary of monthly data - Flow

Station number : 466901   Name : Kafue at Hook Bridge, ZESCO data

Basin no. : 0   Latitude : 14:56:30 S   Longitude : 25:55: 0 E   Altitude : 1073.0
Area : 95051.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Mean
1967/68	-	-	-	-	-		-	-	-	-	-	-	
1968/69	-	-	-	-	-	-	-	-	-	-	-	-	-
1969/70	-	-	-	-	-	-	-	-	-	-	-	-	-
1970/71	-	-	-	-	-	-	-	-	-	-	-	-	-
1971/72	-	-	-	-	-	-	-	-	-	-	-	-	-
1972/73	-	-	-	-	-	-	-	-	-	-	-	36.30e	-
1973/74	38.17	37.82	92.21	351.16	1045.06	827.30	624.24	329.34	168.67	109.80	83.73	61.77	307.61
1974/75	43.54	34.71	213.90	842.26	735.98	1044.42	771.68	469.75	194.46	131.02	93.17	71.99	384.67
1975/76	53.33	40.56	91.50	300.99	854.43	1055.02	1258.16	905.50	553.46	366.68	173.46	121.50	477.43
1976/77	93.18	78.60	109.33	240.68	414.60	713.03	789.90	517.72	229.16	146.10	115.77	85.66	299.42
1977/78	58.32	46.08	204.48	799.84	1267.49e	1873.40	2064.41	1426.29	913.03	512.29	339.59	230.96	808.08
1978/79	143.77	203.58	356.67	642.48	788.08	1313.00	1533.76	974.08	579.37	344.71	253.34	169.63	590.94
1979/80	119.47	148.34	425.31e	604.88	778.88	1005.64	861.12	703.21	397.60e	247.37	186.49	128.10	466.39
1980/81	93.72	103.99	148.90	410.34	862.46	1422.98	1075.51	683.57	348.02	227.38	169.11	122.16	469.71
1981/82	87.56	70.36	101.27	188.00	584.50	623.15	-	242.00	143.63	105.80	85.54	68.99	-
1982/83	56.91	70.44	204.61	238.55	438.20	505.03	366.11	277.38	103.43	80.31	67.11	54.83	195.54
1983/84	43.71	44.98	102.50	275.46	345.60	423.62	407.37	180.43	87.50	68.24	56.73	45.79	173.02
1984/85	35.88	43.06	132.05	433.90	873.54	[illegible]	707.46	433.70	202.44	124.43	92.68	70.17	316.81
1985/86	48.68	48.22	83.04	399.76	621.58	757.28	781.38	684.64	379.89	188.78	126.62	91.44	339.83
1986/87	72.48	107.15	153.71	190.64	508.42	553.37	414.69	216.26	114.16	98.78e	77.58	58.79	211.17
1987/88	45.47	33.80	73.16	172.43	466.03e	847.51	686.84	333.75	132.77	94.10	74.40	56.04	250.45
1988/89	43.31	45.14	69.34	184.76	663.80	543.06	555.37e	361.15	-	181.61	78.81	-	-
1989/90	41.95	35.30	60.17	190.30	472.38	343.77	370.67	195.78	107.69	69.60	53.88	40.53	163.45
1990/91	30.46	24.30	41.73	352.99	530.86	523.91	433.38	226.19	106.49	74.61	58.51	46.35	193.96
1991/92	36.79	40.67	57.34	95.66	132.97	102.75	145.61	83.29	50.16	38.75	33.65	25.61	69.81
1992/93	18.22	22.60	36.09	175.90	628.68	1033.43	861.32	524.12	197.37	108.23	77.84	55.49	309.22
1993/94	40.13	37.86	58.79	383.07	675.75	643.35	338.57	-	-	-	-	-	-
Mean	58.67	62.70	134.10	349.72	651.91	863.78	752.38	483.55	263.65	155.59	114.05	82.15	323.94
Median	45.47	44.98	101.27	275.46	628.68	757.28	686.84	361.15	194.46	108.23	83.73	61.77	
Maximum	143.77	203.58	425.31	842.26	1267.49	1873.40	2064.41	1426.29	913.03	512.29	339.59	230.96	
Minimum	18.22	22.60	36.09	95.66	132.97	102.75	145.61	83.29	50.16	38.75	33.65	25.61	
St. dev.	31.83	44.96	100.80	209.67	253.39	393.92	455.81	334.51	220.13	114.82	75.79	50.40	
CV	.54	.72	.75	.60	.39	.49	.61	.69	.83	.74	.66	.61	

Mean monthly flow in cubic metres per second

Data flags

Missing - flag "-"   Original - no flag set   Estimate - flag "e"

Printed on 28/10/1994

Table B.10

ELEVATION-AREA-VOLUME RELATIONSHIPS

Itezhi-tezhi Reservoir

Elevation masl	Area km2	Volume Mcm
989.0	4.0	2.0
990.0	6.0	7.0
991.0	10.0	15.0
992.0	14.0	27.0
993.0	18.0	43.0
994.0	22.0	63.0
995.0	27.0	87.5
996.0	31.0	116.5
997.0	35.6	149.5
998.0	40.4	187.8
999.0	46.0	231.0
1000.0	50.0	279.0
1001.0	57.0	332.5
1002.0	64.0	393.0
1003.0	70.0	460.0
1004.0	75.6	532.8
1005.0	83.6	612.4
1006.0	90.0	699.2
1007.0	97.0	792.7
1008.0	105.0	893.7
1009.0	113.0	1002.7
1010.0	120.0	1119.2
1011.0	129.0	1243.7
1012.0	138.0	1377.2
1013.0	148.0	1520.2
1014.0	158.0	1673.2
1015.0	167.0	1835.7
1016.0	177.0	2007.7
1017.0	189.0	2190.7
1018.0	203.0	2386.7
1019.0	214.0	2595.2
1020.0	224.0	2814.2
1021.0	238.0	3045.2
1022.0	253.0	3290.7
1023.0	268.0	3551.2
1024.0	284.0	3827.2
1025.0	298.0	4118.2
1026.0	314.0	4424.2
1027.0	330.0	4746.2
1028.0	346.0	5084.2
1029.0	364.0	5439.2
1029.5	374.0	5623.7
1030.0	380.0	5812.2
1031.0	404.0	6204.2
1031.5	411.0	6408.0
1032.0	420.0	6616.2
1033.0	446.0	7049.2

SLHP(1990a).
V = 0.0625*(E-983)^2.97
A = 0.1440*(E-983)^2.05

Kafue Gorge Reservoir

Elevation masl	Area km2	Volume Mcm
972.3	20.0	0.0
972.5	25.0	5.0
972.8	30.0	11.0
973.0	35.0	20.0
973.3	40.0	29.0
973.5	47.0	40.0
973.8	58.0	53.0
974.0	70.0	69.0
974.3	83.0	88.0
974.5	98.0	111.0
974.8	119.0	138.0
975.0	142.0	170.0
975.3	180.0	211.0
975.5	235.0	263.0
975.8	310.0	331.0
976.0	430.0	423.0
976.3	565.0	548.0
976.5	725.0	709.0
976.6	805.0	785.0
976.8	925.0	915.0
977.0	1175.0	1178.0
978.0	2160.0	2845.0

JICA(1992) :
V = 0.6630*(E-971)^4.112
A = 12.864*(E-971)^1.526 (E < 974.7 m)
A = 0.128*(E-971)^5.054 (E >= 974.7 m)

Table B.11

Institute of Hydrology
Summary of monthly data - Storage

Station number : 460991   Name : Itezhi-tezhi reservoir levels

Basin no. : 0   Latitude : 15:45:30 S   Longitude : 26. 1:12 E   Altitude : 1000.0

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Mean
1976/77	-	-	-	-	-	-	-	-	1016.1	1014.6	1010.8	1002.3	-
1977/78	999.7	999.5	989.6	1003.1	1009.6	1023.0	1027.0	1029.4	1029.2	1029.3	1029.5	1029.2	1016.5
1978/79	1028.3	1027.7	1028.0	1026.4	1026.0	1028.3	1029.0	1029.4	1029.4	1029.4	1029.5	1029.2	1028.4
1979/80	1028.6	1028.3	1027.8	1025.2	1025.3	1025.8	1027.7	1028.8	1029.3	1029.6	1029.6	1029.4	1028.0
1980/81	1028.4	1027.7	1027.6	1028.9	1029.5	1029.4	1029.2	1029.5	1029.5	1029.5	1029.4	1029.3	1029.0
1981/82	1028.8	1028.2	1027.5	1027.5	1028.3	1028.5	1029.4	1029.6	1029.4	1029.1	1027.9	1026.5	1028.4
1982/83	1025.8	1024.1	1024.4	1025.0	1027.1	1028.0	1029.3	1029.3	1028.5	1027.1	1025.7	1024.2	1026.5
1983/84	1022.8	1021.7	1023.1	1021.8	1022.9	1023.6	1024.8	1024.1	1022.8	1021.5	1020.1	1018.6	1022.2
1984/85	1017.3	1016.3	1016.3	1019.3	1025.7	1028.6	1029.6	1029.5	1029.5	1029.2	1028.4	1027.1	1024.7
1985/86	1025.7	1024.6	1024.3	1025.7	1027.8	1028.3	1029.5	1029.5	1029.5	1029.5	1029.3	1028.8	1027.7
1986/87	1028.2	1027.7	1026.7	1026.5	1028.4	1029.5	1029.5	1029.2	1028.8	1028.3	1027.8	1027.1	1028.2
1987/88	1026.3	1025.4	1025.2	1025.7	1027.4	1029.3	1029.5	1029.4	1029.6	1029.2	1028.3	1027.1	1027.7
1988/89	1025.8	1024.6	1024.0	1025.0	1027.6	1028.9	1029.5	1029.5	1029.4	1029.0	1028.4	1027.6	1027.4
1989/90	1026.8	1026.0	1025.4	1025.7	1026.2	1027.0	1028.5	1028.6	1028.2	1027.7	1026.5	1025.1	1026.8
1990/91	1023.5	1022.1	1021.0	1022.5	1026.0	1029.0	1029.6	1029.6	1029.1	1028.3	1027.4	1025.6	1026.1
1991/92	1023.8	1022.2	1020.9	1020.2	1020.1	1020.0	1020.1	1019.6	1016.8	1017.9	1016.7	1015.3	1019.6
1992/93	1013.7	1011.8	1010.3	1012.2	1021.5	1029.3	1029.7	1030.1	1030.3	1030.5	1030.3	1029.8	1023.3
1993/94	1029.1	1028.4	1027.8	1029.6	1029.2	1030.3	1030.5	1030.6	1030.5	-	-	-	-
Mean	1023.6	1022.7	1021.6	1023.0	1025.2	1027.5	1028.4	1028.6	1027.7	1027.0	1026.2	1024.8	1025.5
Median	1025.8	1024.6	1024.4	1025.2	1026.2	1028.5	1029.4	1029.4	1029.3	1029.1	1028.3	1027.1	
Maximum	1029.1	1028.4	1028.0	1029.6	1029.5	1030.3	1030.5	1030.6	1030.5	1030.5	1030.3	1029.8	
Minimum	999.7	999.5	989.6	1003.1	1009.6	1020.8	1020.1	1019.6	1016.1	1014.6	1010.8	1002.3	
St. dev.	7.4	7.5	9.5	6.6	4.8	2.8	2.5	2.7	4.1	4.5	5.3	7.8	
CV	.01	.01	.01	01	.00	.00	.00	.00	00	.00	.01	.01	

Mean monthly storage in million cubic metres

Data flags

Missing - flag "-"   Original - no flag set   Estimate - flag "e"

Printed on 28/10/1994

Table B.12

Institute of Hydrology
Summary of monthly data - Flow

Station number : 460995   Name : Itezhi-tezhi Reservoir Outflow

Basin no : 0   Latitude : 15:45: 0 S   Longitude : 26: 1: 0 E   Altitude : 1000.0
Area : 105620.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Mean
1976/77	-	-	-	-	-	-	-	-	-	-	-	-	-
1977/78	-	-	-	-	-	-	-	-	934.9	437.4	263.4	385.2	-
1978/79	381.1	395.5	341.6	877.0	864.6	849.6	1386.4	842.9	543.1	250.3	204.4	208.4	592.8
1979/80	235.4	225.6	520.1	896.2	772.0	931.2	520.8	486.5	274.8	173.5	162.5	126.2	442.7
1980/81	197.1	164.5	146.7	216.4	918.3	1465.6	986.6	557.3	278.8	194.8	163.0	145.3	449.7
1981/82	147.7	225.4	166.3	166.2	415.6	488.7	385.1	163.8	136.8	131.9	211.5	214.4	219.1
1982/83	194.7	153.5	144.8	151.3	215.5	296.5	115.2	135.1	176.8	221.6	203.4	183.0	182.5
1983/84	150.8	135.8	173.7	190.6	107.7	285.2	218.2	230.6	195.4	169.9	135.3	132.6	183.8
1984/85	191.8	189.1	188.0	194.6	244.8	278.5	480.4	374.7	172.9	134.8	167.8	211.3	235.3
1985/86	175.4	143.2	117.5	123.3	298.0	587.8	532.4	567.1	366.2	164.2	134.7	132.3	273.2
1986/87	141.5	155.2	293.3	204.8	216.5	344.2	355.6	218.8	141.4	128.6	124.8	121.4	203.9
1987/88	115.7	109.2	105.1	115.3	216.8	644.8	501.8	302.9	96.8	128.9	163.7	184.3	230.4
1988/89	169.8	156.6	121.1	97.4	409.4	391.0	413.2	320.7	150.8	133.4	129.3	124.5	216.4
1989/90	119.5	113.8	107.6	181.3	427.8	213.5	159.2	154.3	133.0	134.0	159.4	177.2	170.7
1990/91	172.9	152.6	153.1	110.2	105.8	109.9	303.9	199.4	161.4	155.0	155.8	232.6	167.7
1991/92	203.0	197.4	190.2	160.0	150.8	119.5	123.2	130.0	120.9	130.1	119.9	119.7	146.3
1992/93	120.9	137.6	122.9	103.0	107.2	274.1	754.8	632.3	161.8	83.2	103.8	123.8	210.4
1993/94	162.6	155.4	141.5	220.8	843.5	457.6	296.2	-	-	-	-	-	-
Mean	179.9	175.7	189.6	250.5	399.6	483.1	463.2	340.4	249.8	172.0	162.7	176.4	269.2
Median	169.8	155.2	146.7	166.2	244.8	344.2	355.6	302.9	161.8	134.8	159.4	145.3	
Maximum	381.1	395.5	520.1	896.2	918.3	1465.6	1386.4	842.9	934.9	437.4	263.4	385.2	
Minimum	115.7	109.2	105.1	97.4	105.8	109.9	115.2	130.0	96.8	83.2	103.8	119.7	
St. dev.	62.4	67.7	109.4	251.6	287.0	353.1	343.3	204.5	212.6	83.0	41.1	68.3	
CV	.35	.39	.58	1.00	.72	.73	.74	.60	.85	.48	.25	.39	

Mean monthly flow in cubic metres per second

Data flags

Missing - flag "-"   Original - no flag set   Estimate - flag "e"

Printed on 28/10/1994

Table B.13

Institute of Hydrology
Summary of monthly data - Storage

Station number : 470750 Name : Reservoir level at Kasaka (masl)

Basin no. . 8 Latitude : 15:49: 0 S Longitude : 28.11. 0 E Altitude : 969.3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Mean
1976/77	-	-	-	-	-	-	-	977.8	978.0	977.7	977.4	977.1	-
1977/78	976.7	976.5	977.0	976.4	976.5	976.5	976.6	976.5	976.5	976.8	976.6	976.4	976.6
1978/79	976.5	976.6	976.4	976.6	976.5	976.5	976.5	976.5	976.6	976.5	976.1	975.5	976.4
1979/80	975.5	975.6	976.6	976.5	976.6	976.5	976.5	976.5	976.5	976.6	976.6	976.6	976.4
1980/81	976.4	976.6	976.8	976.6	976.6	976.5	976.6	976.5	976.5	976.4	976.4	976.6	976.6
1981/82	976.4	976.3	976.2	976.6	976.6	976.5	976.7	976.7	976.5	976.4	976.1	976.0	976.4
1982/83	976.1	976.1	975.9	975.9	975.9	976.0	976.0	975.7	975.2	975.3	975.5	975.6	975.8
1983/84	975.4	975.3	975.2	975.1	975.1	975.0	975.3	975.5	975.7	975.9	975.8	975.8	975.4
1984/85	975.6	975.0	974.3	974.7	976.1	976.5	976.5	976.5	976.7	976.7	976.6	976.5	976.0
1985/86	976.5	976.4	976.6	976.7	976.6	976.7	976.8	976.7	976.8	976.8	976.7	976.7	976.7
1986/87	976.7	976.5	976.1	976.5	976.6	976.6	976.6	976.7	976.6	976.7	976.7	976.7	976.6
1987/88	976.5	976.2	975.8	975.5	975.8	976.1	976.2	976.6	976.7	976.7	976.7	976.5	976.3
1988/89	976.4	976.3	976.3	976.6	976.5	976.2	976.2	976.2	976.2	976.1	976.5	976.3	976.3
1989/90	976.6	976.8	976.6	976.4	975.9	976.8	976.7	976.5	976.1	976.2	976.0	976.0	976.4
1990/91	975.8	975.9	976.0	976.3	976.3	976.2	976.2	976.4	976.3	976.3	976.0	975.8	976.1
1991/92	975.7	975.7	975.4	975.4	974.9	975.0	974.5	974.7	974.8	974.7	974.8	974.9	975.0
1992/93	974.7	974.5	975.4	976.0	976.4	976.7	976.7	976.9	977.1	977.1	977.0	976.9	976.3
1993/94	976.7	976.6	976.3	976.3	976.1	976.2	976.6	976.8	-	-	-	-	-
Mean	976.1	976.1	976.1	976.1	976.2	976.3	976.3	976.4	976.4	976.4	976.3	976.2	976.2
Median	976.4	976.3	976.2	976.4	976.4	976.5	976.5	976.5	976.5	976.5	976.5	976.4	
Maximum	976.7	976.8	977.0	976.7	976.6	976.8	976.8	977.8	978.0	977.7	977.4	977.1	
Minimum	974.7	974.5	974.3	974.7	974.9	975.0	974.5	974.7	974.8	974.7	974.8	974.9	
St. dev.	.6	.6	.7	.6	.5	.5	.6	.6	.7	.7	.6	.6	
CV	00	00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	

Mean monthly storage in million cubic metres

Data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

Printed on 28/10/1994

Table B.14

Institute of Hydrology
Summary of monthly data - Flow

Station number : 470800   Name : Kafue Gorge Turbine Discharge

Basin no. : 0   Latitude : 15:51:17 S   Longitude : 28:28:19 E   Altitude : 577.28
Area : 152810.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Mean
1971/72	-	-	-	-	-	58.5	66.6	81.1	87.1	86.1	88.0	84.3	-
1972/73	-	82.0	68.9	74.3	105.5	94.3	99.1	84.3	60.3	49.1	31.5	45.0	-
1973/74	47.3	55.3	64.4	-	123.2	125.1	122.4	151.9	168.1	167.0	162.8	149.0	-
1974/75	149.3	144.7	167.3	163.3	164.3	161.1	157.3	153.9	165.7	168.0	168.0	157.3	158.3
1975/76	136.9	153.1	167.1	153.5	157.1	162.7	162.9	155.5	158.1	155.8	149.7	162.1	154.5
1976/77	137.5	134.9	146.0	144.5	152.8	142.2	142.9	161.9	170.3	127.9	132.3	128.6	143.4
1977/78	121.2	126.2	97.1	108.7	118.9	132.5	134.6	141.5	145.8	143.8	141.2	139.1	129.2
1978/79	127.0	131.0	123.9	131.7	132.3	133.2	129.9	133.4	137.2	134.6	145.0	143.6	132.7
1979/80	144.4	141.3	124.6	130.5	126.7	127.7	131.4	140.3	146.4	156.9	157.1	164.9	141.0
1980/81	154.0	153.0	153.2	157.0	165.3	161.2	174.5	156.6	160.5	158.9	156.9	161.7	159.4
1981/82	161.5	159.7	166.7	156.3	180.1	210.5	211.1	208.7	209.1	175.1	175.3	174.6	182.3
1982/83	174.4	170.2	173.9	162.5	171.3	168.4	161.4	167.3	169.9	167.4	162.7	165.1	168.5
1983/84	158.3	155.9	158.9	164.4	172.3	187.4	175.0	166.8	173.8	155.7	154.8	138.1	163.4
1984/85	139.5	145.3	139.7	145.2	150.3	144.6	180.2	209.9	214.1	197.1	195.0	168.0	169.1
1985/86	165.9	157.2	158.7	169.5	185.3	180.0	185.1	191.3	208.6	178.7	183.0	189.1	178.6
1986/87	178.0	159.7	134.5	157.2	170.3	182.9	177.3	180.7	185.5	127.1	111.4	104.0	155.6
1987/88	113.1	114.2	152.9	148.2	125.7	176.0	175.9	149.6	185.2	151.1	140.5	160.3	149.5
1988/89	157.5	144.8	158.1	149.9	139.0	137.4	.0	.0	.0	.0	.0	.0	73.8
1989/90	.0	.0	79.7	72.5	93.9	107.1	99.0	132.7	138.0	148.9	150.5	144.8	96.6
1990/91	139.7	141.5	134.1	116.5	131.1	129.3	128.8	128.6	144.5	165.0	168.1	173.8	140.1
1991/92	170.9	179.5	198.6	178.5	174.1	133.2	119.8	98.1	91.2	89.4	83.4	88.3	133.7
1992/93	97.3	104.9	100.4	115.5	120.3	152.3	168.6	173.2	198.2	205.7	180.8	155.5	147.9
1993/94	133.1	140.7	135.3	138.2	151.6	180.7	169.4	186.8	-	-	-	-	-
Mean	133.6	132.0	134.4	139.5	146.0	147.4	142.3	145.8	150.8	140.1	138.1	136.2	140.5
Median	139.7	141.5	139.7	148.2	150.3	144.6	157.3	153.9	160.5	151.1	150.5	149.0	
Maximum	178.0	179.5	198.6	178.5	185.3	210.5	211.1	209.9	214.1	205.7	195.0	189.1	
Minimum	.0	.0	64.4	72.5	93.9	58.5	.0	.0	.0	.0	.0	.0	
St. dev.	42.5	41.2	34.0	28.9	25.7	33.9	45.7	46.4	51.0	47.6	48.6	45.9	
CV	.32	.31	.25	.21	.18	.23	.32	.32	.34	.34	.35	34	

Mean monthly flow in cubic metres per second

Data flags

Missing - flag "-"   Original - no flag set   Estimate - flag "e"

Printed on 28/10/1994

Table B.15

Institute of Hydrology
Summary of monthly data - Flow

Station number : 470755 **Name :** Kafue Gorge Spillway Discharge

Basin no. : 0 Latitude : 15:48:19 S Longitude : 28:35:18 E Altitude : 967.74
Area : 152010.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Mean
1971/72	-	-	-	-	-	-	273.9	258.9	-	-	-	-	-
1972/73	4.5	11.2	10.8	8.3	.0	.0	.0	.0	.0	.0	.0	.0	2.9
1973/74	330.4	313.0	294.5	332.3	365.3	497.9	805.1	715.9	481.6	317.4	80.3	.0	377.6
1974/75	.0	.0	0	.0	70.4	418.4	617.5	719.4	625.6	446.3	191.1	8.5	259.0
1975/76	.0	.0	.0	.0	.0	146.3	756.3	1080.3	1036.7	790.7	474.7	155.0	370.0
1976/77	.0	.0	.0	.0	.0	.0	.0	10.2	127.5	210.9	206.8	202.5	63.5
1977/78	196.7	59.0	22.6	399.5	512.2	864.3	1192.5	1202.5	1152.2	996.3	807.6	578.5	665.0
1978/79	271.9	193.6	343.3	190.0	329.5	429.4	445.4	485.9	580.1	666.0	496.4	381.1	402.4
1979/80	153.0	110.4	130.0	246.9	209.9	619.5	650.8	618.6	500.0	394.4	167.3	47.0	329.6
1980/81	.0	.0	5.3	214.3	522.0	846.3	986.6	1028.3	853.0	652.6	129.1	79.9	459.1
1981/82	.0	0	.0	.0	37.1	52.4	3.2	.0	.0	.0	.0	.0	7.6
1982/83	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1983/84	.0	.0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1984/85	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1985/86	30.4	30.4	30.5	59.0	71.4	33.9	97.9	185.0	174.3	221.6	165.3	30.2	94.6
1986/87	.0	31.8	134.6	41.1	.0	.0	.0	.0	.0	14.4	5.6	.0	19.2
1987/88	.0	15.6	10.9	4.1	.0	.0	.0	.0	32.9	88.9	27.5	.0	15.0
1988/89	.0	0	.0	.0	468.8	-	-	-	-	-	-	184.1	-
1989/90	56.7	32.0	13.5	201.6	354.5	49.9	153.3	90.6	90.1	7.5	.0	.0	85.6
1990/91	.0	1.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1
1991/92	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1992/93	.0	.0	.0	.0	.0	.0	68.9	79.1	40.5	97.3	60.3	.0	29.1
1993/94	.0	.0	.0	4.5	72.0	.0	.0	.0	-	-	-	-	-
Mean	47.0	37.1	46.4	77.0	140.6	180.5	275.1	394.3	285.2	245.2	150.6	79.4	155.6
Median	.0	.0	0	.0	.0	.0	3.2	10.3	40.5	88.9	27.5	.0	
Maximum	330.4	313.0	343.3	399.5	522.0	864.3	1192.5	1202.5	1152.2	996.3	807.6	578.5	
Minimum	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0	.0	
St. dev.	97.5	77.7	96.9	125.2	193.7	294.6	382.2	410.0	382.6	312.1	220.6	151.0	
CV	2.04	2.09	2.09	1.61	1.38	1.56	1.39	1.39	1.34	1.27	1.46	1.90	

Mean monthly flow in cubic metres per second

Data flags

Missing - flag "-" Original - no flag set Estimate - flag "e"

Printed on 28/10/1994

Table B.16

Institute of Hydrology
Summary of monthly data - Flow

Station number : 470805 **Name : Kafue Gorge (II) Total Discharge**

Basin no. : 0 Latitude : 15:50:40 S Longitude : 28:29: 2 E Altitude : 577.20
Area : 152810

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Mean
1971/72	-	-	-	-	-	305.4e	340.5	340.0	350.8e	-	-	-	-
1972/73	-	94.8	79.6	82.6	105.5	94.3	99.1	84.3	60.3	49.1	31.5	45.0	-
1973/74	377.7	368.2	358.9	-	488.5	623.0	927.5	867.8	649.7	484.4	242.9	149.0	-
1974/75	149.3	144.7	147.3	163.3	234.6	579.6	774.8	873.3	791.3	614.2	359.1	165.7	417.4
1975/76	136.9	153.1	147.1	153.5	157.1	309.1	919.2	1235.8	1194.8	946.5	624.4	317.2	525.2
1976/77	137.5	134.9	146.0	144.5	152.8	142.2	142.9	172.1	297.8	318.8	339.1	331.1	206.9
1977/78	317.9	186.0	119.7	508.2	631.3	996.7	1327.1	1344.0	1298.0	1140.1	949.0	717.6	795.0
1978/79	398.9	324.5	467.1	320.5	461.9	562.7	575.3	619.2	717.3	800.6	641.4	524.7	535.1
1979/80	297.3	259.7	262.7	377.4	416.6	747.3	782.2	758.9	655.1	551.3	324.3	211.9	470.6
1980/81	354.0	153.0	158.5	372.1	687.3	1007.5	1161.0	1184.9	1014.3	811.5	486.0	241.6	618.5
1981/82	161.5	159.7	166.7	156.3	217.2	262.9	214.2	208.7	209.1	175.1	175.3	174.6	189.9
1982/83	174.4	178.2	173.9	162.5	171.3	168.4	161.4	167.3	169.9	167.4	162.7	165.1	168.5
1983/84	158.3	155.9	158.9	164.4	172.3	187.4	175.0	166.8	173.8	155.7	154.8	138.1	163.4
1984/85	139.5	145.3	139.7	145.2	150.3	144.6	180.2	209.9	234.1	197.1	195.0	168.0	169.1
1985/86	204.3	195.6	169.2	229.3	256.6	214.7	282.9	377.1	382.9	400.3	348.3	319.3	275.2
1986/87	178.0	191.5	269.2	198.3	170.3	182.9	177.3	180.7	185.5	141.5	117.0	104.0	174.8
1987/88	133.1	130.0	371.8	152.3	125.7	176.8	175.9	149.6	218.1	240.0	160.3	160.3	165.3
1988/89	157.5	144.8	158.1	149.9	607.8	619.1e	-	-	-	-	-	184.1	-
1989/90	56.7	32.8	93.3	274.1	448.4	157.1	252.4	223.3	228.1	148.4	150.5	144.8	182.2
1990/91	139.7	142.7	134.1	116.5	131.1	129.3	128.8	128.6	144.5	145.0	168.1	173.8	140.2
1991/92	175.9	179.6	198.6	178.5	174.1	133.2	119.8	98.1	91.2	89.4	83.4	88.3	133.7
1992/93	97.3	104.9	180.4	115.5	128.3	152.3	246.0	260.1	247.8	314.6	242.9	155.5	180.2
1993/94	133.1	140.7	135.3	142.7	-	-	-	-	-	-	-	-	-
Mean	183.5	169.1	180.7	205.1	289.6	350.9	436.4	459.5	442.6	395.6	290.2	218.1	303.1
Median	157.5	153.0	158.1	162.5	174.1	187.4	246.0	223.3	247.8	240.0	195.0	168.0	
Maximum	398.9	368.2	467.1	508.2	687.3	1007.5	1327.1	1344.0	1298.0	1140.1	949.0	717.6	
Minimum	56.7	32.8	79.6	82.6	105.5	94.3	99.1	84.3	60.3	49.1	31.5	45.0	
St. dev.	89.1	72.0	89.4	106.5	189.9	286.3	383.3	413.2	371.1	316.9	225.7	152.2	
CV	.49	.43	.49	.52	.66	.80	.88	.90	.84	.80	.76	.70	

Mean monthly flow in cubic metres per second

Data flags

Missing - flag "-" Original - no-flag set Estimate - flag "e"

Printed on 28/10/1994

Appendix C

SIMULATION STUDY INPUT FILES AND RESULTS

Table C.1 Inflow (Mcm) to Itezhi-tezhi Reservoir

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1905/6	67.0	67.4	139.3	508.9	1176.5	2271.3	1277.9	511.6	54.4	166.1	139.3	106.3
1906/7	83.0	82.9	324.1	383.0	756.6	1987.4	1065.3	484.6	155.5	166.7	142.0	100.7
1907/8	60.4	88.1	313.4	974.9	1547.5	1809.5	806.7	107.1	88.1	88.4	85.7	80.4
1908/9	64.3	77.8	262.5	1331.2	2357.8	3498.0	2084.0	980.3	443.2	306.0	117.8	101.1
1909/10	58.9	49.2	42.9	80.4	639.5	1818.6	997.9	522.3	241.1	160.7	104.5	80.4
1910/11	61.6	62.2	131.2	573.2	1159.4	1982.0	1887.0	977.6	458.8	238.4	152.7	108.3
1911/12	72.3	70.0	155.3	476.8	1166.7	2043.6	1293.4	634.6	220.3	184.8	155.3	108.9
1912/13	83.0	75.2	174.1	460.0	983.6	1845.4	1179.4	632.1	484.7	233.0	147.3	108.9
1913/14	77.7	72.8	217.0	297.3	739.6	2011.5	1161.2	567.6	248.8	163.4	133.9	90.7
1914/15	69.6	95.9	190.2	790.1	1759.6	1371.3	789.8	417.6	261.6	163.4	64.3	59.6
1915/16	72.3	90.7	238.4	1312.4	834.8	685.7	456.2	316.1	217.7	142.0	104.5	62.9
1916/17	64.3	46.7	174.1	650.9	1059.3	1949.9	1653.3	878.5	458.8	289.3	160.7	62.2
1917/18	60.9	75.2	200.9	857.1	2753.2	1876.7	1441.2	500.9	292.8	208.9	179.5	132.2
1918/19	77.7	49.2	174.1	375.0	771.3	1805.2	863.1	377.7	184.0	107.1	67.0	51.6
1919/20	42.9	64.8	166.1	321.4	866.0	2239.1	2356.1	934.8	362.9	249.1	155.3	100.7
1920/21	96.4	88.1	117.8	744.6	1342.4	2624.8	1485.2	613.4	331.8	190.2	91.1	51.8
1921/22	42.9	49.2	93.7	233.0	371.0	653.5	331.8	120.5	51.8	32.1	24.1	18.1
1922/23	16.1	20.7	56.2	196.2	1020.3	2651.6	1798.8	906.0	335.1	160.7	91.1	51.8
1923/24	40.2	31.1	77.7	318.7	515.0	557.1	342.1	206.9	124.4	69.6	37.5	20.7
1924/25	18.1	18.1	75.0	573.2	1708.6	2835.5	2247.3	993.7	352.5	125.9	64.3	36.3
1925/26	24.1	15.6	77.7	691.0	2201.6	4767.6	2322.4	1232.1	489.8	281.2	195.5	119.2
1926/27	61.6	25.9	133.9	795.5	820.1	1470.4	920.2	506.2	248.2	152.7	101.8	82.2
1927/28	34.8	31.1	77.7	455.3	1418.1	1724.9	1044.6	653.5	311.0	182.1	123.2	75.2
1928/29	50.9	38.9	131.2	326.8	788.4	1438.3	1481.9	634.8	329.2	182.1	131.2	80.4
1929/30	45.5	23.3	179.5	456.0	815.2	1086.0	658.4	591.9	337.0	200.9	131.2	85.6
1930/31	66.2	46.7	107.1	482.1	1386.4	1736.3	1130.1	681.2	305.9	196.2	155.3	106.3
1931/32	83.0	93.3	455.3	782.1	1796.4	3305.1	1301.2	618.7	408.8	305.3	196.2	124.4
1932/33	83.0	59.6	182.1	776.7	1623.1	2089.9	1104.2	487.5	259.2	214.3	142.0	80.4
1933/34	48.2	72.8	206.2	741.9	1369.3	2654.3	1723.7	859.8	342.1	217.0	144.6	93.3
1934/35	53.6	59.8	233.0	641.0	1842.6	1406.2	902.0	802.6	378.4	265.2	179.5	116.6
1935/36	131.2	168.5	152.7	257.1	422.3	2215.0	2037.3	1074.0	482.1	321.4	238.4	145.2
1936/37	83.0	93.3	158.0	583.9	1435.2	2118.6	1161.2	546.4	295.5	200.9	163.4	119.2
1937/38	83.0	62.2	123.2	642.6	2018.1	1430.3	1384.1	808.9	370.7	200.9	147.3	101.1
1938/39	72.3	62.2	158.0	589.2	1674.4	2935.5	1493.0	578.5	264.4	184.8	147.3	106.3
1939/40	75.0	90.7	441.9	1352.6	2279.7	2860.5	3600.3	1852.6	652.6	562.5	407.1	241.1
1940/41	166.1	127.0	262.5	811.6	1669.5	2255.2	1436.6	916.7	378.4	160.7	160.7	101.1
1941/42	75.0	60.4	337.5	760.7	1237.5	1901.7	1054.9	225.0	72.6	174.1	123.2	95.9
1942/43	77.7	65.5	380.3	1111.5	2252.9	2051.7	1734.0	873.2	412.1	160.7	158.0	90.7
1943/44	64.3	70.0	163.4	894.6	2240.7	1966.6	1653.3	1031.2	492.5	283.9	187.5	134.8
1944/45	93.7	93.3	441.9	969.6	1591.4	1939.2	1671.8	1049.9	673.9	361.6	254.4	173.7
1945/46	123.2	114.0	458.0	1237.4	2089.3	1596.3	1130.1	203.6	49.2	147.3	104.5	75.2
1946/47	61.6	70.0	211.6	656.2	1222.8	1962.0	1332.3	1157.1	705.0	383.0	273.2	191.8
1947/48	139.3	137.4	728.5	1901.7	2702.0	4462.2	2996.4	1378.7	808.7	581.2	433.9	282.5
1948/49	195.5	163.3	479.4	557.1	627.3	1735.6	616.9	155.3	49.2	131.2	83.0	70.0
1949/50	56.2	59.6	72.3	541.0	1615.8	1853.5	2192.8	1232.1	780.2	468.7	270.5	173.7
1950/51	104.5	77.8	147.3	516.9	620.1	1036.5	521.0	348.2	210.0	120.5	50.9	25.9
1951/52	37.5	88.1	300.0	2177.5	3959.0	3939.9	1889.6	1194.6	570.2	412.5	348.2	269.6
1952/53	179.5	187.0	289.3	819.6	1637.9	2906.1	2050.3	1213.3	495.1	289.3	217.0	134.8
1953/54	99.1	98.5	294.6	891.9	1388.8	2003.4	1303.6	605.3	277.3	211.6	168.7	121.8
1954/55	83.0	75.2	241.1	1317.6	2038.1	2239.1	1542.2	918.0	388.2	248.4	174.1	121.8
1955/56	85.7	69.6	174.1	905.3	1698.8	2967.7	2871.9	2306.1	1436.0	752.8	458.0	318.2
1956/57	195.6	171.1	522.3	1505.3	2579.9	3621.2	2636.7	1896.3	1023.8	533.0	404.4	285.1
1957/58	195.5	147.7	257.1	1438.3	3236.5	2624.8	793.2	326.8	189.2	160.7	131.2	96.5
1958/59	77.7	62.9	166.7	361.6	590.7	2622.2	1130.1	375.0	165.9	128.6	96.4	72.6
1959/60	53.6	46.7	99.1	420.5	749.3	1604.4	1329.7	660.3	256.6	166.7	125.9	82.9
1960/61	56.2	57.0	93.7	396.4	1318.0	3348.0	2947.1	1568.3	663.6	366.9	246.4	165.9
1961/62	109.6	121.8	535.7	1250.8	2924.1	3966.7	3849.1	2592.7	1695.2	918.0	578.5	368.8
1962/63	287.8	215.1	2035.6	3958.0	4864.5	5605.9	2996.4	2038.3	1049.8	709.8	522.3	365.5
1963/64	267.8	318.8	824.9	1221.4	2482.6	2464.1	1381.5	597.3	368.1	318.1	265.2	191.8
1964/65	142.0	124.4	249.1	1151.7	1872.1	1696.1	898.8	444.6	274.8	225.0	184.8	137.4
1965/66	104.5	106.3	238.4	340.2	771.3	1984.7	1088.6	498.2	281.8	192.8	150.0	111.5
1966/67	83.0	57.0	123.2	318.7	825.0	1521.3	1448.3	956.2	388.2	254.4	192.8	142.6
1967/68	101.8	127.0	261.2	538.4	1095.9	1339.2	793.2	460.7	256.6	217.0	192.8	145.2
1968/69	104.5	95.9	589.2	2129.3	3011.9	4491.7	4782.2	2276.6	1316.7	709.8	511.6	375.6
1969/70	263.9	326.8	1159.7	2501.6	2504.3	1928.4	1246.8	648.2	406.9	337.5	267.8	194.4
1970/71	147.3	160.7	554.4	1917.7	2721.5	2461.4	1806.6	1224.0	546.9	407.1	316.1	226.1
1971/72	176.6	176.8	305.3	958.9	942.1	1376.7	1347.8	966.9	476.9	332.1	257.1	184.0
1972/73	147.3	121.8	139.3	273.2	324.6	650.9	388.8	230.3	127.0	107.1	91.1	70.0
1973/74	58.9	80.4	297.3	1264.2	2648.4	2209.7	1513.7	816.9	404.4	265.2	192.8	129.6
1974/75	107.2	177.0	702.2	2522.2	2017.9	3107.8	2243.0	1372.4	541.0	342.0	259.7	190.6
1975/76	136.1	193.4	347.4	1186.0	2330.6	3147.2	3606.8	2659.9	1567.5	772.4	496.9	332.3
1976/77	259.7	300.1	399.1	779.6	1169.5	2350.6	2294.1	1514.1	840.2	416.1	326.5	229.9
1977/78	166.7	206.9	674.7	2399.3	3421.0	5526.6	5666.9	4196.7	2595.6	1496.1	987.8	645.3
1978/79	409.2	650.4	1115.6	1943.5	2155.4	3613.5	4379.4	2862.5	1641.6	1002.9	733.0	470.0
1979/80	337.4	495.6	1314.4	1834.6	2130.9	2995.5	2493.7	2062.2	1121.8	715.0	535.4	351.2
1980/81	256.4	371.3	513.7	1271.0	2351.8	4204.4	3094.7	2004.2	980.0	656.3	484.1	334.2
1981/82	243.1	277.0	375.7	627.0	1618.0	1887.5	837.2	699.5	395.6	294.7	237.2	162.2
1982/83	152.6	277.2	675.1	773.4	1231.8	1548.2	1106.1	506.5	280.7	221.7	182.7	141.7
1983/84	113.6	205.8	379.3	880.3	987.4	1315.3	1221.7	517.5	235.1	186.0	152.0	115.9
1984/85	90.4	200.4	464.9	1310.6	2381.0	2134.3	2083.0	1265.9	563.8	352.1	258.3	165.6
1985/86	126.2	214.9	322.9	950.7	1715.9	2276.1	2270.2	2007.3	1071.2	518.6	358.5	246.4
1986/87	196.6	360.1	527.6	634.6	1417.2	1665.4	1242.2	623.4	311.4	252.7	213.6	153.0
1987/88	118.8	172.2	294.3	581.9	1305.3	2537.4	2005.2	970.5	364.6	262.5	204.3	147.5
1988/89	112.4	206.3	283.2	617.6	1627.4	1670.0	1636.6	1051.5	386.2	284.6	217.3	142.6
1989/90	106.4	178.7	256.7	633.6	1322.1	1064.0	1118.8	574.7	292.8	190.1	143.6	100.8
1990/91	74.4	147.8	203.3	815.2	1478.4	1614.5	1294.6	652.7	269.4	204.9	157.3	117.4
1991/92	93.1	193.7	248.5	359.5	426.1	380.0	487.9	227.6	128.4	96.9	60.9	56.1
1992/93	38.2	143.1	166.9	591.9	1734.7	3073.1	2494.3	1533.0	549.3	304.2	214.4	143.6

Table C.2 Rainfall (mm) for Itezhi-tezhi Reservoir

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1905/6	12.4	80.3	178.4	183.5	151.3	85.0	10.9	1.8	0.1	0.0	0.0	0.7
1906/7	12.4	79.5	179.0	183.6	150.2	84.7	11.0	1.4	0.1	0.0	0.0	0.7
1907/8	12.5	80.1	180.3	182.9	150.3	85.8	11.1	1.4	0.1	0.0	0.0	0.7
1908/9	12.7	81.0	180.5	183.9	149.8	85.2	10.8	1.1	0.1	0.0	0.0	0.7
1909/10	12.8	81.2	182.0	184.1	149.2	86.0	10.8	1.1	0.1	0.0	0.0	0.7
1910/11	9.1	144.3	126.2	175.2	241.4	107.1	2.7	36.3	0.0	0.0	0.0	0.0
1911/12	2.7	38.1	77.1	243.2	146.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1912/13	0.0	4.5	161.6	103.5	190.6	126.9	39.0	29.0	0.0	0.0	0.0	0.0
1913/14	1.6	69.0	63.5	166.1	196.0	24.5	28.3	0.0	0.0	0.9	0.0	0.0
1914/15	0.0	135.2	145.2	189.7	247.6	49.0	8.2	0.0	0.0	0.0	0.0	0.0
1915/16	4.5	57.2	149.8	210.6	77.1	35.4	0.0	0.0	0.0	0.0	0.0	0.0
1916/17	0.0	102.6	263.2	108.9	49.0	82.8	11.8	0.0	0.0	0.0	0.0	0.0
1917/18	6.4	113.5	248.7	232.3	249.6	97.1	20.0	0.0	0.0	0.0	0.0	0.0
1918/19	1.6	173.4	70.8	223.3	261.4	30.9	0.0	0.0	0.0	0.0	0.0	0.0
1919/20	56.1	57.2	231.4	190.6	250.5	126.0	1.8	1.8	0.0	0.0	0.0	0.0
1920/21	14.5	28.3	132.5	305.0	117.1	68.1	3.6	0.0	0.0	0.0	0.0	0.0
1921/22	25.4	89.9	128.0	40.8	136.1	6.4	19.1	0.0	0.0	0.0	0.0	0.0
1922/23	24.5	84.4	178.6	147.0	117.1	186.8	0.0	0.0	0.0	0.0	0.0	0.0
1923/24	0.0	47.2	113.5	49.9	92.6	43.6	0.0	0.0	0.0	0.0	0.0	0.0
1924/25	5.4	118.0	206.9	363.0	208.7	112.5	15.4	16.3	0.0	0.0	0.0	22.7
1925/26	32.7	25.4	67.1	316.8	201.5	163.4	0.0	0.0	0.0	0.0	0.0	0.9
1926/27	0.0	46.3	219.6	72.6	86.2	24.5	0.0	0.0	0.0	0.0	0.0	0.0
1927/28	5.4	132.5	141.6	206.7	59.9	91.7	3.6	0.0	0.0	0.0	0.0	0.0
1928/29	0.0	182.4	236.9	407.5	43.6	176.1	0.0	0.0	0.0	0.0	0.0	0.0
1929/30	0.8	74.4	192.4	49.9	27.2	118.6	15.4	0.0	0.0	0.0	0.0	0.0
1930/31	0.0	161.6	274.1	123.4	78.2	80.8	2.7	0.0	0.0	0.0	0.0	0.0
1931/32	0.0	166.8	163.4	192.4	189.7	173.4	25.4	0.0	0.0	0.0	0.0	0.0
1932/33	0.0	60.8	363.9	298.6	215.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1933/34	0.0	49.9	94.4	82.6	174.3	42.7	20.0	0.0	0.0	0.0	0.0	0.0
1934/35	31.8	222.4	260.5	191.5	80.6	51.7	4.5	6.4	0.0	0.0	0.0	0.0
1935/36	2.7	36.3	130.7	138.0	195.1	166.1	16.3	0.0	0.0	0.0	0.0	0.0
1936/37	43.6	21.8	158.8	124.3	139.8	59.9	0.0	0.0	0.0	0.0	0.0	0.0
1937/38	0.0	61.7	158.8	216.0	89.9	31.8	25.4	0.0	0.0	0.0	0.0	0.0
1938/39	9.1	72.6	181.5	283.2	302.2	145.2	0.9	0.0	0.0	0.0	0.0	0.0
1939/40	0.0	152.5	259.6	54.5	205.1	148.6	39.0	0.0	0.0	0.0	0.0	0.0
1940/41	51.7	78.1	157.9	324.0	135.2	102.6	0.0	0.0	0.0	0.0	0.0	0.0
1941/42	45.4	75.3	251.4	242.3	37.2	37.2	0.0	0.0	0.0	0.0	0.0	0.0
1942/43	65.3	40.8	188.8	232.3	134.3	149.8	30.0	0.0	0.0	0.0	0.0	0.0
1943/44	0.0	118.9	197.9	181.5	444.7	120.2	0.0	0.0	10.0	0.0	0.0	0.0
1944/45	3.6	104.4	67.2	118.0	100.7	171.5	6.4	0.0	0.0	0.0	0.0	0.0
1945/46	11.8	48.1	108.0	275.0	167.9	116.2	0.0	0.0	0.0	0.0	0.0	0.0
1946/47	0.0	30.9	153.4	66.3	47.2	58.1	34.5	0.0	0.0	0.0	0.0	0.0
1947/48	11.8	64.4	230.5	103.5	115.3	236.9	2.7	0.0	0.0	0.0	0.0	0.0
1948/49	56.3	153.4	31.8	132.5	52.6	3.6	10.0	0.0	0.0	0.0	0.0	0.0
1949/50	0.0	69.0	183.3	123.4	150.7	31.8	11.6	0.0	0.0	0.0	0.0	0.0
1950/51	0.0	58.1	128.0	160.6	57.2	20.0	0.0	0.0	0.0	0.0	0.0	0.0
1951/52	33.6	47.2	261.4	373.9	147.0	34.5	0.9	0.0	0.0	0.0	0.0	0.0
1952/53	7.3	112.5	167.0	251.4	203.3	176.1	15.4	0.0	0.0	0.0	0.0	0.0
1953/54	0.0	65.3	152.5	202.4	180.6	52.6	0.0	0.0	0.0	0.0	0.0	0.0
1954/55	0.9	162.5	218.7	269.6	179.7	59.9	0.0	0.0	0.0	0.0	0.0	0.0
1955/56	4.5	34.5	129.8	173.4	314.9	208.7	0.0	0.0	0.0	0.0	0.0	0.0
1956/57	0.0	65.3	185.2	70.8	159.7	59.0	3.8	0.0	0.0	0.0	0.0	8.4
1957/58	10.0	38.1	335.8	333.1	370.3	84.4	0.0	0.0	0.0	0.0	0.0	10.9
1958/59	20.9	34.5	224.2	146.1	168.6	46.5	2.7	0.0	0.0	0.0	0.0	0.0
1959/60	9.1	55.4	212.4	206.9	160.6	25.4	0.0	0.0	0.0	0.0	0.0	0.0
1960/61	2.7	98.2	101.7	198.8	170.8	133.4	0.0	0.0	0.0	0.0	0.0	0.0
1961/62	0.0	140.7	154.3	179.7	145.2	48.1	25.4	0.0	0.0	0.0	0.0	0.0
1962/63	0.0	129.8	354.0	72.6	236.0	34.5	0.0	0.0	0.0	0.0	0.0	0.0
1963/64	3.6	40.8	143.4	205.1	106.2	9.1	0.0	0.0	0.0	0.0	0.0	0.0
1964/65	2.8	70.5	221.9	120.1	62.6	81.8	0.0	0.0	0.0	0.0	0.0	7.8
1965/66	16.5	69.6	37.4	221.0	237.5	48.1	5.2	7.8	0.9	0.0	0.0	0.0
1966/67	2.6	14.8	217.5	139.2	134.0	36.5	22.6	11.3	0.0	0.0	0.0	0.0
1967/68	61.8	67.9	156.8	168.6	99.2	13.9	8.7	1.7	0.0	0.0	0.0	0.0
1968/69	0.0	105.3	177.5	115.7	76.6	184.4	20.9	0.0	0.0	0.0	0.0	0.0
1969/70	36.5	16.3	332.3	74.6	66.1	22.6	5.2	0.0	0.0	0.0	0.0	0.0
1970/71	4.4	248.0	140.1	203.6	85.3	18.3	15.7	2.6	0.0	0.0	0.0	0.0
1971/72	0.0	81.7	147.9	325.6	136.1	30.0	46.3	0.0	0.0	0.0	0.0	0.0
1972/73	4.5	22.7	179.7	201.5	172.4	106.0	0.9	0.0	0.0	0.0	0.0	0.0
1973/74	11.6	20.0	107.1	99.8	64.4	2.7	0.0	0.0	0.0	0.0	0.0	0.0
1974/75	0.0	140.7	195.1	327.6	138.9	57.2	0.0	0.0	0.0	0.0	0.0	0.0
1975/76	0.0	91.7	236.0	147.9	143.4	323.1	43.6	9.1	0.0	0.0	0.0	5.4
1976/77	15.4	22.7	114.4	56.3	116.2	136.0	0.0	0.0	0.0	0.0	0.0	0.0
1977/78	0.0	127.1	232.3	260.5	85.3	230.5	44.5	0.0	0.0	0.0	0.0	0.0
1978/79	0.0	17.2	384.6	114.4	122.5	52.6	0.0	0.0	0.0	0.0	0.0	0.0
1979/80	21.0	146.0	330.0	56.0	141.0	104.0	12.0	0.0	0.0	0.0	0.0	0.0
1980/81	2.0	105.0	329.0	228.0	335.0	92.0	15.0	0.0	0.0	0.0	0.0	0.0
1981/82	18.0	72.0	55.0	251.0	177.0	1.0	3.0	0.0	0.0	0.0	0.0	5.0
1982/83	34.0	115.0	81.0	195.0	58.0	38.0	1.0	5.0	0.0	0.0	0.0	0.0
1983/84	16.0	60.0	116.0	49.0	122.0	161.0	0.0	0.0	0.0	0.0	0.0	0.0
1984/85	16.0	45.0	100.0	140.0	155.0	46.0	6.0	0.0	0.0	0.0	0.0	0.0
1985/86	0.0	35.0	209.0	197.0	133.0	86.0	63.0	0.0	0.0	0.0	0.0	0.0
1986/87	59.0	43.0	225.0	105.0	80.0	41.0	0.0	0.0	0.0	0.0	0.0	0.0
1987/88	12.0	13.0	178.0	173.0	84.0	39.0	0.0	0.0	0.0	0.0	0.0	0.0
1988/89	0.0	0.0	60.0	304.0	189.0	46.0	7.0	0.0	0.0	0.0	0.0	0.0
1989/90	11.0	40.0	193.0	222.0	133.0	97.0	76.0	0.0	0.0	0.0	0.0	0.0
1990/91	0.0	87.0	197.0	223.0	42.0	91.0	0.0	0.0	0.0	0.0	0.0	0.0
1991/92	47.0	96.0	104.0	127.0	18.0	148.0	4.0	23.0	0.0	0.0	0.0	0.0
1992/93	15.0	128.0	187.0	232.0	450.0	135.0	40.0	0.0	0.0	0.0	0.0	0.0

Table C.3 Rainfall (mm) for Kafue Gorge Reservoir

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1905/6	12.2	88.5	194.3	206.6	169.4	92.0	13.8	1.7	0.1	0.0	0.0	0.6
1906/7	12.2	88.5	194.3	206.6	169.4	92.0	13.8	1.7	0.1	0.0	0.0	0.6
1907/8	12.2	88.5	194.3	206.6	169.4	92.0	13.8	1.7	0.1	0.0	0.0	0.6
1908/9	12.2	88.5	194.3	206.6	169.4	92.0	13.8	1.7	0.1	0.0	0.0	0.6
1909/10	12.2	88.5	194.3	206.6	169.4	92.0	13.8	1.7	0.1	0.0	0.0	0.6
1910/11	10.0	159.0	139.0	193.0	266.0	118.0	3.0	40.0	0.0	0.0	0.0	0.0
1911/12	3.0	42.0	85.0	266.0	161.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1912/13	0.0	5.0	178.0	114.0	210.0	142.0	43.0	32.0	0.0	0.0	0.0	0.0
1913/14	2.0	78.0	70.0	183.0	216.0	27.0	29.0	0.0	0.0	1.0	0.0	0.0
1914/15	0.0	149.0	160.0	209.0	273.0	54.0	9.0	0.0	0.0	0.0	0.0	0.0
1915/16	5.0	63.0	165.0	232.0	85.0	39.0	0.0	0.0	0.0	0.0	0.0	0.0
1916/17	0.0	113.0	290.0	120.0	54.0	91.0	13.0	0.0	0.0	0.0	0.0	0.0
1917/18	7.0	125.0	274.0	256.0	275.0	107.0	22.0	0.0	0.0	0.0	0.0	0.0
1918/19	2.0	191.0	78.0	248.0	268.0	34.0	0.0	0.0	0.0	0.0	0.0	0.0
1919/20	64.0	63.0	255.0	210.0	276.0	141.0	2.0	2.0	0.0	0.0	0.0	0.0
1920/21	16.0	29.0	146.0	336.0	129.0	75.0	4.0	0.0	0.0	0.0	0.0	0.0
1921/22	28.0	77.0	141.0	45.0	150.0	7.0	21.0	0.0	0.0	0.0	0.0	0.0
1922/23	27.0	93.0	187.0	182.0	129.0	208.0	0.0	0.0	0.0	0.0	0.0	0.0
1923/24	0.0	52.0	125.0	55.0	102.0	48.0	0.0	0.0	0.0	0.0	0.0	0.0
1924/25	6.0	130.0	228.0	400.0	230.0	124.0	17.0	18.0	0.0	0.0	0.0	25.0
1925/26	38.0	28.0	96.0	349.0	222.0	160.0	0.0	0.0	0.0	0.0	0.0	1.0
1926/27	0.0	51.0	242.0	80.0	95.0	27.0	0.0	0.0	0.0	0.0	0.0	0.0
1927/28	6.0	146.0	156.0	230.0	66.0	101.0	4.0	0.0	0.0	0.0	0.0	0.0
1928/29	0.0	201.0	261.0	449.0	48.0	194.0	0.0	0.0	0.0	0.0	0.0	0.0
1929/30	1.0	82.0	212.0	55.0	30.0	132.0	17.0	0.0	0.0	0.0	0.0	0.0
1930/31	0.0	178.0	302.0	136.0	84.0	89.0	3.0	0.0	0.0	0.0	0.0	0.0
1931/32	0.0	166.0	180.0	212.0	209.0	191.0	28.0	0.0	0.0	0.0	0.0	0.0
1932/33	0.0	67.0	401.0	329.0	237.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1933/34	0.0	55.0	104.0	91.0	192.0	47.0	22.0	0.0	0.0	0.0	0.0	0.0
1934/35	35.0	245.0	287.0	211.0	89.0	57.0	5.0	7.0	0.0	0.0	0.0	0.0
1935/36	3.0	40.0	144.0	152.0	215.0	205.0	18.0	0.0	0.0	0.0	0.0	0.0
1936/37	48.0	24.0	175.0	137.0	154.0	66.0	0.0	0.0	0.0	0.0	0.0	0.0
1937/38	0.0	57.0	175.0	238.0	99.0	35.0	28.0	0.0	0.0	0.0	0.0	0.0
1938/39	10.0	80.0	200.0	312.0	333.0	160.0	1.0	0.0	0.0	0.0	0.0	0.0
1939/40	0.0	168.0	286.0	60.0	226.0	164.0	43.0	0.0	0.0	0.0	0.0	0.0
1940/41	57.0	86.0	174.0	357.0	149.0	113.0	0.0	0.0	0.0	0.0	0.0	0.0
1941/42	50.0	83.0	277.0	267.0	41.0	41.0	0.0	0.0	0.0	0.0	0.0	0.0
1942/43	72.0	45.0	206.0	256.0	148.0	165.0	33.0	0.0	0.0	0.0	0.0	0.0
1943/44	0.0	131.0	218.0	200.0	490.0	139.0	0.0	0.0	11.0	0.0	0.0	0.0
1944/45	4.0	115.0	74.0	130.0	111.0	169.0	7.0	0.0	0.0	0.0	0.0	0.0
1945/46	13.0	53.0	119.0	303.0	207.0	128.0	0.0	0.0	0.0	0.0	0.0	0.0
1946/47	0.0	34.0	169.0	73.0	52.0	64.0	38.0	0.0	0.0	0.0	0.0	0.0
1947/48	13.0	71.0	254.0	114.0	127.0	261.0	3.0	0.0	0.0	0.0	0.0	0.0
1948/49	82.0	169.0	35.0	148.0	58.0	4.0	11.0	0.0	0.0	0.0	0.0	0.0
1949/50	0.0	76.0	202.0	136.0	166.0	35.0	13.0	0.0	0.0	0.0	0.0	0.0
1950/51	0.0	64.0	141.0	177.0	63.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0
1951/52	37.0	52.0	288.0	412.0	162.0	38.0	1.0	0.0	0.0	0.0	0.0	0.0
1952/53	8.0	124.0	184.0	277.0	224.0	194.0	17.0	0.0	0.0	0.0	0.0	0.0
1953/54	0.0	72.0	168.0	223.0	199.0	56.0	0.0	0.0	0.0	0.0	0.0	0.0
1954/55	1.0	179.0	241.0	297.0	196.0	66.0	0.0	0.0	0.0	0.0	0.0	0.0
1955/56	5.0	38.0	143.0	191.0	347.0	230.0	0.0	0.0	0.0	0.0	0.0	0.0
1956/57	0.0	72.0	204.0	78.0	176.0	65.0	4.0	0.0	0.0	0.0	0.0	7.0
1957/58	11.0	42.0	370.0	367.0	406.0	71.0	0.0	0.0	0.0	0.0	0.0	12.0
1958/59	23.0	38.0	247.0	161.0	206.0	51.0	3.0	0.0	0.0	0.0	0.0	0.0
1959/60	10.0	61.0	234.0	226.0	177.0	26.0	0.0	0.0	0.0	0.0	0.0	0.0
1960/61	3.0	106.0	112.0	219.0	188.0	147.0	0.0	0.0	0.0	0.0	0.0	0.0
1961/62	0.0	155.0	170.0	198.0	180.0	53.0	28.0	0.0	0.0	0.0	0.0	0.0
1962/63	0.0	143.0	390.0	80.0	260.0	38.0	0.0	0.0	0.0	0.0	0.0	0.0
1963/64	4.0	45.0	158.0	226.0	117.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0
1964/65	3.2	85.1	268.0	145.0	75.7	74.6	0.0	0.0	0.0	0.0	0.0	9.5
1965/66	20.0	64.1	45.2	266.9	286.8	55.7	6.3	9.5	1.1	0.0	0.0	0.0
1966/67	0.0	51.0	262.7	168.2	161.8	44.1	27.3	13.7	0.0	0.0	0.0	0.0
1967/68	74.6	82.0	189.2	203.9	119.8	16.8	10.5	2.1	0.0	0.0	0.0	0.0
1968/69	0.0	127.2	214.4	139.8	92.5	222.6	25.2	0.0	0.0	0.0	0.0	0.0
1969/70	44.1	22.1	401.5	90.4	79.9	27.3	6.3	0.0	0.0	0.0	0.0	0.0
1970/71	5.3	299.5	169.2	245.9	103.0	22.1	18.9	3.2	0.0	0.0	0.0	0.0
1971/72	0.0	90.0	163.0	359.0	150.0	33.0	51.0	0.0	0.0	0.0	0.0	0.0
1972/73	5.0	25.0	198.0	222.0	190.0	119.0	1.0	0.0	0.0	0.0	0.0	0.0
1973/74	13.0	22.0	116.0	110.0	71.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
1974/75	0.0	155.0	215.0	361.0	153.0	63.0	0.0	0.0	0.0	0.0	0.0	0.0
1975/76	0.0	101.0	260.0	163.0	158.0	356.0	48.0	10.0	0.0	0.0	0.0	6.0
1976/77	17.0	25.0	126.0	62.0	126.0	152.0	0.0	0.0	0.0	0.0	0.0	0.0
1977/78	0.0	140.0	256.0	287.0	105.0	254.0	49.0	0.0	0.0	0.0	0.0	0.0
1978/79	0.0	19.0	424.0	126.0	135.0	58.0	0.0	0.0	0.0	0.0	0.0	0.0
1979/80	31.0	211.0	184.0	68.0	158.0	19.0	6.0	0.0	0.0	0.0	0.0	0.0
1980/81	0.0	66.0	206.0	286.0	268.0	114.0	66.0	0.0	0.0	0.0	0.0	0.0
1981/82	19.8	179.0	92.0	298.0	183.0	1.1	3.3	0.0	0.0	0.0	0.0	0.0
1982/83	0.0	90.0	42.0	230.0	89.0	37.0	50.0	0.0	0.0	0.0	0.0	0.0
1983/84	0.0	57.0	153.0	89.0	197.0	79.0	11.0	0.0	0.0	0.0	0.0	0.0
1984/85	0.0	89.0	119.0	204.0	145.0	38.0	0.0	0.0	0.0	0.0	0.0	0.0
1985/86	16.0	54.0	282.0	298.0	86.0	102.0	117.0	0.0	0.0	0.0	0.0	0.0
1986/87	65.0	107.0	211.0	217.0	98.0	52.0	0.0	0.0	0.0	0.0	0.0	5.0
1987/88	4.0	28.0	207.0	153.0	149.0	54.0	16.0	0.0	0.0	0.0	0.0	0.0
1988/89	0.0	15.0	51.0	360.0	581.0	195.0	0.0	0.0	0.0	0.0	0.0	0.0
1989/90	0.0	41.0	191.0	318.0	138.0	43.0	68.0	0.0	0.0	0.0	0.0	0.0
1990/91	0.0	15.0	187.0	267.0	135.0	99.0	14.0	0.0	0.0	0.0	0.0	0.0
1991/92	16.0	0.0	153.0	131.0	77.0	77.0	13.0	4.0	0.0	0.0	0.0	0.0
1992/93	0.0	53.0	206.0	89.0	164.0	148.7	44.1	0.0	0.0	0.0	0.0	0.0

Table C.4 *Itezhi-tezhi Simulation Run 1440 Input Details*

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MULTIPURPOSE RESERVOIR ANALYSIS                                    RUN 1440                  28.10.94  AT 13:17

ITEZHI-TEZHI                  1       1                            USING DATA: ITEZHI-TEZHI RESERVOIR INPUT FILE 28/10/


INITIAL CONDITIONS       Reservoir contents  3045.0 mcm                                         Tailwater level  976.0 m

DEMANDS                              OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP

         Water supply       mcm      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
         Compensation flow  mcm    348.0   337.0   482.0   482.0   513.0   804.0   337.0   348.0   337.0   348.0   348.0   337.0
         Irrigation         mcm      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
         Firm energy        Gwh      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
         Peak power          Mw      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

RULE CURVES

         Design flood curve mcm   4118.0  3827.0  3689.0  3772.0  3973.0  4424.0  5084.0  5550.0  5624.0  5550.0  5262.0  4915.0
         Operating curve    mcm    699.2   699.2   699.2   699.2   699.2   699.2   699.2   699.2   699.2   699.2   699.2   699.2
         Max release target mcm    844.0   816.0   844.0   844.0   769.0   844.0   816.0   844.0   816.0   844.0   844.0   816.0

EVAPORATION                 mm     233.0   191.0   168.0   172.0   154.0   176.0   157.0   136.0   109.0   125.0   157.0   202.0

MINIMUM RELEASE LEVELS   Water supply   0.0 m       Compensation flow 991.0 m      Irrigation   0.0 m        Energy   0.0 m

RESERVOIR AND TURBINE    Water Storage   Area Seepage        Outflow  Tailwater          Net    Peak     Efficiency  Efficiency
CHARACTERISTICS          level                                            level          head    cap     peak power  aver power
                             m     mcm   sqkm mcm/mth        mcm/mth              m        m     Mw              %           %

                          989.0    2.0    4.0     0.0            0.0     970.0             5.0    1.0            5.0         0.0
                         1000.0  279.0   50.0     0.0          100.0     972.0             6.0    1.5           10.0         0.0
                         1006.0  699.2   90.0     0.0          300.0     976.0             7.0    2.0           15.0         0.0
                         1010.0 1119.2  120.0     0.0          600.0     978.0             8.0    3.0           20.0         0.0
                         1013.0 1520.2  148.0     0.0          800.0     979.0             9.0    3.5           25.0         0.0
                         1016.0 2007.7  177.0     0.0         1000.0     980.0             0.0    0.0            0.0         0.0
                         1020.0 2814.2  224.0     0.0            0.0       0.0             0.0    0.0            0.0         0.0
                         1024.0 3827.2  284.0     0.0            0.0       0.0             0.0    0.0            0.0         0.0
                         1028.0 5084.2  346.0     0.0            0.0       0.0             0.0    0.0            0.0         0.0
                         1029.5 5623.7  374.0     0.0            0.0       0.0             0.0    0.0            0.0         0.0
                         1031.0 6204.2  404.0     0.0            0.0       0.0             0.0    0.0            0.0         0.0
                         1033.0 7049.2  446.0     0.0            0.0       0.0             0.0    0.0            0.0         0.0

HEAD CONDITIONS          Turbine head loss   1.0 m                            Minimum net head on turbines   5.0 m

OPTIONS/OUTPUT           INY  ISY  ISM  IDM  IRA          IND  IPR(1) IPR(2) IPR(3) IPR(4)          IMS  IIR  IPC  IMH  IEP
                          88 1905   10    1    1            1       2      0      0      0            1    0    0    0    0

                         IOP list    1  2  3  5  6  7 12 16 17 31 36  0              IMX  INT(1) INT(2) IRS(1) IRS(2)
                         IAS list    1  1  1  2  3  2  1  1  1  1  2  0                1      12     17      1     17
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Table C.5 *Itezhi-tezhi Simulation Run 1440 Annual Results*

MULTIPURPOSE RESERVOIR ANALYSIS RUN 1440 28.10.94 AT 13:17

ITEZHI-TEZHI 1 1 USING DATA: ITEZHI-TEZHI RESERVOIR INPUT FILE 28/10/

ANNUAL SUMMARY OF SELECTED VARIABLES

	Total inflow (mcm)	Total rain (mcm)	Total evap loss (mcm)	Average end of month content (mcm)	Maximum change in content (mcm)	Average end of month level (m)	Total comp flow release (mcm)	Total spill (mcm)	Total outflow (mcm)	Total comp flow cutback (mcm)	Average comp flow cutback (%)
1905/ 6	6486.0	144.4	522.4	3720.1	1443.5	1023.0	5021.0	25.3	5046.3	0.0	0.0
1906/ 7	5737.0	185.4	588.2	4197.2	939.1	1025.1	5021.0	238.2	5259.2	0.0	0.0
1907/ 8	6132.2	196.0	574.3	3976.0	451.0	1024.4	5021.0	1548.0	6569.0	0.0	0.0
1908/ 9	11626.0	173.5	585.8	4334.4	851.9	1025.3	5021.0	4644.3	9665.3	0.0	0.0
1909/10	4796.4	184.0	578.1	4010.5	990.5	1024.4	5021.0	437.9	5458.9	0.0	0.0
1910/11	7790.4	215.8	596.2	4371.4	800.8	1025.5	5021.0	1332.5	6353.5	0.0	0.0
1911/12	6582.2	137.2	614.9	4410.8	660.0	1025.8	5021.0	1575.2	6596.2	0.0	0.0
1912/13	6412.7	186.3	618.7	4497.0	660.0	1026.1	5021.0	655.4	5676.4	0.0	0.0
1913/14	5781.5	148.8	607.4	4344.5	848.2	1025.6	5021.0	702.8	5723.8	0.0	0.0
1914/15	6013.6	216.6	592.7	4175.8	451.0	1025.1	5021.0	1114.4	6135.4	0.0	0.0
1915/16	4553.7	138.1	526.1	3501.3	810.4	1022.7	5021.0	128.8	5149.8	0.0	0.0
1916/17	7648.0	119.9	532.4	3913.5	1365.4	1023.5	5021.0	143.8	5164.8	0.0	0.0
1917/18	8369.6	274.9	617.7	4427.1	660.0	1025.9	5021.0	3485.7	8506.7	0.0	0.0
1918/19	4903.2	206.6	588.5	4127.8	764.0	1024.9	5021.0	194.6	5215.6	0.0	0.0
1919/20	7882.2	217.0	580.2	4218.9	1404.0	1025.0	5021.0	1398.6	6419.6	0.0	0.0
1920/21	7777.6	186.0	618.4	4447.6	660.0	1025.9	5021.0	2768.1	7789.1	0.0	0.0
1921/22	2021.7	108.7	440.4	2585.3	-35.0	1018.4	5021.0	0.0	5021.0	0.0	0.0
1922/23	7328.6	85.8	400.0	2910.8	1049.9	1018.0	3977.8	0.0	3977.8	1043.2	20.4
1923/24	2143.0	81.6	420.7	2432.2	-11.6	1017.7	5021.0	0.0	5021.0	0.0	0.0
1924/25	8846.5	136.2	438.3	3311.3	1817.2	1019.6	4308.0	760.9	5068.9	713.0	14.6
1925/26	12417.9	229.6	627.3	4591.9	660.0	1026.3	5021.0	6644.4	11665.4	0.0	0.0
1926/27	5296.7	124.2	606.4	4297.5	511.9	1025.5	5021.0	638.6	5659.6	0.0	0.0
1927/28	6131.5	163.9	591.6	4267.5	880.9	1025.2	5021.0	293.8	5314.8	0.0	0.0
1928/29	5594.1	285.1	608.4	4381.4	839.6	1025.7	5021.0	234.2	5255.2	0.0	0.0
1929/30	4592.4	132.4	570.6	3913.4	279.6	1024.2	5021.0	0.0	5021.0	0.0	0.0
1930/31	6293.8	167.6	565.9	4084.3	907.1	1024.5	5021.0	17.0	5038.0	0.0	0.0
1931/32	9469.9	263.5	625.4	4549.4	660.0	1026.3	5021.0	3787.2	8808.2	0.0	0.0
1932/33	7112.0	261.3	614.5	4398.6	660.0	1025.8	5021.0	2196.8	7217.8	0.0	0.0
1933/34	8473.0	128.9	628.6	4516.5	660.0	1026.1	5021.0	2503.5	7524.5	0.0	0.0
1934/35	6880.5	242.2	618.1	4442.4	515.3	1025.9	5021.0	1729.5	6750.5	0.0	0.0
1935/36	7645.2	188.3	619.2	4522.4	1250.7	1026.1	5021.0	1797.2	6818.2	0.0	0.0
1936/37	6958.6	154.3	616.3	4419.8	660.0	1025.8	5021.0	1945.6	6966.6	0.0	0.0
1937/38	7370.6	158.7	622.9	4540.4	660.0	1026.2	5021.0	1592.2	6613.2	0.0	0.0
1938/39	8265.9	278.7	614.9	4416.0	660.0	1025.8	5021.0	3245.6	8266.6	0.0	0.0
1939/40	14426.8	248.2	632.2	4641.7	660.0	1026.5	5021.0	8498.0	13519.0	0.0	0.0
1940/41	8450.1	242.0	630.8	4589.1	660.0	1026.4	5021.0	3183.8	8204.8	0.0	0.0
1941/42	6138.5	195.9	601.8	4231.0	660.0	1025.3	5021.0	1655.3	6676.3	0.0	0.0
1942/43	9388.3	229.0	607.1	4457.7	660.0	1025.9	5021.0	3025.7	8046.7	0.0	0.0
1943/44	9384.8	307.6	633.4	4631.6	660.0	1026.5	5021.0	3914.3	8935.3	0.0	0.0
1944/45	9314.4	165.9	636.1	4649.0	660.0	1026.5	5021.0	3823.2	8844.2	0.0	0.0
1945/46	7328.1	213.4	600.2	4203.1	660.0	1025.2	5021.0	3116.1	8137.1	0.0	0.0
1946/47	8246.6	98.3	591.9	4349.7	800.8	1025.4	5021.0	1536.2	6557.2	0.0	0.0
1947/48	16550.5	221.3	636.1	4649.0	660.0	1026.5	5021.0	11114.7	16135.7	0.0	0.0
1948/49	4863.8	127.4	579.1	3952.7	585.2	1024.3	5021.0	1086.8	6107.8	0.0	0.0
1949/50	9316.4	120.1	559.4	4119.5	1103.1	1024.4	5021.0	2160.4	7181.4	0.0	0.0
1950/51	3979.6	115.7	557.5	3724.6	280.6	1023.5	5021.0	479.4	5500.4	0.0	0.0
1951/52	15186.7	204.7	573.0	4268.9	1616.6	1024.9	5021.0	7834.8	12855.8	0.0	0.0
1952/53	10629.2	267.5	635.3	4641.8	660.0	1026.5	5021.0	5240.4	10261.4	0.0	0.0
1953/54	7464.8	185.0	621.2	4468.6	660.0	1026.0	5021.0	2420.0	7441.0	0.0	0.0
1954/55	9381.8	252.0	630.7	4616.4	660.0	1026.4	5021.0	3587.1	8608.1	0.0	0.0
1955/56	14032.0	247.1	631.5	4628.7	660.0	1026.5	5021.0	8606.4	13627.4	0.0	0.0
1956/57	15376.6	157.4	636.1	4649.0	660.0	1026.5	5021.0	9876.9	14897.9	0.0	0.0
1957/58	9599.5	328.7	598.4	4181.0	451.0	1025.1	5021.0	5429.0	10450.0	0.0	0.0
1958/59	5872.4	155.4	558.2	3948.2	1591.8	1024.1	5021.0	273.7	5294.7	0.0	0.0
1959/60	5627.7	158.7	564.4	3990.7	944.2	1024.3	5021.0	0.0	5021.0	0.0	0.0
1960/61	11247.5	184.2	610.3	4469.6	809.3	1025.9	5021.0	5047.1	10068.1	0.0	0.0
1961/62	18929.2	198.6	636.1	4649.0	660.0	1026.5	5021.0	13470.7	18491.7	0.0	0.0
1962/63	24627.0	235.0	636.1	4649.0	660.0	1026.5	5021.0	19204.9	24225.9	0.0	0.0
1963/64	10679.8	143.4	627.8	4547.2	660.0	1026.3	5021.0	5239.1	10260.1	0.0	0.0
1964/65	7400.8	155.1	610.0	4332.8	508.6	1025.6	5021.0	2529.7	7550.7	0.0	0.0
1965/66	5848.3	170.4	598.0	4286.4	879.0	1025.4	5021.0	305.5	5326.5	0.0	0.0
1966/67	6306.7	152.9	611.6	4459.3	940.8	1025.9	5021.0	251.6	5272.6	0.0	0.0
1967/68	5549.0	164.8	605.6	4277.4	451.0	1025.4	5021.0	849.7	5870.7	0.0	0.0
1968/69	20395.2	194.2	626.1	4604.7	660.0	1026.4	5021.0	14179.8	19200.8	0.0	0.0
1969/70	11806.1	158.2	630.7	4582.7	660.0	1026.4	5021.0	6312.6	11333.6	0.0	0.0
1970/71	12491.8	203.5	636.1	4649.0	660.0	1026.5	5021.0	7040.2	12061.2	0.0	0.0
1971/72	7503.4	218.5	635.7	4645.3	660.0	1026.5	5021.0	2065.2	7086.2	0.0	0.0
1972/73	2671.4	177.4	478.9	2924.9	15.7	1020.2	5021.0	550.4	5571.4	0.0	0.0
1973/74	10881.5	44.1	498.9	3762.2	2279.0	1022.1	5021.0	1404.3	6425.3	0.0	0.0
1974/75	13583.2	243.7	636.1	4649.0	660.0	1026.5	5021.0	8169.7	13190.7	0.0	0.0
1975/76	16776.5	293.1	636.1	4649.0	660.0	1026.5	5021.0	11411.5	16432.5	0.0	0.0
1976/77	10679.5	134.1	636.1	4649.0	660.0	1026.5	5021.0	5156.5	10177.5	0.0	0.0
1977/78	28179.6	286.1	636.1	4649.0	660.0	1026.5	5021.0	22808.6	27829.6	0.0	0.0
1978/79	20977.0	195.5	636.1	4649.0	660.0	1026.5	5021.0	15515.3	20536.3	0.0	0.0
1979/80	16387.7	232.8	636.1	4649.0	660.0	1026.5	5021.0	10963.4	15984.4	0.0	0.0
1980/81	16524.1	315.3	636.1	4649.0	660.0	1026.5	5021.0	11182.2	16203.2	0.0	0.0
1981/82	7674.7	165.5	622.6	4484.4	451.0	1026.1	5021.0	2394.3	7415.3	0.0	0.0
1982/83	7099.7	151.2	618.1	4441.7	660.0	1025.9	5021.0	1871.7	6892.7	0.0	0.0
1983/84	6309.9	152.6	614.4	4413.7	660.0	1025.8	5021.0	955.4	5976.4	0.0	0.0
1984/85	11270.3	144.9	631.6	4639.7	660.0	1026.5	5021.0	5176.7	10197.7	0.0	0.0
1985/86	12080.9	214.8	636.0	4648.2	660.0	1026.5	5021.0	6638.7	11659.7	0.0	0.0
1986/87	7639.8	158.7	624.9	4511.9	660.0	1026.2	5021.0	2398.9	7419.9	0.0	0.0
1987/88	8964.5	140.6	631.9	4618.7	660.0	1026.5	5021.0	3206.0	8227.0	0.0	0.0
1988/89	8435.7	170.6	634.1	4627.5	660.0	1026.5	5021.0	2951.3	7972.3	0.0	0.0
1989/90	6004.3	321.4	613.9	4302.9	755.7	1025.7	5021.0	1179.7	6200.7	0.0	0.0
1990/91	7047.9	178.8	615.8	4459.6	660.0	1026.0	5021.0	1377.9	6398.9	0.0	0.0
1991/92	2782.7	151.0	483.0	2983.2	115.4	1020.4	5021.0	227.7	5248.7	0.0	0.0
1992/93	11006.7	180.0	479.2	3599.3	2139.2	1021.2	5021.0	2511.6	7532.6	0.0	0.0
PERIOD	9170.8	187.5	595.2	4273.4	2279.0	1025.1	5001.1	3740.8	8741.8	20.0	0.4

Table C.6 Kafue Gorge Simulation Run 1350 Input Details

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MULTIPURPOSE RESERVOIR ANALYSIS                                        RUN 1350                          28.10.94  AT 14:51

KAFUE GORGE                     1       1                              USING DATA: KAFUE GORGE RESERVOIR INPUT FILE 28/10/9


INITIAL CONDITIONS        Reservoir contents   219.0 mcm                                                 Tailwater level  583.0 m

DEMANDS                                 OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP

          Water supply       mcm        6.1     5.9     6.1     6.1     5.6     6.1     5.9     6.1     5.9     6.1     6.1     5.8
          Compensation flow  mcm        0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
          Irrigation         mcm       18.6    16.0     8.5     5.1     4.7     8.0    14.9    17.0    15.4    15.1    16.5    17.4
          Firm energy        Gwh      319.9   309.6   319.9   319.9   291.5   319.9   309.6   319.9   309.6   319.9   319.9   309.6
          Peak power          Mw      900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0


RULE CURVES

          Design flood curve mcm      240.0   240.0   345.0   550.0   785.0   785.0   475.0   350.0   240.0   240.0   240.0   240.0
          Operating curve    mcm       20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0
          Max release target mcm     6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0


EVAPORATION                  mm       233.0   191.0   168.0   172.0   154.0   176.0   157.0   136.0   109.0   125.0   157.0   202.0

MINIMUM RELEASE LEVELS    Water supply 972.0 m       Compensation flow   0.0 m       Irrigation 972.0 m         Energy 958.1 m

RESERVOIR AND TURBINE     Water Storage   Area Seepage        Outflow  Tailwater          Net    Peak    Efficiency  Efficiency
CHARACTERISTICS           level                                           level           head    cap    peak power  aver power
                             m      mcm   sqkm mcm/mth        mcm/mth             m         m      Mw            %           %

                          972.3     0.0   20.0     0.0            0.0     577.3         360.0   853.0          89.1        90.3
                          972.5     5.0   25.0     0.0          210.1     579.1         365.8   870.0          89.4        90.5
                          973.0    20.0   35.0     0.0          420.2     580.7         367.0   888.0          89.4        90.6
                          973.5    40.0   47.0     0.0         1024.3     582.2         370.0   893.0          89.2        90.6
                          974.0    69.0   70.0     0.0         1943.7     583.7         375.0   900.0          89.1        90.7
                          974.5   111.0   98.0     0.0         3125.6     585.2         380.0   900.0          88.9        90.8
                          975.0   170.0  142.0     0.0         4465.2     586.7         385.0   900.0          88.7        90.9
                          975.5   263.0  235.0     0.0         5205.8     587.4         387.0   900.0          88.6        91.0
                          976.0   423.0  430.0     0.0            0.0       0.0         390.0   900.0          88.5        91.0
                          976.6   785.0  805.0     0.0            0.0       0.0         394.0   900.0          88.3        91.0
                          977.0  1178.0 1175.0     0.0            0.0       0.0         396.0   900.0          88.1        90.9
                          978.0  2845.0 2160.0     0.0            0.0       0.0           0.0     0.0           0.0         0.0

HEAD CONDITIONS           Turbine head loss   8.5 m                                      Minimum net head on turbines 360.0 m

OPTIONS/OUTPUT            INY  ISY  ISM  IDM  IRA          IND  IPR(1) IPR(2) IPR(3) IPR(4)          IWS  IIR  IPC  IMM  IEF
                           88 1905  10    1    1             3     1      4      3      0              0    0    0    2    1

                          IOP list   1  7 11 13 14 16 17 20 21 22 25 26                 IMX  INT(1) INT(2) IRS(1) IRS(2)
                          IAS list   1  2  1  1  1  1  1  1  1  1  1  2                   1    21     22     22     25
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Table C.7 Kafue Gorge Simulation Run 1350 Annual Results

MULTIPURPOSE RESERVOIR ANALYSIS RUN 1350 28.10 94 AT 14:51

KAFUE GORGE 1 1 USING DATA: KAFUE GORGE RESERVOIR INPUT FILE 28/10/9

ANNUAL SUMMARY OF SELECTED VARIABLES

	Total inflow (mcm)	Average end of month level (m)	Total water supply release (mcm)	Total irrig release (mcm)	Total energy release (mcm)	Total spill (mcm)	Total outflow (mcm)	Total firm energy (Gwh)	Total second energy (Gwh)	Total energy (Gwh)	Total turbine flow (mcm)	Average firm power (Mw)
1905/ 6	5808.7	975.7	71.9	157.2	3933.0	1302.0	5464.1	3769.2	1120.3	4889.5	5161.9	430.0
1906/ 7	5860.0	975.6	71.9	157.2	3932.0	1347.8	5508.9	3769.2	1060.8	4830.0	5104.3	430.0
1907/ 8	7618.1	975.6	71.9	157.2	3936.5	3105.4	7271.0	3769.2	1568.0	5337.2	5657.5	430.0
1908/ 9	11717.1	975.7	71.9	157.2	3944.0	7156.6	11129.7	3769.2	1998.1	5767.3	6140.5	430.0
1909/10	5824.4	975.7	71.9	157.2	3932.1	1332.2	5493.5	3769.2	1156.2	4925.4	5200.2	430.0
1910/11	7292.2	975.6	71.9	157.2	3936.2	2814.2	6979.5	3769.2	1646.1	5415.3	5743.0	430.0
1911/12	7259.6	975.7	71.9	157.2	3935.5	2651.3	6815.9	3769.2	1625.8	5395.1	5719.5	430.0
1912/13	6389.3	975.6	71.9	157.2	3934.0	1911.6	6074.7	3769.2	1312.9	5082.1	5374.4	430.0
1913/14	6266.4	975.7	71.9	157.2	3932.7	1691.5	5853.3	3769.2	1263.5	5032.7	5318.7	430.0
1914/15	7233.2	975.6	71.9	157.2	3935.6	2751.6	6916.3	3769.2	1590.2	5359.4	5680.6	430.0
1915/16	5729.3	975.6	71.9	157.2	3931.7	1126.4	5287.2	3769.2	954.4	4723.6	4978.5	430.0
1916/17	5738.9	975.6	71.9	157.2	3931.4	1138.6	5299.1	3769.2	945.5	4714.8	4968.6	430.0
1917/18	10149.7	975.7	71.9	157.2	3942.0	5768.2	9939.3	3769.2	2094.1	5863.3	6242.1	430.0
1918/19	6803.6	975.6	71.9	157.2	3931.9	1316.7	5477.6	3769.2	1073.1	4842.4	5108.9	430.0
1919/20	7452.7	975.7	71.9	157.2	3936.3	3011.0	7176.4	3769.2	1561.0	5330.2	5649.9	430.0
1920/21	8924.1	975.7	71.9	157.2	3939.3	4393.9	8562.3	3769.2	1820.3	5589.6	5938.1	430.0
1921/22	5565.7	975.6	71.9	157.2	3931.0	951.2	5111.3	3769.2	847.1	4616.3	4860.1	430.0
1922/23	4621.5	974.7	71.9	142.9	3653.0	498.7	4366.5	3129.4	454.6	3584.1	3766.7	350.3
1923/24	5556.3	975.6	71.9	157.2	3931.3	926.2	5086.6	3769.2	838.4	4607.6	4850.7	430.0
1924/25	5911.4	974.9	71.9	143.6	3806.3	1599.0	5620.8	3129.4	1292.3	4421.7	4688.4	350.3
1925/26	14027.5	975.7	71.9	157.2	3947.2	9572.2	13748.5	3769.2	2195.7	5964.9	6362.2	430.0
1926/27	6110.9	975.7	71.9	157.2	3932.5	1498.2	5659.8	3769.2	1246.2	5015.5	5299.5	430.0
1927/28	5915.3	975.6	71.9	157.2	3932.3	1363.0	5524.4	3769.2	1050.8	4820.0	5084.9	430.0
1928/29	5888.6	975.7	71.9	157.2	3932.5	1485.8	5647.3	3769.2	1229.0	4998.2	5280.5	430.0
1929/30	5565.7	975.6	71.9	157.2	3931.1	988.7	5148.9	3769.2	847.0	4616.3	4860.1	430.0
1930/31	5589.2	975.6	71.9	157.2	3931.0	1031.5	5191.6	3769.2	882.5	4651.7	4898.8	430.0
1931/32	10377.1	975.7	71.9	157.2	3941.7	5976.1	10146.9	3769.2	1876.8	5646.1	6003.6	430.0
1932/33	8288.4	975.7	71.9	157.2	3937.9	3826.6	7993.6	3769.2	1880.8	5650.0	6002.3	430.0
1933/34	8868.2	975.6	71.9	157.2	3938.8	4264.1	8432.0	3769.2	1679.7	5448.9	5783.7	430.0
1934/35	7741.2	975.7	71.9	157.2	3936.8	3201.0	7366.9	3769.2	1846.1	5615.3	5962.7	430.0
1935/36	7545.2	975.7	71.9	157.2	3936.4	3037.8	7203.3	3769.2	1783.5	5552.7	5893.9	430.0
1936/37	7877.7	975.7	71.9	157.2	3936.9	3302.5	7468.6	3769.2	1719.4	5488.6	5824.1	430.0
1937/38	7893.5	975.7	71.9	157.2	3937.1	3287.1	7453.3	3769.2	1686.5	5455.7	5788.3	430.0
1938/39	9671.0	975.7	71.9	157.2	3940.7	5343.5	9513.3	3769.2	1969.3	5738.6	6103.5	430.0
1939/40	15553.8	975.7	71.9	157.2	3951.0	11048.2	15228.3	3769.2	2826.7	6596.0	7059.8	430.0
1940/41	9610.8	975.8	71.9	157.2	3942.2	5150.6	9321.9	3769.2	2470.2	6239.4	6654.2	430.0
1941/42	7443.0	975.7	71.9	157.2	3936.0	2856.1	7021.3	3769.2	1652.3	5421.6	5749.3	430.0
1942/43	9819.9	975.7	71.9	157.2	3940.9	5358.7	9528.7	3769.2	2006.2	5775.4	6144.6	430.0
1943/44	10441.3	975.7	71.9	157.2	3942.8	6119.8	10291.7	3769.2	2226.0	5995.2	6388.1	430.0
1944/45	9796.6	975.8	71.9	157.2	3941.8	5217.6	9388.6	3769.2	2586.4	6355.6	6781.4	430.0
1945/46	9303.3	975.7	71.9	157.2	3941.1	4863.5	9033.7	3769.2	2308.9	6078.2	6475.9	430.0
1946/47	7026.1	975.6	71.9	157.2	3935.6	2347.8	6512.6	3769.2	1644.7	5414.0	5740.7	430.0
1947/48	18244.7	975.8	71.9	157.2	3956.3	13749.7	17935.1	3769.2	3530.4	7299.7	7838.8	430.0
1948/49	6759.9	975.7	71.9	157.2	3934.9	2109.5	6273.4	3769.2	1721.2	5490.4	5823.2	430.0
1949/50	7035.3	975.6	71.9	157.2	3937.2	3189.1	7355.3	3769.2	1796.6	5565.9	5909.9	430.0
1950/51	6003.5	975.7	71.9	157.2	3932.7	1378.6	5540.4	3769.2	1205.9	4975.2	5255.5	430.0
1951/52	15421.3	975.7	71.9	157.2	3949.7	10865.8	15044.6	3769.2	2341.6	6110.9	6525.8	430.0
1952/53	11956.0	975.8	71.9	157.2	3946.7	7552.9	11728.8	3769.2	2804.2	6573.5	7027.5	430.0
1953/54	8410.6	975.7	71.9	157.2	3938.7	3892.0	8059.8	3769.2	2048.6	5817.9	6187.2	430.0
1954/55	10139.2	975.7	71.9	157.2	3941.4	5642.5	9813.1	3769.2	2132.2	5901.5	6283.3	430.0
1955/56	14818.4	975.7	71.9	157.2	3950.1	10430.8	14610.0	3769.2	2889.9	6659.2	7127.8	430.0
1956/57	17055.1	975.8	71.9	157.2	3955.8	12406.2	16591.0	3769.2	3745.6	7514.9	8073.7	430.0
1957/58	12567.9	975.7	71.9	157.2	3947.4	8316.9	12493.4	3769.2	2592.4	6361.6	6796.0	430.0
1958/59	5913.1	975.6	71.9	157.2	3932.3	1363.1	5524.5	3769.2	1079.9	4849.2	5117.0	430.0
1959/60	5556.3	975.6	71.9	157.2	3931.0	1014.0	5174.1	3769.2	878.8	4648.0	4894.8	430.0
1960/61	11540.5	975.6	71.9	157.2	3944.3	6981.5	11154.9	3769.2	2185.5	5954.8	6346.7	430.0
1961/62	20700.8	975.8	71.9	157.2	3959.1	16102.2	20290.4	3769.2	3375.1	7144.3	7673.2	430.0
1962/63	27577.3	975.8	71.9	157.2	3970.4	23011.3	27210.8	3769.2	4093.1	7862.4	8478.0	430.0
1963/64	12062.1	975.7	71.9	157.2	3947.2	7413.9	11590.3	3769.2	3139.3	6908.6	7395.5	430.0
1964/65	8513.4	975.7	71.9	157.2	3938.8	3904.9	8072.8	3769.2	1999.3	5768.5	6133.3	430.0
1965/66	5945.6	975.6	71.9	157.2	3932.4	1446.4	5608.0	3769.2	1122.5	4891.7	5163.7	430.0
1966/67	5814.2	975.6	71.9	157.2	3931.9	1268.0	5429.0	3769.2	1049.0	4818.2	5082.6	430.0
1967/68	6240.5	975.7	71.9	157.2	3933.0	1756.2	5918.3	3769.2	1464.1	5233.3	5538.9	430.0
1968/69	22116.7	975.7	71.9	157.2	3959.7	17552.8	21741.6	3769.2	3082.4	6851.6	7353.9	430.0
1969/70	12799.8	975.7	71.9	157.2	3949.0	8171.8	12350.0	3769.2	3095.1	6864.5	7349.6	430.0
1970/71	13458.9	975.7	71.9	157.2	3948.9	8817.6	12995.6	3769.2	3072.2	6841.4	7324.5	430.0
1971/72	7536.2	975.8	71.9	157.2	3937.7	3004.2	7171.0	3769.2	2334.0	6103.3	6498.6	430.0
1972/73	5990.1	975.7	71.9	157.2	3932.5	1531.7	5693.3	3769.2	1345.6	5114.8	5408.3	430.0
1973/74	7365.8	975.6	71.9	157.2	3936.2	2679.1	6844.4	3769.2	1461.5	5230.8	5540.3	430.0
1974/75	14545.6	975.7	71.9	157.2	3951.1	9991.2	14171.4	3769.2	3066.9	6836.1	7322.0	430.0
1975/76	18205.6	975.8	71.9	157.2	3956.1	13867.5	18052.6	3769.2	3322.3	7091.5	7610.6	430.0
1976/77	11443.7	975.8	71.9	157.2	3946.6	6804.1	10979.8	3769.2	3139.1	6908.4	7394.6	430.0
1977/78	30699.0	975.8	71.9	157.2	3971.5	26083.5	30284.1	3769.2	3709.9	7479.1	8060.2	430.0
1978/79	22906.9	975.8	71.9	157.2	3966.1	18277.9	22473.1	3769.2	4120.2	7889.4	8500.6	430.0
1979/80	17481.0	975.8	71.9	157.2	3958.4	12808.0	16995.5	3769.2	4120.2	7889.4	8488.1	430.0
1980/81	18404.0	975.8	71.9	157.2	3958.0	13997.4	18184.5	3769.2	4008.4	7777.6	8365.6	430.0
1981/82	8659.6	975.7	71.9	157.2	3940.3	4122.9	8292.4	3769.2	2456.8	6226.0	6636.9	430.0
1982/83	7546.9	975.7	71.9	157.2	3936.9	2909.6	7075.6	3769.2	2026.8	5796.0	6160.7	430.0
1983/84	6660.8	975.7	71.9	157.2	3934.0	2079.2	6242.3	3769.2	1627.1	5396.4	5719.0	430.0
1984/85	11847.3	975.7	71.9	157.2	3945.3	7171.8	11346.2	3769.2	2465.7	6235.0	6654.5	430.0
1985/86	12810.1	975.8	71.9	157.2	3948.2	8324.3	12501.6	3769.2	3282.4	7051.7	7554.5	430.0
1986/87	8423.2	975.7	71.9	157.2	3940.2	3858.9	8028.2	3769.2	2489.8	6259.0	6672.7	430.0
1987/88	9507.4	975.7	71.9	157.2	3940.2	4885.1	9054.3	3769.2	1935.1	5704.3	6065.5	430.0
1988/89	9116.0	975.7	71.9	157.2	3941.2	4944.0	9114.3	3769.2	2307.1	6076.4	6474.2	430.0
1989/90	6890.7	975.7	71.9	157.2	3934.9	2397.9	6561.9	3769.2	1750.5	5519.8	5855.4	430.0
1990/91	7480.4	975.6	71.9	157.2	3936.6	2940.1	7105.8	3769.2	1575.0	5344.2	5665.2	430.0
1991/92	5728.8	975.7	71.9	157.2	3931.1	1107.4	5267.6	3769.2	956.6	4725.8	4980.2	430.0
1992/93	8511.6	975.6	71.9	157.2	3939.1	3945.4	8113.6	3769.2	1803.2	5572.5	5919.6	430.0
PERIOD	9911.2	975.7	71.9	156.9	3936.2	5386.4	9551.3	3754.7	2018.1	5772.8	6342.5	428.4

Table C.8 Kafue Gorge Simulation Run 1360 Input Details

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MULTIPURPOSE RESERVOIR ANALYSIS                                  RUN 1360                    28.10.94  AT 15:33

KAFUE GORGE               1     1                                USING DATA: KAFUE GORGE RESERVOIR INPUT FILE 28/10/9


INITIAL CONDITIONS      Reservoir contents   219.0 mcm                                        Tailwater level  583.0 m

DEMANDS                                   OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP

        Water supply          mcm         6.1     5.9     6.1     6.1     5.6     6.1     5.9     6.1     5.9     6.1     6.1     5.9
        Compensation flow     mcm         0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
        Irrigation            mcm        34.6    27.4    12.0     7.4     6.8    14.8    23.5    25.2    23.7    23.7    26.9    36.5
        Firm energy           Gwh       319.9   309.6   319.9   319.9   291.5   319.9   309.6   319.9   309.6   319.9   319.9   309.6
        Peak power             Mw       900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0

RULE CURVES

        Design flood curve    mcm       240.0   240.0   345.0   550.0   785.0   785.0   475.0   350.0   240.0   240.0   240.0   240.0
        Operating curve       mcm        20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0
        Max release target    mcm      6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0

EVAPORATION                   mm        233.0   191.0   168.0   172.0   154.0   176.0   157.0   136.0   109.0   125.0   157.0   202.0

MINIMUM RELEASE LEVELS  Water supply 972.0 m       Compensation flow   0.0 m       Irrigation 972.0 m       Energy 958.3 m

RESERVOIR AND TURBINE   Water Storage   Area Seepage        Outflow  Tailwater         Net   Peak    Efficiency  Efficiency
CHARACTERISTICS         level                                            level         head   cap    peak power  aver power
                            m     mcm   sqkm mcm/mth        mcm/mth              m        m     Mw            %           %

                        972.3     0.0   20.0     0.0            0.0      577.3        360.0  853.0         89.1        90.3
                        972.5     5.0   25.0     0.0          210.1      579.1        365.8  870.0         89.4        90.5
                        973.0    20.0   35.0     0.0          420.2      580.7        367.0  888.0         89.4        90.6
                        973.5    40.0   47.0     0.0         1024.3      582.2        370.0  893.0         89.2        90.6
                        974.0    69.0   70.0     0.0         1943.7      583.7        375.0  900.0         89.1        90.7
                        974.5   111.0   98.0     0.0         3125.6      585.2        380.0  900.0         88.9        90.8
                        975.0   170.0  142.0     0.0         4465.2      586.7        385.0  900.0         88.7        90.9
                        975.5   263.0  235.0     0.0         5205.8      587.4        387.0  900.0         88.6        91.0
                        976.0   423.0  430.0     0.0            0.0        0.0        390.0  900.0         88.5        91.0
                        976.6   785.0  805.0     0.0            0.0        0.0        394.0  900.0         88.3        91.0
                        977.0  1178.0 1175.0     0.0            0.0        0.0        396.0  900.0         88.1        90.9
                        978.0  2845.0 2160.0     0.0            0.0        0.0          0.0    0.0          0.0         0.0

HEAD CONDITIONS         Turbine head loss   8.5 m                                Minimum net head on turbines 360.0 m

OPTIONS/OUTPUT          INY  ISY  ISM  IDM  IRA          IND  IPR(1) IPR(2) IPR(3) IPR(4)        IMS  IIR  IFC  IMH  IEP
                         88 1905   10    1    1            3      1      4      3      0           0    0    0    2    1

                        IOP list   1  7 11 13 14 16 17 20 21 22 25 26               IMX  IMT(1)  IMT(2)  IRS(1)  IRS(2)
                        IAS list   1  2  1  1  1  1  1  1  1  1  1  2                 1      21      22      22      25
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Table C.9 Kafue Gorge Simulation Run 1360 Annual Results

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MULTIPURPOSE RESERVOIR ANALYSIS                                     RUN 1360                    28.10.94  AT 15:33
KAFUE GORGE                       1        1                        USING DATA: KAFUE GORGE RESERVOIR INPUT FILE 28/10/9

ANNUAL SUMMARY OF SELECTED VARIABLES
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	Total inflow (mcm)	Average end of month level (m)	Total water supply release (mcm)	Total irrig release (mcm)	Total energy release (mcm)	Total spill (mcm)	Total outflow (mcm)	Total firm energy (Gwh)	Total second energy (Gwh)	Total energy (Gwh)	Total turbine flow (mcm)	Average firm power (Mw)
1905/ 6	5808.7	975.7	71.9	262.5	3933.0	1235.1	5502.5	3769.2	1067.1	4836.3	5103.5	430.0
1906/ 7	5860.0	975.5	71.9	262.5	3933.3	1256.1	5523.7	3769.2	1000.3	4769.6	5030.6	430.0
1907/ 8	7618.1	975.5	71.9	262.5	3937.7	3012.2	7284.2	3769.2	1511.9	5281.1	5597.1	430.0
1908/ 9	11717.1	975.6	71.9	262.5	3945.0	7042.7	11322.1	3769.2	1931.8	5700.2	6067.9	430.0
1909/10	5824.4	975.6	71.9	262.5	3932.2	1255.1	5521.7	3769.2	1093.6	4862.9	5111.6	430.0
1910/11	7292.2	975.5	71.9	262.5	3937.3	2695.1	6966.8	3769.2	1568.0	5337.3	5658.5	430.0
1911/12	7259.6	975.7	71.9	262.5	3935.5	2567.1	6837.0	3769.2	1581.9	5351.1	5671.2	430.0
1912/13	6389.3	975.5	71.9	262.5	3935.0	1822.3	6091.7	3769.2	1246.7	5015.9	5302.8	430.0
1913/14	6266.4	975.6	71.9	262.5	3932.9	1601.6	5870.9	3769.2	1198.7	4967.9	5247.8	430.0
1914/15	7232.2	975.5	71.9	262.5	3936.6	2657.1	6928.2	3769.2	1525.4	5294.6	5610.6	430.0
1915/16	5729.2	975.5	71.9	262.5	3932.8	1042.8	5310.0	3769.2	885.6	4654.9	4904.2	430.0
1916/17	5738.9	975.5	71.9	262.5	3932.6	1053.1	5320.1	3769.2	920.4	4689.7	4942.2	430.0
1917/18	10149.7	975.7	71.9	262.5	3942.0	5675.7	9952.1	3769.2	2040.7	5810.0	6183.5	430.0
1918/19	5803.6	975.5	71.9	262.5	3933.0	1221.4	5488.8	3769.2	1001.5	4770.7	5031.6	430.0
1919/20	7452.7	975.5	71.9	262.5	3937.4	2884.5	7156.3	3769.2	1476.1	5245.4	5557.9	430.0
1920/21	8924.1	975.7	71.9	262.5	3939.3	4309.4	8583.1	3769.2	1772.3	5541.6	5885.4	430.0
1921/22	5565.7	975.5	71.9	262.5	3932.3	887.4	5154.1	3769.2	809.1	4578.3	4819.7	430.0
1922/23	4621.5	974.6	71.9	240.4	3604.0	470.2	4386.5	3129.4	420.7	3550.1	3739.4	358.3
1923/24	5556.3	975.4	71.9	262.5	3932.7	859.5	5126.6	3769.2	783.7	4552.9	4792.2	430.0
1924/25	5911.4	974.8	71.9	243.1	3757.0	1545.5	5617.5	3129.4	1258.5	4387.9	4652.2	358.3
1925/26	14027.5	975.7	71.9	262.5	3947.7	9471.3	13753.3	3769.2	2178.0	5947.2	6343.1	430.0
1926/27	6110.9	975.6	71.9	262.5	3932.7	1422.1	5689.2	3769.2	1192.2	4961.5	5240.4	430.0
1927/28	5915.3	975.5	71.9	262.5	3933.6	1277.0	5545.1	3769.2	987.6	4756.8	5016.9	430.0
1928/29	5888.6	975.5	71.9	262.5	3933.6	1367.0	5635.0	3769.2	1128.3	4897.6	5171.4	430.0
1929/30	5565.7	975.5	71.9	262.5	3932.3	920.8	5187.6	3769.2	832.1	4601.3	4844.9	430.0
1930/31	5589.2	975.5	71.9	262.5	3932.2	947.5	5214.1	3769.2	840.1	4609.3	4853.5	430.0
1931/32	10377.1	975.6	71.9	262.5	3942.2	5874.6	10151.2	3769.2	1815.1	5584.3	5936.3	430.0
1932/33	8288.4	975.7	71.9	262.5	3938.2	3730.8	8003.4	3769.2	1824.4	5593.7	5940.7	430.0
1933/34	8868.2	975.5	71.9	262.5	3939.9	4181.3	8455.6	3769.2	1671.9	5441.1	5776.2	430.0
1934/35	7741.2	975.6	71.9	262.5	3936.9	3112.4	7383.7	3769.2	1786.8	5556.1	5897.7	430.0
1935/36	7545.2	975.6	71.9	262.5	3936.8	2912.5	7183.7	3769.2	1699.8	5469.0	5802.6	430.0
1936/37	7877.7	975.7	71.9	262.5	3936.7	3227.1	7498.2	3769.2	1679.7	5448.9	5780.2	430.0
1937/38	7893.5	975.5	71.9	262.5	3938.1	3192.6	7465.1	3769.2	1629.3	5398.4	5726.4	430.0
1938/39	9671.0	975.7	71.9	262.5	3940.9	5251.2	9526.5	3769.2	1914.2	5683.4	6043.2	430.0
1939/40	15553.8	975.7	71.9	262.5	3951.6	10922.0	15208.1	3769.2	2759.9	6529.2	6987.1	430.0
1940/41	9610.8	975.7	71.9	262.5	3942.1	5068.6	9345.1	3769.2	2424.5	6193.8	6603.9	430.0
1941/42	7443.0	975.7	71.9	262.5	3936.1	2776.0	7046.5	3769.2	1608.4	5377.6	5701.0	430.0
1942/43	9819.9	975.6	71.9	262.5	3942.1	5252.6	9529.0	3769.2	1957.9	5727.2	6092.7	430.0
1943/44	10441.3	975.7	71.9	262.5	3942.7	6013.4	10290.5	3769.2	2170.3	5939.5	6326.8	430.0
1944/45	9796.6	975.8	71.9	262.5	3941.8	5102.9	9379.1	3769.2	2518.7	6287.9	6707.0	430.0
1945/46	9303.1	975.7	71.9	262.5	3940.9	4788.0	9063.3	3769.2	2271.1	6040.3	6434.1	430.0
1946/47	7026.1	975.5	71.9	262.5	3936.3	2240.3	6511.1	3769.2	1569.4	5338.6	5658.7	430.0
1947/48	18244.7	975.8	71.9	262.5	3956.0	13644.7	17935.1	3769.2	3475.7	7244.9	7778.3	430.0
1948/49	6759.9	975.7	71.9	262.5	3934.9	2043.1	6312.5	3769.2	1676.1	5445.3	5773.8	430.0
1949/50	7835.3	975.5	71.9	262.5	3938.4	3074.4	7347.3	3769.2	1769.8	5539.1	5881.6	430.0
1950/51	6002.5	975.7	71.9	262.5	3932.7	1312.2	5579.4	3769.2	1153.3	4922.5	5197.7	430.0
1951/52	15421.3	975.6	71.9	262.5	3950.6	10715.4	15000.4	3769.2	2303.1	6072.4	6484.4	430.0
1952/53	11956.0	975.8	71.9	262.5	3946.4	7452.7	11733.6	3769.2	2751.7	6520.9	6969.4	430.0
1953/54	8410.6	975.7	71.9	262.5	3938.7	3815.5	8088.6	3769.2	2008.0	5777.2	6142.6	430.0
1954/55	10139.2	975.6	71.9	262.5	3943.1	5535.5	9811.9	3769.2	2065.5	5834.7	6210.7	430.0
1955/56	14818.4	975.7	71.9	262.5	3950.0	10313.6	14598.0	3769.2	2851.1	6620.3	7085.0	430.0
1956/57	17055.1	975.8	71.9	262.5	3955.6	12301.1	16591.0	3769.2	3705.4	7474.7	8029.2	430.0
1957/58	12567.9	975.7	71.9	262.5	3947.5	8249.8	12531.7	3769.2	2562.3	6331.5	6763.0	430.0
1958/59	5913.1	975.5	71.9	262.5	3933.3	1262.4	5530.2	3769.2	1003.3	4772.5	5033.9	430.0
1959/60	5556.3	975.5	71.9	262.5	3932.0	928.8	5195.2	3769.2	823.3	4592.6	4835.0	430.0
1960/61	11540.5	975.5	71.9	262.5	3945.4	6850.5	11130.4	3769.2	2158.7	5928.0	6318.3	430.0
1961/62	20700.0	975.8	71.9	262.5	3958.8	15997.2	20290.4	3769.2	3345.0	7114.3	7639.9	430.0
1962/63	27577.3	975.8	71.9	262.5	3970.2	22906.2	27210.8	3769.2	4082.8	7852.0	8466.4	430.0
1963/64	12042.1	975.7	71.9	262.5	3947.2	7318.3	11619.9	3769.2	3104.6	6873.8	7357.2	430.0
1964/65	8513.4	975.6	71.9	262.5	3939.0	3821.3	8094.7	3769.2	1954.1	5723.3	6083.8	430.0
1965/66	5945.6	975.5	71.9	262.5	3933.6	1340.1	5608.2	3769.2	1040.8	4810.0	5075.3	430.0
1966/67	5634.2	975.5	71.9	262.5	3932.6	1168.6	5435.6	3769.2	992.5	4761.8	5021.4	430.0
1967/68	6340.5	975.7	71.9	262.5	3933.3	1677.4	5945.1	3769.2	1402.6	5171.8	5471.7	430.0
1968/69	22116.7	975.6	71.9	262.5	3960.6	17423.2	21718.2	3769.2	3043.8	6812.2	7311.6	430.0
1969/70	12799.5	975.7	71.9	262.5	3948.9	8096.2	12379.5	3769.2	3062.6	6831.9	7313.6	430.0
1970/71	13458.9	975.7	71.9	262.5	3949.0	8690.9	12974.2	3769.2	2997.5	6766.8	7242.6	430.0
1971/72	7536.2	975.8	71.9	262.5	3937.3	2899.4	7171.0	3769.2	2267.3	6036.4	6424.7	430.0
1972/73	5990.1	975.7	71.9	262.5	3932.5	1464.7	5731.6	3769.2	1292.4	5061.6	5349.9	430.0
1973/74	7365.8	975.5	71.9	262.5	3937.4	2597.4	6869.2	3769.2	1409.7	5179.0	5484.8	430.0
1974/75	14545.6	975.7	71.9	262.5	3951.1	9867.5	14153.0	3769.2	2995.1	6764.3	7243.2	430.0
1975/76	18205.6	975.8	71.9	262.5	3955.7	13762.5	18052.6	3769.2	3292.3	7061.5	7577.3	430.0
1976/77	11442.7	975.8	71.9	262.5	3946.4	6699.1	10979.8	3769.2	3080.3	6849.5	7329.7	430.0
1977/78	30499.0	975.8	71.9	262.5	3971.3	25978.4	30284.1	3769.2	3681.9	7451.1	8029.1	430.0
1978/79	22906.9	975.8	71.9	262.5	3965.9	18172.8	22473.1	3769.2	4120.2	7889.4	8500.3	430.0
1979/80	17481.0	975.8	71.9	262.5	3958.2	12702.9	16995.5	3769.2	4120.2	7889.4	8487.8	430.0
1980/81	18404.0	975.8	71.9	262.5	3957.8	13892.3	18184.5	3769.2	3978.3	7747.5	8332.2	430.0
1981/82	8659.6	975.7	71.9	262.5	3940.4	4055.9	8330.7	3769.2	2424.7	6194.0	6601.7	430.0
1982/83	7546.9	975.7	71.9	262.5	3937.0	2812.5	7083.8	3769.2	1967.3	5736.5	6095.5	430.0
1983/84	6660.8	975.6	71.9	262.5	3934.3	1990.6	6259.3	3769.2	1567.8	5337.0	5654.2	430.0
1984/85	11847.3	975.6	71.9	262.5	3945.9	7051.5	11331.8	3769.2	2394.8	6164.1	6577.3	430.0
1985/86	12810.1	975.8	71.9	262.5	3947.9	8219.4	12501.6	3769.2	3244.9	7014.1	7512.8	430.0
1986/87	8423.2	975.7	71.9	262.5	3940.1	3783.3	8057.8	3769.2	2449.9	6219.2	6628.8	430.0
1987/88	9507.4	975.7	71.9	262.5	3940.1	4784.6	9059.2	3769.2	1880.4	5649.6	6005.4	430.0
1988/89	9116.0	975.7	71.9	262.5	3941.1	4848.8	9124.3	3769.2	2251.3	6020.5	6412.9	430.0
1989/90	6890.7	975.7	71.9	262.5	3935.2	2320.7	6590.3	3769.2	1695.5	5464.7	5795.2	430.0
1990/91	7480.4	975.5	71.9	262.5	3937.5	2836.8	7108.7	3769.2	1509.5	5278.8	5594.3	430.0
1991/92	5728.8	975.6	71.9	262.5	3931.5	1029.3	5295.1	3769.2	893.1	4662.3	4911.0	430.0
1992/93	8511.6	975.5	71.9	262.5	3939.9	1823.8	8098.2	3769.2	1722.8	5492.0	5832.2	430.0
PERIOD	9911.2	975.6	71.9	262.0	3935.4	5292.1	9561.4	3754.7	1967.4	5722.1	6087.3	428.4

Table C.10 Itezhi-tezhi Simulation Run 1450 Input Details

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MULTIPURPOSE RESERVOIR ANALYSIS                                             RUN 1450                                  28.10.94  AT 13:54

ITEZHI-TEZHI                  1       1                                     USING DATA:  ITEZHI-TEZHI RESERVOIR INPUT FILE 28/10/


INITIAL CONDITIONS          Reservoir contents  3045.0 mcm                                                          Tailwater level  976.0 m

DEMANDS                                  OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP

        Water supply        mcm      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
        Compensation flow   mcm    348.0   337.0   482.0   482.0   513.0   348.0   337.0   348.0   337.0   348.0   348.0   337.0
        Irrigation          mcm      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
        Firm energy         Gwh      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
        Peak power           Mw      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

RULE CURVES

        Design flood curve  mcm   4118.0  3827.0  3689.0  3772.0  3973.0  4424.0  5084.0  5550.0  5624.0  5550.0  5262.0  4915.0
        Operating curve     mcm    699.2   699.2   699.2   699.2   699.2   699.2   699.2   699.2   699.2   699.2   699.2   699.2
        Max release target  mcm    844.0   816.0   844.0   844.0   769.0   844.0   816.0   844.0   816.0   844.0   844.0   816.0

EVAPORATION                  mm    233.0   191.0   168.0   172.0   154.0   176.0   157.0   136.0   109.0   125.0   157.0   202.0

MINIMUM RELEASE LEVELS      Water supply   0.0 m            Compensation flow 991.0 m       Irrigation   0.0 m        Energy   0.0 m

RESERVOIR AND TURBINE       Water Storage   Area Seepage        Outflow  Tailwater          Net  Peak    Efficiency  Efficiency
CHARACTERISTICS             level                                             level         head   cap   peak power  aver power
                                 m    mcm   sqkm mcm/mth        mcm/mth              m         m    Mw            %           %

                             989.0    2.0    4.0     0.0            0.0      970.0          5.0   1.0          5.0         0.0
                            1000.0  279.0   50.0     0.0          100.0      972.0          6.0   1.5         10.0         0.0
                            1006.0  699.2   90.0     0.0          300.0      976.0          7.0   2.0         15.0         0.0
                            1010.0 1119.2  120.0     0.0          600.0      978.0          8.0   3.0         20.0         0.0
                            1013.0 1520.2  148.0     0.0          800.0      979.0          9.0   3.5         25.0         0.0
                            1016.0 2007.7  177.0     0.0         1000.0      980.0          0.0   0.0          0.0         0.0
                            1020.0 2814.2  224.0     0.0            0.0        0.0          0.0   0.0          0.0         0.0
                            1024.0 3827.2  284.0     0.0            0.0        0.0          0.0   0.0          0.0         0.0
                            1028.0 5084.2  346.0     0.0            0.0        0.0          0.0   0.0          0.0         0.0
                            1029.5 5623.7  374.0     0.0            0.0        0.0          0.0   0.0          0.0         0.0
                            1031.0 6204.2  404.0     0.0            0.0        0.0          0.0   0.0          0.0         0.0
                            1033.0 7049.2  446.0     0.0            0.0        0.0          0.0   0.0          0.0         0.0

HEAD CONDITIONS             Turbine head loss   1.0 m                                    Minimum net head on turbines   5.0 m

OPTIONS/OUTPUT              INY  ISY  ISM  IDM  IRA              IND  IPR(1) IPR(2) IPR(3) IPR(4)        IMS  IIR  IPC  IMH  IEP
                             88 1905   10    1    1                1       2      0      0      0          0    0    0    0    0

                            IOP list    1  2  3  5  6  7 12 16 17 31 36  0                        IMX  IMT(1) IMT(2) IRS(1) IRS(2)
                            IAS list    1  1  1  2  3  2  1  1  1  1  2  0                          1      12     17      1     17
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Table C.11 Itezhi-tezhi Simulation Run 1450 Annual Results

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MULTIPURPOSE RESERVOIR ANALYSIS                                              RUN 1450                       28.10.94  AT 13:54
ITEZHI-TEZHI                    1       1                                    USING DATA: ITEZHI-TEZHI RESERVOIR INPUT FILE 28/10/

ANNUAL SUMMARY OF SELECTED VARIABLES

              Total     Total     Total   Average   Maximum   Average     Total     Total     Total     Total   Average
             inflow      rain      evap    end of    change    end of      comp     spill   outflow      comp      comp
                                   loss     month        in     month      flow                          flow      flow
                                          content   content     level   release                       cutback   cutback
              (mcm)     (mcm)     (mcm)     (mcm)     (mcm)       (m)     (mcm)     (mcm)     (mcm)     (mcm)       (%)

1905/ 6      6486.0     144.9     524.0    3737.5    1651.6    1023.1    4565.0     480.1    5045.1       0.0       0.0
1906/ 7      5737.0     185.4     548.2    4197.2     939.1    1025.1    4565.0     694.2    5259.2       0.0       0.0
1907/ 8      6132.2     196.0     574.3    3976.0     451.0    1024.4    4565.0    2004.0    6569.0       0.0       0.0
1908/ 9     11626.0     173.5     585.8    4136.4     851.9    1025.3    4565.0    5100.3    9665.3       0.0       0.0
1909/10      4796.4     184.9     594.2    4207.1    1334.3    1025.1    4565.0     549.3    5114.3       0.0       0.0
1910/11      7790.4     230.0     615.0    4506.6     670.1    1026.0    4565.0    2113.2    6678.2       0.0       0.0
1911/12      6582.2     137.2     614.9    4410.0     660.0    1025.8    4565.0    2031.2    6596.2       0.0       0.0
1912/13      6412.7     186.3     618.7    4497.0     660.0    1026.1    4565.0    1111.4    5676.4       0.0       0.0
1913/14      5781.5     148.8     607.4    4144.5     848.2    1025.6    4565.0    1158.8    5723.8       0.0       0.0
1914/15      6013.6     216.6     592.7    4175.8     451.0    1025.1    4565.0    1570.4    6135.4       0.0       0.0
1915/16      4553.7     138.5     549.5    3760.6     810.4    1023.6    4565.0     128.8    4693.8       0.0       0.0
1916/17      7648.8     135.8     563.6    4149.7    1405.3    1024.5    4565.0    1017.6    5582.6       0.0       0.0
1917/18      8369.6     274.9     617.7    4427.3     660.0    1025.9    4565.0    3941.7    8506.7       0.0       0.0
1918/19      4983.2     206.6     588.5    4127.8     764.0    1024.9    4565.0     650.6    5215.6       0.0       0.0
1919/20      7882.2     217.0     580.2    4238.9    1404.0    1025.0    4565.0    1854.6    6419.6       0.0       0.0
1920/21      7777.6     186.8     618.4    4447.6     660.0    1025.9    4565.0    3224.1    7789.1       0.0       0.0
1921/22      2021.7     109.3     466.6    2843.7     265.5    1019.8    4565.0       0.0    4565.0       0.0       0.0
1922/23      7328.6      90.3     431.7    3201.9    2306.0    1019.2    3962.5       0.0    3962.5     602.5      10.4
1923/24      2343.8      90.8     490.1    3067.7     176.2    1020.8    4565.0      22.7    4587.7       0.0       0.0
1924/25      8846.5     150.0     468.4    3474.8    2272.3    1020.7    4565.0    1278.4    5843.4       0.0       0.0
1925/26     12417.9     229.6     627.3    4591.9     660.0    1026.3    4565.0    7100.4   11665.4       0.0       0.0
1926/27      5296.7     124.2     606.4    4297.5     531.9    1025.5    4565.0    1094.6    5659.6       0.0       0.0
1927/28      6131.5     163.9     591.6    4267.5     880.9    1025.2    4565.0     749.8    5314.8       0.0       0.0
1928/29      5894.1     285.8     609.9    4396.4     813.9    1025.7    4565.0     689.5    5254.5       0.0       0.0
1929/30      4592.4     234.1     592.3    4173.7     701.6    1025.0    4565.0       0.0    4565.0       0.0       0.0
1930/31      6293.8     185.3     592.1    4269.2     853.0    1025.3    4565.0     900.4    5465.4       0.0       0.0
1931/32      9469.9     263.5     625.4    4549.4     660.0    1026.3    4565.0    4243.2    8808.2       0.0       0.0
1932/33      7112.8     261.3     614.5    4398.6     660.0    1025.8    4565.0    2652.8    7217.8       0.0       0.0
1933/34      8473.8     128.9     618.6    4516.5     660.0    1026.1    4565.0    2959.5    7524.5       0.0       0.0
1934/35      6880.5     242.2     618.1    4442.4     515.3    1025.9    4565.0    2185.5    6750.5       0.0       0.0
1935/36      7645.2     188.3     619.2    4522.4    1250.7    1026.1    4565.0    2253.2    6818.2       0.0       0.0
1936/37      6958.6     154.3     616.3    4419.8     660.0    1025.8    4565.0    2401.6    6966.6       0.0       0.0
1937/38      7370.6     158.7     622.9    4540.4     660.0    1026.2    4565.0    2048.3    6613.3       0.0       0.0
1938/39      8265.9     278.7     614.9    4416.0     660.0    1025.8    4565.0    3701.6    8266.6       0.0       0.0
1939/40     14416.8     248.2     632.2    4641.7     660.0    1026.5    4565.0    8954.0   13519.0       0.0       0.0
1940/41      8450.1     242.0     630.8    4589.1     660.0    1026.4    4565.0    3639.8    8204.8       0.0       0.0
1941/42      6138.5     195.9     601.8    4231.0     660.0    1025.3    4565.0    2111.3    6676.3       0.0       0.0
1942/43      9388.3     229.8     607.1    4457.7     660.0    1025.9    4565.0    3481.7    8046.7       0.0       0.0
1943/44      9384.8     307.6     633.4    4631.6     660.0    1026.5    4565.0    4370.3    8935.3       0.0       0.0
1944/45      9314.4     165.9     636.1    4649.0     660.0    1026.5    4565.0    4279.2    8844.2       0.0       0.0
1945/46      7328.1     213.4     600.2    4203.1     660.0    1025.2    4565.0    3572.1    8137.1       0.0       0.0
1946/47      8246.6      98.3     591.9    4349.7     800.8    1025.4    4565.0    1992.2    6557.2       0.0       0.0
1947/48     16550.5     221.3     636.1    4649.0     660.0    1026.5    4565.0   11570.7   16135.7       0.0       0.0
1948/49      4863.8     127.4     579.1    3952.7     585.2    1024.3    4565.0    1542.8    6107.8       0.0       0.0
1949/50      9316.4     120.2     560.2    4128.0    1110.6    1024.8    4565.0    2615.7    7180.7       0.0       0.0
1950/51      3979.6     115.9     580.1    3981.1     637.0    1024.4    4565.0     484.5    5049.5       0.0       0.0
1951/52     15186.7     219.0     590.5    4374.4    1194.4    1025.5    4565.0    8716.1   13281.1       0.0       0.0
1952/53     10629.2     267.5     635.3    4641.8     660.0    1026.5    4565.0    5696.4   10261.4       0.0       0.0
1953/54      7464.8     185.0     621.2    4468.6     660.0    1026.0    4565.0    2876.0    7441.0       0.0       0.0
1954/55      9381.0     252.0     630.7    4616.4     660.0    1026.4    4565.0    4043.1    8608.1       0.0       0.0
1955/56     14032.0     247.1     633.5    4628.7     660.0    1026.5    4565.0    9062.4   13627.4       0.0       0.0
1956/57     15376.6     157.4     636.1    4649.0     660.0    1026.5    4565.0   10332.9   14897.9       0.0       0.0
1957/58      9599.5     328.7     598.4    4181.8     451.0    1025.1    4565.0    5885.0   10450.0       0.0       0.0
1958/59      5872.4     155.4     558.2    3948.2    1591.8    1024.1    4565.0     729.7    5294.7       0.0       0.0
1959/60      5617.7     160.0     579.2    4166.4    1215.1    1024.8    4565.0     171.2    4736.2       0.0       0.0
1960/61     11347.5     192.8     624.0    4570.8     695.2    1026.2    4565.0    5768.3   10333.4       0.0       0.0
1961/62     18929.2     198.6     636.1    4649.0     660.0    1026.5    4565.0   13926.7   18491.7       0.0       0.0
1962/63     24627.0     235.0     636.1    4649.0     660.0    1026.5    4565.0   19660.9   24225.9       0.0       0.0
1963/64     10679.8     143.4     627.8    4547.2     660.0    1026.3    4565.0    5695.1   10260.1       0.0       0.0
1964/65      7400.8     155.1     610.0    4332.8     508.6    1025.6    4565.0    2985.7    7550.7       0.0       0.0
1965/66      5848.3     170.4     598.0    4286.4     879.0    1025.4    4565.0     761.5    5326.5       0.0       0.0
1966/67      6306.7     153.3     611.9    4482.7     958.9    1025.9    4565.0     705.8    5270.8       0.0       0.0
1967/68      5549.0     164.8     605.6    4277.4     451.0    1025.4    4565.0    1305.7    5870.7       0.0       0.0
1968/69     20395.2     194.2     626.1    4604.7     660.0    1026.4    4565.0   14635.8   19200.8       0.0       0.0
1969/70     11806.1     158.2     630.7    4582.7     660.0    1026.4    4565.0    6768.6   11333.6       0.0       0.0
1970/71     12491.8     205.5     636.1    4649.0     660.0    1026.5    4565.0    7496.2   12061.2       0.0       0.0
1971/72      7503.4     218.5     635.7    4645.3     660.0    1026.5    4565.0    2521.2    7086.2       0.0       0.0
1972/73      2671.4     178.9     504.3    3184.0     385.9    1021.3    4565.0     550.4    5115.4       0.0       0.0
1973/74     10081.5      52.0     522.5    3902.6    1861.2    1023.1    4565.0    2276.7    6841.7       0.0       0.0
1974/75     13583.2     243.7     636.1    4649.0     660.0    1026.5    4565.0    8625.7   13190.7       0.0       0.0
1975/76     16776.5     292.1     636.1    4649.0     660.0    1026.5    4565.0   11867.5   16432.5       0.0       0.0
1976/77     10679.5     138.1     636.1    4649.0     660.0    1026.5    4565.0    5612.5   10177.5       0.0       0.0
1977/78     28179.6     286.1     636.1    4649.0     660.0    1026.5    4565.0   23264.6   27829.6       0.0       0.0
1978/79     20977.0     195.5     636.1    4649.0     660.0    1026.5    4565.0   15971.3   20536.3       0.0       0.0
1979/80     16387.7     232.8     636.1    4649.0     660.0    1026.5    4565.0   11419.4   15984.4       0.0       0.0
1980/81     16524.1     315.3     636.1    4649.0     660.0    1026.5    4565.0   11638.2   16203.2       0.0       0.0
1981/82      7674.7     165.5     622.6    4484.4     451.0    1026.1    4565.0    2850.3    7415.3       0.0       0.0
1982/83      7099.7     151.2     618.1    4441.7     660.0    1025.9    4565.0    2327.7    6892.7       0.0       0.0
1983/84      6309.9     152.6     614.4    4413.7     660.0    1025.8    4565.0    1411.4    5976.4       0.0       0.0
1984/85     11270.3     144.9     631.6    4639.7     660.0    1026.5    4565.0    5632.7   10197.7       0.0       0.0
1985/86     12080.9     214.8     636.0    4640.2     660.0    1026.5    4565.0    7094.7   11659.7       0.0       0.0
1986/87      7639.8     158.7     624.9    4511.9     660.0    1026.2    4565.0    2854.9    7419.9       0.0       0.0
1987/88      8964.5     140.6     631.9    4618.7     660.0    1026.5    4565.0    3662.0    8227.0       0.0       0.0
1988/89      8435.7     170.6     634.1    4627.5     660.0    1026.5    4565.0    3407.3    7972.3       0.0       0.0
1989/90      6004.3     222.4     619.4    4447.7     660.0    1025.9    4565.0    1535.9    6100.9       0.0       0.0
1990/91      7047.9     180.3     618.7    4470.1     660.0    1026.0    4565.0    1927.9    6492.9       0.0       0.0
1991/92      2782.7     153.7     508.5    3242.8     111.3    1021.6    4565.0     227.7    4792.7       0.0       0.0
1992/93     11006.7     210.8     507.6    3778.0    1703.0    1022.5    4565.0    3403.1    7968.1       0.0       0.0

PERIOD       9170.8     189.1     600.7    4321.6    2306.0    1025.4    4558.2    4179.9    8738.1       6.8       0.1
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Table C.12 Kafue Gorge Simulation Run 1370 Input Details

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MULTIPURPOSE RESERVOIR ANALYSIS                               RUN 1370                         28.10.94  AT 16:10
KAFUE GORGE                  1      1                         USING DATA: KAFUE GORGE RESERVOIR RAINFALL INPUT FIL

INITIAL CONDITIONS        Reservoir contents   219.0 mcm                                      Tailwater level  583.0 m

DEMANDS                           OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP
      Water supply       mcm      6.1     5.9     6.1     6.1     5.6     6.1     5.9     6.1     5.9     6.1     6.1     5.9
      Compensation flow  mcm      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
      Irrigation         mcm     34.6    27.4    12.0     7.4     6.8    14.8    23.5    25.2    23.7    23.7    26.9    36.5
      Firm energy        Gwh    319.9   309.6   319.9   319.9   291.5   319.9   309.6   319.9   309.6   319.9   319.9   309.6
      Peak power          Mw    900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0

RULE CURVES

      Design flood curve mcm    240.0   240.0   345.0   550.0   785.0   785.0   475.0   350.0   240.0   240.0   240.0   240.0
      Operating curve    mcm     20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0
      Max release target mcm   6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0

EVAPORATION               mm    233.0   191.0   168.0   172.0   154.0   176.0   157.0   136.0   109.0   125.0   157.0   202.0

MINIMUM RELEASE LEVELS    Water supply 972.0 m      Compensation flow   0.0 m      Irrigation 972.0 m        Energy 958.3 m

RESERVOIR AND TURBINE     Water Storage   Area Seepage        Outflow  Tailwater        Net   Peak    Efficiency  Efficiency
CHARACTERISTICS           level                                           level        head    cap    peak power  aver power
                              m    mcm    sqkm mcm/mth        mcm/mth             m       m     Mw             %           %

                          972.3    0.0    20.0     0.0            0.0     577.3       360.0  853.0          89.1        90.3
                          972.5    5.0    25.0     0.0          210.1     579.1       365.8  870.0          89.4        90.5
                          973.0   20.0    35.0     0.0          420.2     580.7       367.0  888.0          89.4        90.6
                          973.5   40.0    47.0     0.0         1024.3     582.2       370.0  893.0          89.2        90.6
                          974.0   69.0    70.0     0.0         1943.7     583.7       375.0  900.0          89.1        90.7
                          974.5  111.0    98.0     0.0         3125.6     585.2       380.0  900.0          88.9        90.8
                          975.0  170.0   142.0     0.0         4465.2     586.7       385.0  900.0          88.7        90.9
                          975.5  263.0   235.0     0.0         5205.8     587.4       387.0  900.0          88.6        91.0
                          976.0  423.0   430.0     0.0            0.0       0.0       390.0  900.0          88.5        91.0
                          976.6  785.0   805.0     0.0            0.0       0.0       394.0  900.0          88.3        91.0
                          977.0 1178.0  1175.0     0.0            0.0       0.0       396.0  900.0          88.1        90.9
                          978.0 2845.0  2160.0     0.0            0.0       0.0         0.0    0.0           0.0         0.0

HEAD CONDITIONS           Turbine head loss   8.5 m                              Minimum net head on turbines 360.0 m

OPTIONS/OUTPUT            INY  ISY  ISM  IDM  IRA        IND  IPR(1) IPR(2) IPR(3) IPR(4)         INS  IIR  IPC  IMH  IEF
                           88 1905  10    1    1           3      1      4      3      0            0    0    0    2    1

                          IOP list   1  7 11 13 14 16 17 20 21 22 25 26               INX  INT(1) INT(2) IRS(1) IRS(2)
                          IAS list   1  2  1  1  1  1  1  1  1  1  1  2                 1     21     22     22     25
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Table C.13 Kafue Gorge Simulation Run 1370 Annual Results

MULTIPURPOSE RESERVOIR ANALYSIS RUN 1370 28.10.94 AT 16:10

KAFUE GORGE 1 1 USING DATA: KAFUE GORGE RESERVOIR RAINFALL INPUT FIL

ANNUAL SUMMARY OF SELECTED VARIABLES

	Total inflow (mcm)	Average end of month level (m)	Total water supply release (mcm)	Total irrig release (mcm)	Total energy release (mcm)	Total spill (mcm)	Total outflow (mcm)	Total firm energy (Gwh)	Total second energy (Gwh)	Total energy (Gwh)	Total turbine flow (mcm)	Average firm power (Mw)
1905/ 6	5039.7	975.7	71.9	262.5	3933.2	1257.4	5524.9	3769.2	1071.0	4840.3	5108.1	430.0
1906/ 7	5860.0	975.5	71.9	262.5	3933.1	1260.6	5528.2	3769.2	1004.5	4773.7	5035.0	430.0
1907/ 8	7618.1	975.5	71.9	262.5	3937.7	3012.2	7284.3	3769.2	1511.9	5281.1	5597.1	430.0
1908/ 9	11717.1	975.6	71.9	262.5	3945.0	7042.7	11322.1	3769.2	1931.0	5700.2	6067.9	430.0
1909/10	5403.2	975.6	71.9	262.5	3930.8	835.1	5100.3	3769.2	761.6	4530.9	4765.9	430.0
1910/11	7689.1	975.5	71.9	262.5	3938.1	3091.3	7363.8	3769.2	1672.5	5441.8	5774.1	430.0
1911/12	7259.6	975.7	71.9	262.5	3935.5	2567.1	6837.0	3769.2	1581.9	5351.1	5671.2	430.0
1912/13	6389.3	975.6	71.9	262.5	3935.0	1822.3	6091.7	3769.2	1246.7	5015.9	5302.8	430.0
1913/14	6266.4	975.6	71.9	262.5	3932.9	1603.6	5870.9	3769.2	1198.7	4967.9	5247.8	430.0
1914/15	7232.2	975.5	71.9	262.5	3936.6	2657.1	6928.2	3769.2	1525.4	5294.6	5610.6	430.0
1915/16	5171.8	975.5	71.9	262.5	3931.5	506.9	4772.8	3769.2	462.4	4231.6	4438.4	430.0
1916/17	6359.1	975.5	71.9	262.5	3934.7	1683.4	5952.5	3769.2	1286.3	5055.5	5346.1	430.0
1917/18	10149.7	975.7	71.9	262.5	3942.0	5675.3	9951.7	3769.2	2040.4	5809.6	6103.1	430.0
1918/19	5803.6	975.5	71.9	262.5	3933.0	1221.4	5488.8	3769.2	1001.5	4770.7	5031.6	430.0
1919/20	7452.7	975.5	71.9	262.5	3937.4	2884.5	7156.3	3769.2	1476.1	5245.4	5557.9	430.0
1920/21	8924.1	975.7	71.9	262.5	3939.3	4309.4	8583.1	3769.2	1772.3	5541.6	5885.4	430.0
1921/22	5008.4	975.4	71.9	262.5	3931.1	354.4	4619.8	3769.2	323.3	4092.5	4285.4	430.0
1922/23	4471.5	974.8	71.9	262.5	3937.2	13.2	4284.7	3769.2	12.0	3781.2	3950.3	430.0
1923/24	5011.6	975.4	71.9	262.5	3931.3	334.2	4599.8	3769.2	304.8	4074.0	4265.4	430.0
1924/25	6716.7	975.6	71.9	262.5	3935.5	2196.4	6466.3	3769.2	1321.8	5091.0	5386.3	430.0
1925/26	14027.5	975.7	71.9	262.5	3947.7	9471.3	13753.3	3769.2	2178.0	5947.2	6343.1	430.0
1926/27	6110.9	975.6	71.9	262.5	3932.7	1422.1	5689.2	3769.2	1192.2	4961.5	5240.4	430.0
1927/28	5915.3	975.5	71.9	262.5	3933.6	1277.0	5545.1	3769.2	987.6	4756.8	5016.9	430.0
1928/29	5915.5	975.5	71.9	262.5	3933.5	1394.2	5662.0	3769.2	1138.9	4908.2	5103.0	430.0
1929/30	5008.4	975.4	71.9	262.5	3931.2	379.4	4644.9	3769.2	346.0	4115.2	4310.5	430.0
1930/31	6121.6	975.5	71.9	262.5	3932.8	1462.4	5729.6	3769.2	1069.3	4838.5	5106.9	430.0
1931/32	10377.1	975.6	71.9	262.5	3942.1	5881.8	10158.3	3769.2	1821.7	5590.9	5943.4	430.0
1932/33	8288.4	975.7	71.9	262.5	3938.2	3730.8	8003.4	3769.2	1824.4	5593.7	5940.7	430.0
1933/34	8868.2	975.5	71.9	262.5	3939.9	4181.3	8455.6	3769.2	1671.9	5441.1	5776.2	430.0
1934/35	7741.2	975.6	71.9	262.5	3936.9	3112.4	7383.7	3769.2	1786.8	5556.1	5897.7	430.0
1935/36	7545.2	975.6	71.9	262.5	3936.8	2912.5	7183.7	3769.2	1699.8	5469.0	5802.6	430.0
1936/37	7877.7	975.7	71.9	262.5	3936.7	3227.1	7498.2	3769.2	1679.7	5448.9	5780.2	430.0
1937/38	7893.5	975.5	71.9	262.5	3938.1	3192.6	7465.1	3769.2	1629.2	5398.4	5726.4	430.0
1938/39	9671.0	975.7	71.9	262.5	3940.9	5251.2	9526.5	3769.2	1914.2	5683.4	6043.2	430.0
1939/40	15553.8	975.7	71.9	262.5	3951.6	10922.0	15208.1	3769.2	2759.9	6529.2	6907.1	430.0
1940/41	9610.8	975.7	71.9	262.5	3942.1	5068.6	9345.1	3769.2	2424.5	6193.8	6603.9	430.0
1941/42	7443.0	975.7	71.9	262.5	3936.1	2776.0	7046.5	3769.2	1608.4	5377.6	5701.0	430.0
1942/43	9819.9	975.6	71.9	262.5	3942.1	5252.6	9529.0	3769.2	1957.9	5727.2	6092.7	430.0
1943/44	10441.3	975.7	71.9	262.5	3942.7	6013.4	10290.5	3769.2	2170.3	5939.5	6326.8	430.0
1944/45	9796.6	975.8	71.9	262.5	3941.8	5102.9	9379.1	3769.2	2518.7	6287.9	6707.0	430.0
1945/46	9303.3	975.7	71.9	262.5	3940.9	4788.0	9063.3	3769.2	2271.1	6040.3	6434.1	430.0
1946/47	7026.1	975.5	71.9	262.5	3936.3	2240.3	6511.1	3769.2	1569.4	5338.6	5658.7	430.0
1947/48	18244.7	975.8	71.9	262.5	3956.0	13644.7	17935.1	3769.2	3475.7	7244.9	7778.3	430.0
1948/49	6759.9	975.7	71.9	262.5	3934.9	2043.1	6312.5	3769.2	1676.1	5445.3	5773.8	430.0
1949/50	7850.2	975.5	71.9	262.5	3938.5	3094.2	7367.1	3769.2	1769.8	5539.0	5881.6	430.0
1950/51	5451.5	975.6	71.9	262.5	3931.5	785.4	5051.3	3769.2	716.1	4485.4	4716.9	430.0
1951/52	15804.4	975.6	71.9	262.5	3951.4	11103.3	15389.1	3769.2	2385.0	6154.2	6575.3	430.0
1952/53	11956.0	975.8	71.9	262.5	3946.4	7452.7	11733.6	3769.2	2751.7	6520.9	6969.4	430.0
1953/54	8410.6	975.7	71.9	262.5	3938.7	3815.5	8088.6	3769.2	2008.0	5777.2	6142.6	430.0
1954/55	10139.3	975.6	71.9	262.5	3942.1	5535.5	9811.9	3769.2	2065.5	5834.7	6210.7	430.0
1955/56	14818.4	975.7	71.9	262.5	3950.0	10313.6	14598.0	3769.2	2851.1	6620.3	7085.0	430.0
1956/57	17055.1	975.8	71.9	262.5	3955.6	12301.1	16591.0	3769.2	3705.4	7474.7	8029.2	430.0
1957/58	12567.9	975.7	71.9	262.5	3947.5	8249.8	12531.7	3769.2	2562.3	6331.5	6763.0	430.0
1958/59	5913.1	975.5	71.9	262.5	3933.3	1262.4	5530.2	3769.2	1003.3	4772.5	5033.9	430.0
1959/60	5234.9	975.5	71.9	262.5	3931.5	609.8	4875.7	3769.2	556.1	4325.3	4541.3	430.0
1960/61	11898.2	975.6	71.9	262.5	3945.5	7219.5	11499.4	3769.2	2158.7	5928.0	6318.7	430.0
1961/62	20700.0	975.8	71.9	262.5	3958.8	15997.2	20290.4	3769.2	3345.0	7114.3	7639.9	430.0
1962/63	27577.3	975.8	71.9	262.5	3970.2	22906.2	27210.8	3769.2	4082.8	7852.0	8466.4	430.0
1963/64	12042.1	975.7	71.9	262.5	3947.2	7338.3	11619.9	3769.2	3104.6	6873.8	7357.2	430.0
1964/65	8513.4	975.6	71.9	262.5	3939.0	3821.3	8094.7	3769.2	1954.1	5723.3	6083.8	430.0
1965/66	5945.6	975.5	71.9	262.5	3933.6	1340.1	5608.2	3769.2	1040.8	4810.0	5075.3	430.0
1966/67	5875.7	975.5	71.9	262.5	3933.1	1222.3	5489.8	3769.2	1099.0	4868.2	5138.7	430.0
1967/68	6340.5	975.7	71.9	262.5	3933.3	1677.4	5945.1	3769.2	1402.6	5171.8	5471.7	430.0
1968/69	22116.7	975.6	71.9	262.5	3960.6	17423.2	21718.2	3769.2	3043.0	6812.2	7311.6	430.0
1969/70	12799.5	975.7	71.9	262.5	3948.9	8096.2	12379.5	3769.2	3062.6	6831.9	7313.6	430.0
1970/71	13458.9	975.7	71.9	262.5	3949.0	8690.9	12974.2	3769.2	2997.5	6766.8	7242.6	430.0
1971/72	7536.2	975.8	71.9	262.5	3937.3	2899.4	7171.0	3769.2	2267.2	6036.4	6424.7	430.0
1972/73	5432.8	975.7	71.9	262.5	3930.6	908.9	5174.0	3769.2	828.9	4598.2	4839.6	430.0
1973/74	7997.0	975.5	71.9	262.5	3938.5	3210.9	7483.9	3769.2	1571.6	5340.9	5663.8	430.0
1974/75	14565.6	975.7	71.9	262.5	3951.1	9867.5	14153.0	3769.2	2995.1	6764.3	7243.2	430.0
1975/76	18205.6	975.8	71.9	262.5	3955.7	13762.5	18052.6	3769.2	3292.2	7061.5	7577.3	430.0
1976/77	11442.7	975.8	71.9	262.5	3946.4	6699.1	10979.8	3769.2	3080.3	6849.5	7329.7	430.0
1977/78	30499.0	975.8	71.9	262.5	3971.3	25978.4	30284.1	3769.2	3681.9	7451.1	8029.1	430.0
1978/79	22906.9	975.8	71.9	262.5	3965.9	18172.8	22473.1	3769.2	4120.2	7889.4	8500.3	430.0
1979/80	17481.0	975.8	71.9	262.5	3958.2	12702.9	16995.5	3769.2	4120.2	7889.4	8487.8	430.0
1980/81	18404.0	975.8	71.9	262.5	3957.8	13892.3	18184.5	3769.2	3978.3	7747.5	8332.2	430.0
1981/82	8659.6	975.7	71.9	262.5	3940.4	4055.9	8330.7	3769.2	2424.7	6194.0	6601.7	430.0
1982/83	7546.9	975.7	71.9	262.5	3937.0	2812.5	7083.8	3769.2	1967.3	5736.5	6095.5	430.0
1983/84	6660.8	975.6	71.9	262.5	3934.3	1990.6	6259.3	3769.2	1567.8	5337.0	5654.2	430.0
1984/85	11847.3	975.6	71.9	262.5	3945.9	7051.5	11331.8	3769.2	2394.8	6164.1	6577.3	430.0
1985/86	12810.1	975.8	71.9	262.5	3947.9	8219.4	12501.6	3769.2	3244.9	7014.1	7512.8	430.0
1986/87	8423.2	975.7	71.9	262.5	3940.1	3783.3	8057.8	3769.2	2449.9	6219.2	6628.8	430.0
1987/88	9507.4	975.7	71.9	262.5	3940.1	4784.6	9059.2	3769.2	1880.4	5649.6	6005.4	430.0
1988/89	9116.0	975.7	71.9	262.5	3941.1	4848.8	9124.3	3769.2	2251.3	6020.5	6412.9	430.0
1989/90	6783.6	975.7	71.9	262.5	3934.8	2192.2	6461.4	3769.2	1583.4	5352.6	5671.7	430.0
1990/91	7565.5	975.6	71.9	262.5	3937.4	2936.7	7208.6	3769.2	1584.2	5353.4	5676.2	430.0
1991/92	5171.4	975.6	71.9	262.5	3929.8	484.1	4748.3	3769.2	441.6	4210.8	4413.9	430.0
1992/93	9043.9	975.5	71.9	262.5	3941.1	4355.1	8630.6	3769.2	1842.9	5612.2	5987.3	430.0
PERIOD	9906.4	975.6	71.9	262.5	3941.2	5283.4	9559.0	3769.2	1933.3	5702.5	6065.0	430.0

Table C.14 Itezhi-tezhi Simulation Run 1460 Input Details

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MULTIPURPOSE RESERVOIR ANALYSIS                                         RUN 1460                                28.10.94  AT 14:17

ITEZHI-TEZHI                     1       1                              USING DATA: ITEZHI-TEZHI RESERVOIR INPUT FILE 28/10/


INITIAL CONDITIONS          Reservoir contents  3045.0 mcm                                             Tailwater level  976.0 m

DEMANDS                               OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP

        Water supply       mcm        0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
        Compensation flow  mcm      348.0   337.0   482.0   482.0   513.0   348.0   337.0   348.0   337.0   348.0   348.0   337.0
        Irrigation         mcm        0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
        Firm energy        Gwh        0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
        Peak power          Mw        0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

RULE CURVES

        Design flood curve mcm     4424.0  4118.0  3973.0  4060.0  4271.0  4746.0  5439.0  5930.0  6008.0  5930.0  5624.0  5262.0
        Operating curve    mcm      699.2   699.2   699.2   699.2   699.2   699.2   699.2   699.2   699.2   699.2   699.2   699.2
        Max release target mcm      844.0   816.0   844.0   844.0   769.0   844.0   816.0   844.0   816.0   844.0   844.0   816.0

EVAPORATION                mm       233.0   191.0   168.0   172.0   154.0   176.0   157.0   136.0   109.0   125.0   157.0   202.0

MINIMUM RELEASE LEVELS      Water supply   0.0 m       Compensation flow 991.0 m       Irrigation   0.0 m        Energy   0.0 m

RESERVOIR AND TURBINE       Water Storage    Area Seepage        Outflow  Tailwater          Net   Peak     Efficiency  Efficiency
CHARACTERISTICS             level                                                 level       head    cap    peak power  aver power
                               m      mcm    sqkm mcm/mth        mcm/mth               m         m     Mw            %           %

                             989.0     2.0     4.0     0.0            0.0      970.0            5.0    1.0          5.0         0.0
                            1000.0   279.0    50.0     0.0          100.0      972.0            6.0    1.5         10.0         0.0
                            1006.0   699.2    90.0     0.0          300.0      976.0            7.0    2.0         15.0         0.0
                            1010.0  1119.2   120.0     0.0          600.0      978.0            8.0    3.0         20.0         0.0
                            1013.0  1520.2   148.0     0.0          800.0      979.0            9.0    3.5         25.0         0.0
                            1016.0  2007.7   177.0     0.0         1000.0      980.0            0.0    0.0          0.0         0.0
                            1020.0  2814.2   224.0     0.0            0.0        0.0            0.0    0.0          0.0         0.0
                            1024.0  3827.2   284.0     0.0            0.0        0.0            0.0    0.0          0.0         0.0
                            1028.0  5084.2   346.0     0.0            0.0        0.0            0.0    0.0          0.0         0.0
                            1029.5  5623.7   374.0     0.0            0.0        0.0            0.0    0.0          0.0         0.0
                            1031.0  6204.2   404.0     0.0            0.0        0.0            0.0    0.0          0.0         0.0
                            1033.0  7049.2   446.0     0.0            0.0        0.0            0.0    0.0          0.0         0.0

HEAD CONDITIONS             Turbine head loss   1.0 m                                  Minimum net head on turbines   5.0 m

OPTIONS/OUTPUT              INY  ISY  ISM  IDM  IRA         IND  IPR(1) IPR(2) IPR(3) IPR(4)          IWS  IIR  IPC  IMH  IEP
                             88 1905   10    1    1           1       2      0      0      0            0    0    0    0    0

                            IOP list   1  2  3  5  6  7 12 16 17 31 36  0                   IMX  INT(1) INT(2) IRS(1) IRS(2)
                            IAS list   1  1  1  2  3  2  1  1  1  1  2  0                     1      12     17      1     17
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Table C.15 Itezhi-tezhi Simulation Run 1460 Annual Results

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MULTIPURPOSE RESERVOIR ANALYSIS                                RUN 1460                              28.10.94  AT 14:17
ITEZHI-TEZHI                       1       1                   USING DATA: ITEZHI-TEZHI RESERVOIR INPUT FILE 28/10/

ANNUAL SUMMARY OF SELECTED VARIABLES

              Total      Total      Total    Average    Maximum    Average      Total      Total      Total      Total    Average
             inflow       rain       evap     end of     change     end of       comp      spill    outflow       comp       comp
                                     loss      month         in      month       flow                             flow       flow
                                             content    content      level    release                          cutback    cutback
              (mcm)      (mcm)      (mcm)      (mcm)      (mcm)        (m)      (mcm)      (mcm)      (mcm)      (mcm)        (%)

1905/ 6      6486.0      145.6      540.0     3932.6     1898.5     1023.7     4565.0      122.6     4687.6        0.0        0.0
1906/ 7      5737.0      199.0      623.4     4531.6      924.2     1026.2     4565.0      687.2     5252.2        0.0        0.0
1907/ 8      6132.2      207.7      606.6     4289.6      475.0     1025.5     4565.0     2003.3     6568.3        0.0        0.0
1908/ 9     11626.0      186.1      621.6     4670.9      852.2     1026.4     4565.0     5038.0     9603.0        0.0        0.0
1909/10      4796.4      197.0      626.3     4518.1     1351.6     1026.1     4565.0      568.1     5133.1        0.0        0.0
1910/11      7790.4      244.3      649.6     4845.6      693.0     1027.1     4565.0     2054.1     6619.1        0.0        0.0
1911/12      6502.2      145.8      647.8     4737.5      693.0     1026.8     4565.0     2011.8     6576.8        0.0        0.0
1912/13      6412.7      198.1      653.5     4817.6      693.0     1027.1     4565.0     1088.1     5653.1        0.0        0.0
1913/14      5781.5      258.1      640.7     4670.9      871.4     1026.6     4565.0     1135.0     5700.0        0.0        0.0
1914/15      6013.6      210.0      625.1     4496.1      475.0     1026.1     4565.0     1585.2     6150.2        0.0        0.0
1915/16      4553.7      147.3      580.0     4054.2      796.5     1024.6     4565.0      132.1     4697.1        0.0        0.0
1916/17      7648.0      145.8      597.9     4473.6     1451.5     1025.6     4565.0      928.8     5493.8        0.0        0.0
1917/18      8369.6      289.8      649.8     4751.6      693.0     1026.9     4565.0     3929.4     8494.4        0.0        0.0
1918/19      4903.2      220.0      621.1     4444.8      768.0     1025.9     4565.0      665.4     5230.4        0.0        0.0
1919/20      7882.2      233.7      616.1     4578.4     1419.8     1026.1     4565.0     1775.0     6340.0        0.0        0.0
1920/21      7777.6      196.6      651.0     4773.5      693.0     1026.9     4565.0     3228.7     7793.7        0.0        0.0
1921/22      2021.7      117.3      503.6     3171.1      262.2     1021.2     4565.0        0.0     4565.0        0.0        0.0
1922/23      7328.6       94.9      443.6     3265.5     2306.0     1019.6     4251.7        0.0     4251.7      313.3        5.4
1923/24      2343.0       90.8      494.3     3105.3      175.9     1021.0     4565.0        0.0     4565.0        0.0        0.0
1924/25      8846.5      153.3      486.1     3678.4     2272.1     1021.4     4565.0      930.8     5495.8        0.0        0.0
1925/26     12417.9      243.4      661.6     4929.0      693.0     1027.4     4565.0     7102.0    11667.0        0.0        0.0
1926/27      5296.7      131.5      637.6     4607.8      529.5     1026.5     4565.0     1109.6     5674.6        0.0        0.0
1927/28      6131.5      175.0      623.8     4578.0      879.3     1026.2     4565.0      728.7     5293.7        0.0        0.0
1928/29      5594.1      303.7      641.3     4725.4      828.0     1026.8     4565.0      640.0     5205.0        0.0        0.0
1929/30      4592.4      142.4      624.6     4488.1      700.6     1026.1     4565.0       15.1     4580.1        0.0        0.0
1930/31      6293.8      197.6      625.6     4595.2      851.8     1026.3     4565.0      840.8     5405.8        0.0        0.0
1931/32      9469.9      277.1      657.6     4872.9      693.0     1027.2     4565.0     4224.9     8789.9        0.0        0.0
1932/33      7112.0      276.2      646.9     4725.3      693.0     1026.8     4565.0     2635.1     7200.1        0.0        0.0
1933/34      8473.0      137.0      653.2     4854.4      693.0     1027.2     4565.0     2933.3     7498.3        0.0        0.0
1934/35      6080.5      255.2      649.0     4749.4      512.9     1026.9     4565.0     2201.5     6766.5        0.0        0.0
1935/36      7645.2      200.0      653.1     4855.5     1282.1     1027.1     4565.0     2192.1     6757.1        0.0        0.0
1936/37      6958.6      163.0      648.8     4744.6      693.0     1026.9     4565.0     2382.7     6947.7        0.0        0.0
1937/38      7370.6      168.5      656.4     4871.1      693.0     1027.2     4565.0     2024.6     6589.6        0.0        0.0
1938/39      8365.9      295.0      647.9     4743.9      693.0     1026.9     4565.0     3684.8     8249.8        0.0        0.0
1939/40     14416.8      261.4      665.9     4979.7      693.0     1027.5     4565.0     8928.7    13493.7        0.0        0.0
1940/41      8450.1      255.0      663.9     4924.5      693.0     1027.4     4565.0     3598.1     8163.1        0.0        0.0
1941/42      6138.5      206.2      632.4     4540.1      663.8     1026.3     4565.0     2145.4     6710.4        0.0        0.0
1942/43      9388.3      242.9      641.3     4789.7      693.0     1026.9     4565.0     3423.6     7988.6        0.0        0.0
1943/44      9384.8      324.1      666.8     4965.4      693.0     1027.5     4565.0     4358.5     8923.5        0.0        0.0
1944/45      9314.4      174.5      669.1     4982.1      693.0     1027.5     4565.0     4254.8     8819.8        0.0        0.0
1945/46      7328.1      224.6      631.9     4526.8      693.0     1026.2     4565.0     3556.3     8121.3        0.0        0.0
1946/47      8246.6      105.7      629.3     4699.7      792.5     1026.5     4565.0     1957.5     6522.5        0.0        0.0
1947/48     16550.5      232.8      669.1     4982.1      693.0     1027.5     4565.0    11549.2    16114.2        0.0        0.0
1948/49      4863.8      133.9      610.0     4257.2      625.2     1025.3     4565.0     1557.9     6122.9        0.0        0.0
1949/50      9316.4      130.3      596.3     4464.4     1132.1     1025.5     4565.0     2550.4     7115.4        0.0        0.0
1950/51      3979.6      122.9      610.6     4275.9      639.8     1025.4     4565.0      522.9     5087.9        0.0        0.0
1951/52     15186.7      233.9      624.8     4704.2     1201.6     1026.5     4565.0     8634.7    13199.7        0.0        0.0
1952/53     10629.2      281.7      668.5     4975.6      693.0     1027.5     4565.0     5677.4    10242.4        0.0        0.0
1953/54      7464.8      194.9      653.2     4792.7      693.0     1027.0     4565.0     2858.9     7423.9        0.0        0.0
1954/55      9381.0      265.6      664.0     4951.6      693.0     1027.5     4565.0     4000.3     8565.3        0.0        0.0
1955/56     14032.0      260.5      667.2     4964.4      693.0     1027.5     4565.0     9060.3    13625.3        0.0        0.0
1956/57     15376.6      165.7      669.1     4982.1      693.0     1027.5     4565.0    10308.2    14873.2        0.0        0.0
1957/58      9599.5      346.3      628.8     4488.0      475.0     1026.1     4565.0     5910.8    10475.8        0.0        0.0
1958/59      5872.4      167.3      592.6     4275.9     1610.7     1025.2     4565.0      673.3     5238.3        0.0        0.0
1959/60      5617.7      173.2      615.5     4509.2     1212.4     1026.0     4565.0      148.4     4713.4        0.0        0.0
1960/61     11247.5      205.3      659.5     4918.6      693.0     1027.3     4565.0     5740.4    10305.4        0.0        0.0
1961/62     18929.2      208.9      669.1     4982.1      693.0     1027.5     4565.0    13904.1    18469.1        0.0        0.0
1962/63     24637.0      247.3      669.1     4982.1      693.0     1027.5     4565.0    19640.2    24205.2        0.0        0.0
1963/64     10679.8      150.9      659.8     4870.8      693.0     1027.2     4565.0     5675.7    10240.7        0.0        0.0
1964/65      7400.8      163.5      640.4     4639.7      506.2     1026.6     4565.0     2997.1     7562.1        0.0        0.0
1965/66      5848.3      181.6      631.5     4614.0      897.8     1026.4     4565.0      705.2     5270.2        0.0        0.0
1966/67      6306.7      164.3      650.4     4833.6      945.6     1027.0     4565.0      675.7     5240.7        0.0        0.0
1967/68      5549.0      173.8      636.3     4584.5      475.0     1026.4     4565.0     1322.6     5887.6        0.0        0.0
1968/69     20395.2      204.9      659.6     4939.0      693.0     1027.4     4565.0    14574.4    19139.4        0.0        0.0
1969/70     11806.1      166.5      662.9     4906.7      693.0     1027.3     4565.0     6744.7    11309.7        0.0        0.0
1970/71     12491.8      216.2      669.1     4982.1      693.0     1027.5     4565.0     7473.9    12038.9        0.0        0.0
1971/72      7503.4      230.2      668.8     4978.9      693.0     1027.5     4565.0     2499.8     7064.8        0.0        0.0
1972/73      2671.4      190.5      536.8     3472.1      284.8     1022.5     4565.0      600.4     5165.4        0.0        0.0
1973/74     10081.5       57.0      555.8     4218.7     1891.7     1024.3     4565.0     2182.6     6747.6        0.0        0.0
1974/75     13583.2      256.6      669.1     4982.1      693.0     1027.5     4565.0     8600.5    13165.5        0.0        0.0
1975/76     16776.5      307.2      669.1     4982.1      693.0     1027.5     4565.0    11849.6    16414.6        0.0        0.0
1976/77     10679.5      141.1      669.1     4982.1      693.0     1027.5     4565.0     5586.5    10151.5        0.0        0.0
1977/78     28179.6      301.0      669.1     4982.1      693.0     1027.5     4565.0    23246.5    27811.5        0.0        0.0
1978/79     20977.0      205.8      669.1     4982.1      693.0     1027.5     4565.0    15948.7    20513.7        0.0        0.0
1979/80     16387.7      244.9      669.1     4982.1      693.0     1027.5     4565.0    11398.6    15963.6        0.0        0.0
1980/81     16524.1      331.8      669.1     4982.1      693.0     1027.5     4565.0    11621.8    16186.8        0.0        0.0
1981/82      7676.7      174.2      653.2     4790.6      475.0     1027.0     4565.0     2867.4     7432.4        0.0        0.0
1982/83      7099.7      159.1      649.8     4765.3      693.0     1026.9     4565.0     2269.7     6834.7        0.0        0.0
1983/84      6309.9      160.5      646.2     4737.2      693.0     1026.9     4565.0     1387.5     5952.5        0.0        0.0
1984/85     11270.3      152.6      665.0     4975.5      693.0     1027.5     4565.0     5602.2    10167.2        0.0        0.0
1985/86     12080.9      226.0      669.1     4981.9      693.0     1027.5     4565.0     7072.9    11637.9        0.0        0.0
1986/87      7639.8      167.0      656.8     4835.4      693.0     1027.1     4565.0     2836.2     7401.2        0.0        0.0
1987/88      8964.5      148.3      665.1     4952.7      693.0     1027.5     4565.0     3631.5     8196.5        0.0        0.0
1988/89      8435.7      179.9      667.2     4960.3      693.0     1027.5     4565.0     3383.5     7948.5        0.0        0.0
1989/90      6004.3      234.2      651.5     4771.9      693.0     1027.0     4565.0     1520.6     6085.6        0.0        0.0
1990/91      7047.9      190.3      651.3     4804.9      693.0     1027.0     4565.0     1905.3     6470.3        0.0        0.0
1991/92      2782.7      162.8      540.8     3527.9      108.7     1022.7     4565.0      274.4     4839.4        0.0        0.0
1992/93     11006.7      230.9      542.3     4101.2     1750.8     1023.8     4565.0     3313.7     7878.7        0.0        0.0

PERIOD       9170.8      200.1      632.8     4638.6     2306.0     1026.4     4561.5     4151.5     8712.9        3.6        0.1
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Table C.16 Kafue Gorge Simulation Run 1380 Input Details

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MULTIPURPOSE RESERVOIR ANALYSIS                              RUN 1380                        28.10.94  AT 16:49

KAFUE GORGE                  1       1                       USING DATA: KAFUE GORGE RESERVOIR INPUT FILE 28/10/9


INITIAL CONDITIONS      Reservoir contents   219.0 mcm                                      Tailwater level  583.0 m

DEMANDS                              OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP

        Water supply        mcm      6.1     5.9     6.1     6.1     5.6     6.1     5.9     6.1     5.9     6.1     6.1     5.9
        Compensation flow   mcm      0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
        Irrigation          mcm     34.6    27.4    12.0     7.4     6.8    14.8    23.5    25.2    23.7    23.7    26.9    36.5
        Firm energy         Gwh    319.9   309.6   319.9   319.9   291.5   319.9   309.6   319.9   309.6   319.9   319.9   309.6
        Peak power           Mw    900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0   900.0

RULE CURVES

        Design flood curve  mcm    350.0   350.0   550.0   785.0  1178.0  1178.0   709.0   523.0   350.0   350.0   350.0   350.0
        Operating curve     mcm     20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0    20.0
        Max release target  mcm   6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0  6000.0


EVAPORATION                 mm     233.0   191.0   168.0   172.0   154.0   176.0   157.0   136.0   109.0   125.0   157.0   202.0

MINIMUM RELEASE LEVELS  Water supply 972.0 m       Compensation flow   0.0 m      Irrigation 972.0 m       Energy 958.3 m

RESERVOIR AND TURBINE   Water Storage   Area Seepage        Outflow  Tailwater        Net   Peak     Efficiency  Efficiency
CHARACTERISTICS         level                                            level        head    cap     peak power  aver power
                            m     mcm   sqkm mcm/mth        mcm/mth              m      m     Mw              %           %

                        972.3     0.0   20.0     0.0            0.0      577.3       360.0  853.0           89.1        90.3
                        972.5     5.0   25.0     0.0          210.1      579.1       365.8  870.0           89.4        90.5
                        973.0    20.0   35.0     0.0          420.2      580.7       367.0  888.0           89.4        90.6
                        973.5    40.0   47.0     0.0         1024.3      582.2       370.0  893.0           89.2        90.6
                        974.0    69.0   70.0     0.0         1943.7      583.7       375.0  900.0           89.1        90.7
                        974.5   111.0   98.0     0.0         3125.6      585.2       380.0  900.0           88.9        90.8
                        975.0   170.0  142.0     0.0         4465.2      586.7       385.0  900.0           88.7        90.9
                        975.5   263.0  235.0     0.0         5205.8      587.4       387.0  900.0           88.6        91.0
                        976.0   423.0  430.0     0.0            0.0        0.0       390.0  900.0           88.5        91.0
                        976.6   785.0  805.0     0.0            0.0        0.0       394.0  900.0           88.3        91.0
                        977.0  1178.0 1175.0     0.0            0.0        0.0       396.0  900.0           88.1        90.9
                        978.0  2845.0 2160.0     0.0            0.0        0.0         0.0    0.0            0.0         0.0

HEAD CONDITIONS         Turbine head loss   8.5 m                                Minimum net head on turbines 360.0 m

OPTIONS/OUTPUT          INY  ISY  ISM  IDM  IRA          IND  IPR(1) IPR(2) IPR(3) IPR(4)         INS  IIR  IFC  IMH  IEP
                         88 1905   10    1    1            3      1      4      3      0            0    0    0    2    1

                        IOP list    1  7 11 13 14 16 17 20 21 22 25 26                IMX  IMT(1) IMT(2) IRS(1) IRS(2)
                        IAS list    1  2  1  1  1  1  1  1  1  1  1  2                  1      21     22     22     25
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Table C.17 Kafue Gorge Simulation Run 1380 Annual Results

MULTIPURPOSE RESERVOIR ANALYSIS RUN 1380 28.10.94 AT 16:49

KAFUE GORGE 1 1 USING DATA: KAFUE GORGE RESERVOIR INPUT FILE 28/10/9

ANNUAL SUMMARY OF SELECTED VARIABLES

	Total inflow (mcm)	Average end of month level (m)	Total water supply release (mcm)	Total irrig release (mcm)	Total energy release (mcm)	Total spill (mcm)	Total outflow (mcm)	Total firm energy (Gwh)	Total second energy (Gwh)	Total energy (Gwh)	Total turbine flow (mcm)	Average firm power (Mw)
1905/ 6	5385.5	976.0	71.9	262.5	3927.0	595.2	4856.6	3769.2	543.1	4312.3	4522.2	430.0
1906/ 7	5848.4	975.8	71.9	262.5	3928.6	1137.0	5400.1	3769.2	949.7	4719.0	4969.9	430.0
1907/ 8	7603.5	975.9	71.9	262.5	3932.6	2829.3	7096.3	3769.2	1376.2	5145.4	5442.3	430.0
1908/ 9	11616.9	975.9	71.9	262.5	3939.5	6751.0	11024.9	3769.2	1725.9	5495.1	5836.2	430.0
1909/10	5415.8	976.0	71.9	262.5	3925.7	722.0	4982.1	3769.2	658.8	4428.0	4647.7	430.0
1910/11	7585.4	975.9	71.9	262.5	3932.7	2825.3	7092.4	3769.2	1376.2	5145.4	5443.1	430.0
1911/12	7225.9	976.1	71.9	262.5	3929.6	2331.1	6595.2	3769.2	1276.2	5045.5	5329.6	430.0
1912/13	6354.4	975.8	71.9	262.5	3929.9	1647.8	5912.2	3769.2	1042.6	4811.8	5073.5	430.0
1913/14	6208.9	976.0	71.9	262.5	3927.8	1375.1	5637.4	3769.2	991.8	4761.0	5015.4	430.0
1914/15	7254.0	975.9	71.9	262.5	3931.4	2523.5	6789.3	3769.2	1376.2	5145.4	5440.9	430.0
1915/16	5168.4	975.8	71.9	262.5	3927.0	369.1	4630.5	3769.2	336.8	4106.0	4296.1	430.0
1916/17	6231.7	975.8	71.9	262.5	3930.3	1419.8	5684.5	3769.2	1161.3	4930.5	5204.1	430.0
1917/18	10104.5	976.1	71.9	262.5	3936.6	5522.0	9793.0	3769.2	1918.4	5687.6	6042.7	430.0
1918/19	5812.6	975.9	71.9	262.5	3928.3	1109.9	5372.6	3769.2	943.8	4713.1	4963.1	430.0
1919/20	7356.6	975.9	71.9	262.5	3932.6	2668.1	6935.2	3769.2	1376.2	5145.4	5443.0	430.0
1920/21	8602.9	976.1	71.9	262.5	3933.3	4094.3	8362.0	3769.2	1528.1	5297.3	5610.5	430.0
1921/22	5008.4	975.7	71.9	262.5	3926.9	234.8	4496.1	3769.2	214.3	3983.5	4161.7	430.0
1922/23	4729.0	975.6	71.9	262.5	3927.4	114.0	4375.8	3769.2	104.0	3873.2	4041.4	430.0
1923/24	4998.9	975.7	71.9	262.5	3927.3	202.9	4464.7	3769.2	185.2	3954.4	4130.3	430.0
1924/25	6248.3	975.9	71.9	262.5	3930.0	1595.2	5859.6	3769.2	1289.1	5058.4	5343.8	430.0
1925/26	13966.3	976.0	71.9	262.5	3942.4	9256.4	13533.2	3769.2	1898.0	5667.3	6029.6	430.0
1926/27	6115.1	976.0	71.9	262.5	3927.2	1249.5	5511.1	3769.2	1058.5	4827.7	5087.7	430.0
1927/28	5889.6	975.8	71.9	262.5	3929.0	1117.7	5381.2	3769.2	920.8	4690.1	4938.6	430.0
1928/29	5849.7	975.9	71.9	262.5	3929.0	1205.8	5469.2	3769.2	1091.5	4860.7	5125.8	430.0
1929/30	5016.8	975.8	71.9	262.5	3926.8	264.0	4525.2	3769.2	240.9	4010.1	4190.8	430.0
1930/31	6042.4	975.8	71.9	262.5	3929.0	1246.9	5510.4	3769.2	977.4	4746.6	5000.7	430.0
1931/32	10320.2	976.0	71.9	262.5	3937.1	5697.1	9968.6	3769.2	1633.6	5402.8	5731.0	430.0
1932/33	8230.1	976.0	71.9	262.5	3932.9	3574.4	7841.7	3769.2	1630.8	5400.1	5722.2	430.0
1933/34	8841.2	975.8	71.9	262.5	3935.5	3956.6	8226.5	3769.2	1612.2	5381.4	5704.9	430.0
1934/35	7729.7	976.0	71.9	262.5	3931.3	2938.0	7203.7	3769.2	1543.7	5312.9	5624.7	430.0
1935/36	7442.5	976.0	71.9	262.5	3931.7	2627.0	6893.1	3769.2	1415.2	5184.5	5484.9	430.0
1936/37	7829.0	976.1	71.9	262.5	3931.0	2982.4	7247.8	3769.2	1517.1	5286.4	5595.2	430.0
1937/38	7848.3	975.9	71.9	262.5	3932.6	2956.3	7223.3	3769.2	1439.4	5208.6	5511.7	430.0
1938/39	9626.7	976.0	71.9	262.5	3935.8	5109.7	9379.9	3769.2	1659.4	5428.6	5757.8	430.0
1939/40	15480.4	976.0	71.9	262.5	3946.0	10667.7	14948.1	3769.2	2629.3	6398.6	6836.3	430.0
1940/41	9537.2	976.1	71.9	262.5	3936.9	4892.1	9163.3	3769.2	2185.1	5954.3	6334.7	430.0
1941/42	7435.1	976.0	71.9	262.5	3930.3	2587.4	6852.2	3769.2	1435.6	5204.8	5504.8	430.0
1942/43	9736.6	975.9	71.9	262.5	3936.6	5023.0	9294.1	3769.2	1648.1	5417.3	5746.4	430.0
1943/44	10366.7	976.1	71.9	262.5	3937.2	5847.2	10118.8	3769.2	2065.3	5834.6	6205.0	430.0
1944/45	9719.0	976.2	71.9	262.5	3935.8	4794.6	9064.8	3769.2	2153.8	5923.1	6299.6	430.0
1945/46	9256.1	976.1	71.9	262.5	3935.2	4629.1	8898.7	3769.2	2165.2	5934.4	6311.0	430.0
1946/47	6958.7	975.8	71.9	262.5	3931.8	1973.1	6239.4	3769.2	1459.5	5228.8	5532.7	430.0
1947/48	18171.1	976.2	71.9	262.5	3950.5	13400.7	17685.6	3769.2	3351.1	7120.3	7633.9	430.0
1948/49	6757.4	976.1	71.9	262.5	3929.6	1851.6	6115.5	3769.2	1470.9	5240.1	5542.7	430.0
1949/50	7745.5	975.8	71.9	262.5	3934.0	2796.5	7064.9	3769.2	1718.5	5487.8	5819.9	430.0
1950/51	5481.9	976.0	71.9	262.5	3926.2	644.3	4904.9	3769.2	587.8	4357.0	4570.5	430.0
1951/52	15678.4	976.0	71.9	262.5	3945.9	10753.1	15033.4	3769.2	2251.8	6021.0	6422.0	430.0
1952/53	11884.7	976.2	71.9	262.5	3941.1	7279.4	11554.9	3769.2	2603.9	6373.1	6800.2	430.0
1953/54	8361.2	976.1	71.9	262.5	3933.1	3591.0	7858.5	3769.2	1734.5	5503.7	5836.0	430.0
1954/55	10053.7	976.0	71.9	262.5	3936.7	5314.3	9585.4	3769.2	1934.0	5703.2	6059.8	430.0
1955/56	14749.1	976.1	71.9	262.5	3944.5	10101.9	14380.9	3769.2	2715.5	6484.7	6928.9	430.0
1956/57	16977.8	976.2	71.9	262.5	3950.0	11977.0	16261.4	3769.2	3556.8	7326.1	7858.4	430.0
1957/58	12576.6	976.1	71.9	262.5	3942.6	8244.7	12521.7	3769.2	2525.4	6294.6	6716.1	430.0
1958/59	5838.7	975.8	71.9	262.5	3928.8	1058.2	5321.4	3769.2	905.7	4674.9	4921.8	430.0
1959/60	5203.5	975.8	71.9	262.5	3926.9	437.7	4699.0	3769.2	399.4	4168.6	4364.6	430.0
1960/61	11850.2	975.9	71.9	262.5	3940.8	6966.7	11241.9	3769.2	2107.4	5876.6	6256.1	430.0
1961/62	20624.7	976.2	71.9	262.5	3953.3	15708.8	19996.5	3769.2	3251.2	7020.4	7529.2	430.0
1962/63	27504.3	976.2	71.9	262.5	3965.1	22641.0	26940.5	3769.2	4094.3	7863.5	8471.0	430.0
1963/64	11990.6	976.1	71.9	262.5	3941.6	7073.7	11349.8	3769.2	2983.0	6752.2	7216.3	430.0
1964/65	8497.6	976.0	71.9	262.5	3933.2	3608.7	7876.3	3769.2	1713.3	5482.6	5813.0	430.0
1965/66	5871.3	975.8	71.9	262.5	3929.1	1158.1	5421.6	3769.2	957.7	4727.0	4979.2	430.0
1966/67	5813.4	975.8	71.9	262.5	3929.1	1009.1	5272.6	3769.2	915.5	4684.7	4933.0	430.0
1967/68	6344.7	976.0	71.9	262.5	3927.7	1501.4	5763.5	3769.2	1132.9	4902.1	5170.0	430.0
1968/69	22008.1	976.0	71.9	262.5	3955.4	17109.5	21399.3	3769.2	2884.2	6653.4	7130.1	430.0
1969/70	12748.0	976.1	71.9	262.5	3943.3	7835.8	12113.5	3769.2	3013.6	6782.8	7252.3	430.0
1970/71	13369.0	976.1	71.9	262.5	3943.3	8363.9	12641.6	3769.2	2851.4	6620.7	7074.8	430.0
1971/72	7461.9	976.2	71.9	262.5	3931.1	2658.7	6924.2	3769.2	1925.9	5695.2	6043.1	430.0
1972/73	5475.5	976.1	71.9	262.5	3926.0	828.9	5089.2	3769.2	756.3	4525.5	4754.8	430.0
1973/74	7867.3	975.8	71.9	262.5	3933.5	2874.8	7142.6	3769.2	1236.9	5006.2	5291.1	430.0
1974/75	14459.1	976.1	71.9	262.5	3945.4	9595.1	13874.9	3769.2	2846.4	6615.6	7072.4	430.0
1975/76	18135.8	976.2	71.9	262.5	3950.3	13598.0	17882.7	3769.2	3197.3	6966.5	7465.5	430.0
1976/77	11364.0	976.2	71.9	262.5	3940.4	6374.1	10648.9	3769.2	2795.0	6564.3	7009.1	430.0
1977/78	30428.2	976.2	71.9	262.5	3966.0	25793.3	30093.7	3769.2	3615.8	7385.0	7948.9	430.0
1978/79	22831.0	976.2	71.9	262.5	3960.7	17875.5	22170.6	3769.2	4120.2	7889.4	8492.4	430.0
1979/80	17407.4	976.2	71.9	262.5	3952.8	12376.4	16663.6	3769.2	4120.2	7889.4	8479.8	430.0
1980/81	18335.8	976.2	71.9	262.5	3952.6	13701.5	17988.4	3769.2	3891.2	7660.4	8220.9	430.0
1981/82	8657.9	976.1	71.9	262.5	3935.0	3895.6	8165.0	3769.2	2202.9	5972.1	6351.9	430.0
1982/83	7463.1	976.0	71.9	262.5	3930.9	2525.4	6790.6	3769.2	1634.6	5403.9	5723.3	430.0
1983/84	6597.5	976.0	71.9	262.5	3929.0	1724.1	5987.6	3769.2	1229.8	4999.0	5277.7	430.0
1984/85	11768.4	976.0	71.9	262.5	3939.9	6716.1	10990.4	3769.2	2223.2	5992.4	6381.4	430.0
1985/86	12735.8	976.2	71.9	262.5	3942.4	7987.2	12264.0	3769.2	2993.9	6763.1	7230.1	430.0
1986/87	8371.9	976.1	71.9	262.5	3934.0	3551.4	7819.8	3769.2	2175.7	5945.0	6320.6	430.0
1987/88	9417.8	976.0	71.9	262.5	3934.5	4493.8	8762.6	3769.2	1725.9	5495.1	5829.2	430.0
1988/89	9048.8	976.1	71.9	262.5	3935.5	4757.9	9027.8	3769.2	2088.1	5857.3	6227.0	430.0
1989/90	6735.4	976.1	71.9	262.5	3928.9	2001.5	6264.8	3769.2	1300.5	5069.7	5355.0	430.0
1990/91	7514.7	975.9	71.9	262.5	3931.8	2710.2	6976.4	3769.2	1439.5	5208.8	5510.9	430.0
1991/92	5202.6	975.9	71.9	262.5	3925.6	369.3	4629.3	3769.2	337.0	4106.2	4294.9	430.0
1992/93	8909.4	975.9	71.9	262.5	3936.0	4024.4	8294.8	3769.2	1631.4	5400.6	5727.4	430.0
PERIOD	9847.4	976.0	71.9	262.5	3935.9	5062.8	9333.1	3769.2	1771.6	5540.8	5881.2	430.0