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INVESTIGATION OF SEEPAGE LOSS FROM THE LUBENGELE TAILINGS DAM

KONKOLA COPPER MINE, CHILILABOMBWE, ZAMBIA

R.S. TYMMS, BSc(Eng) DIE FICE FIWEM FEIZ

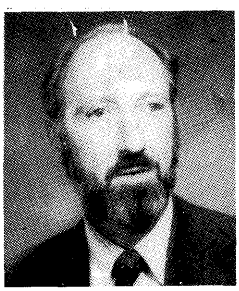
Partner, ZMCK CONSULTING ENGINEERS

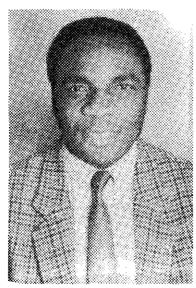
&

S. MULENGA BSc MSc PhD DIC MIMM FGs MIWA MEIZ

Superintendent, Hydrogeology.

KONKOLA DIVISION, ZAMBIA CONSOLIDATED COPPER MINES





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ABSTRACT

The paper describes a study carried out during September and October 1992 to quantity the inflows and outflows to and from the Lubengele Tailings Dam, in order to assess the possibility of water loss through the floor of the dam, and to determine the magnitude of such loss if found to exist. It was suspected by the mine management that any such loss would constitute a contributory source of the water being pumped from the mine workings.

A desk study was made of 20 years' records of data obtained from the mine management and the Government Department of Meteorology, for tailings inflow, water draw-offs, dam water level, evaporation and evapo-transpiration, and rainfall. For each year an excess of inflow over outflow was found to have existed, indicating that significant water loss through the dam floor was occurring.

A month-long field investigation was also conducted during the study period, taking advantage of the seasonally dry, hot weather to study the behaviour of the dam in the absence of rainfall. Daily field measurements of inflows and outflows were made, leading to calculation of daily losses through the dam floor.

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INTRODUCTION

The Lubengele Tailings Dam is situated some 3km. to the north of Chililabombwe; more particularly it lies within 2km of Shaft 3 of the Konkola Mine, from where mining of the north orebody is proceeding in a northerly direction towards the dam. (See MAP 1).

The dam is situated on the upper reaches of the Lubengele River and was constructed in 1964. It is fed also by other small rivers and tributaries of the Lubengele that converge in the dam area. The total catchment area is 79 square kilometres. A known fault (the Lubengele Fault) exists beneath the dam on an east-west axis, and other fault zones in the vicinity are believed to exist.

Because of these factors, the Konkola Division of Zambia Consolidated Copper Mines (Z.C.C.M.) decided that an investigation of the water balance in the dam should be made in order to examine the possibility of water loss through the floor of the dam, and to quantify such loss if found to exist. It was suspected that water leaking from dam the might be reaching the mine workings and contributing to the large quantity of water having to be pumped from the mine.

The author's firm was appointed to undertake the study, and commenced work during September 1992. Fieldwork and the gathering of data took place during September and October, followed by analysis of data and results during November and December. A report was presented to Konkola Division in January 1993.

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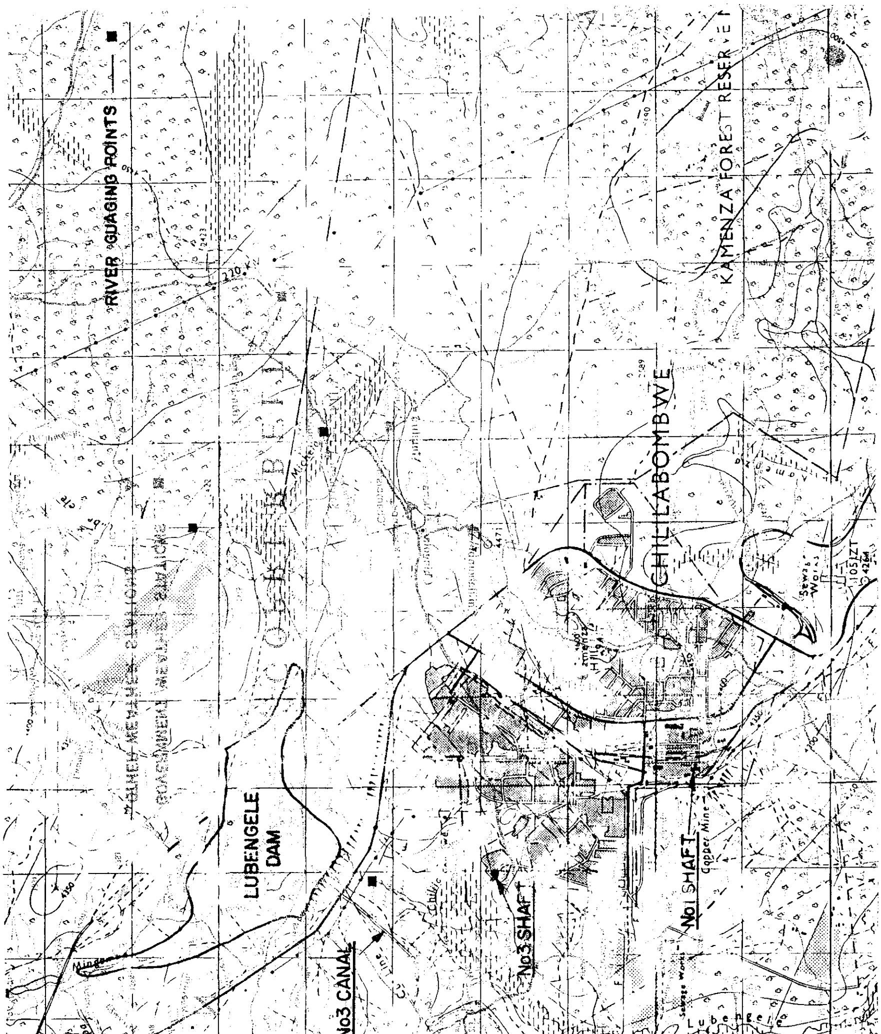

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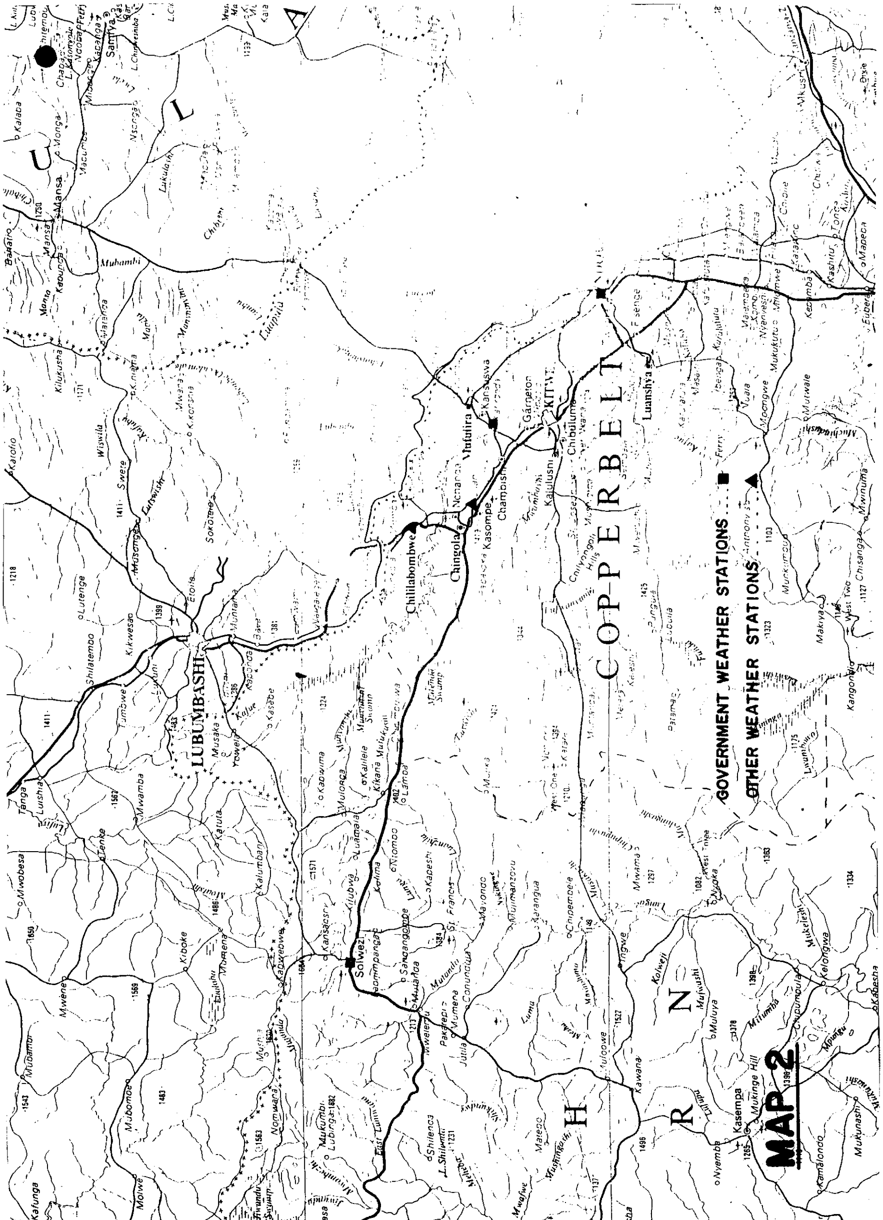

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STUDIES UNDERTAKEN

The basic approach to the investigation was to examine the long-term hydrological and other relevant records that were available. These covered the following factors :-

Rainfall

Evaporation

Evaportranspiration

Tailings inflow

Water draw-offs: a) pumping for domestic use.
b) decanting to waste.

Records were available generally from the Government meteorological service and from the mine management for sufficiently long periods, and the calculations made covered the 20-year period 1972 to 1992.

In addition to the long-term desk study, a short-term study for one month was also undertaken, involving field measurements of river flows and evaporation, in order to assess the water balance on a daily basis during a period when rainfall was absent, and there was no decanting of water from the dam, the decanting valve having been closed on 1 September. This investigation covered the period 14 September to 16 October 1992.

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In both studies the aggregate inflows and outflows to the dam were determined and excess values of inflow over outflow were calculated. The excess is the unaccounted loss from the dam, and represents leakage through the dam floor into the strata below. In the long-term study the annual loss was determined for each year of the 20-year period; for the short-term study, average daily values for inflow and outflow were calculated and the average daily loss determined.

LONG-TERM STUDY

A. INFLOWS to the DAM

For the long-term study the following inflows to the dam were quantified :-

1. Catchment run-off.
2. Direct precipitation
3. Tailings inflow

Source data for items 1 & 2, comprised the following :-

a) Monthly rainfall figures supplied by Z.C.C.M. from rain gauges sited at Shaft 1 (years 1953 to 1992) and Shaft 3 (1977 to 1991).

b) Climatological Summaries 1950 to 1980, supplied by the Government Department of Meteorology for the three nearest weather stations, at Solwezi, (150km. west of the dam), Kafironda (45km South-east of the dam) and Ndola (110km. South-east of the dam). (see MAP 2).

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c) Monthly potential evapotranspiration figures supplied by the Government Department of Meteorology based upon climatological records 1950 to 1980 at their Ndola and Solwezi weather stations.

The Shaft 3 rain-gauge is situated some 2km. from the dam and its records are thus the best available for any study of the Lubengele Dam. However, records at this station have only been kept for 13 years, as compared with the Shaft 1 rain-gauge, located some 4.5km. from the dam, for which 39 years' records are available. Comparison of the records at the two stations for the common 13-year period 1977 to 1990 indicates that the rainfall at Shaft 3 has been consistently less than that at Shaft 1, the annual average varying from 83% to 90%, except for a single result at 98%, with a mean value of 87.5%.

The mean percentage was applied therefore to the pre-1977 records from Shaft 1, to give a reasonable assessment of rainfall at Shaft 3 for that period, thereby extending the range of data relevant to the dam area.

In order to assess the potential evapotranspiration (PET) at the Lubengele catchment, the mean annual values of PET and free water evaporation at the Ndola and Solwezi weather stations were first examined. It was noted that PET was in each case equal to 72% of the free water evaporation.

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Having assessed the annual evaporation at Lubengele to be 1800 mm. (as noted later in the Paper) the annual PET at Lubengele was assumed to be 72% also, i.e. 1300 mm. The monthly variation was assumed to be similar to that of the nearer station (Ndola) and a set of monthly PET values was prepared on this basis.

The following table list the mean monthly precipitation records and the potential evapotranspiration values assessed for the Lubengele catchment. The rains in the Copperbelt region occur normally from October to April, but exceptionally rainfall has been recorded during some years before and after these months. The Department of Meterorology has adopted therefore a hydrological year running from July to June.

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PRECIPITATION

MONTH - YEAR	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	YEARLY TOTAL
1972/73	3	51	103	149	144	163	150	22	-	785
1973/74	-	10	155	211	254	126	136	37	103	1032
1974/75	-	1	99	390	281	127	399	68	-	1364
1975/76	-	-	51	351	333	184	326	167	6	1419
1976/77	30	31	201	180	289	266	236	25	-	1257
1977/78	27	23	163	381	173	133	364	40	-	1304
1978/79	-	66	256	273	106	74	183	35	-	994
1979/80	-	42	120	321	190	162	68	170	-	1072
1980/81	11	76	87	240	219	172	207	31	-	1044
1981/82	1	14	124	171	281	292	124	106	16	1128
1982/83	-	56	261	262	237	230	71	139	1	1256
1983/84	-	37	86	354	299	252	143	7	-	1179
1984/85	-	12	185	328	154	174	119	126	10	1108
1985/86	-	11	225	359	304	228	274	119	-	1519
1986/87	-	102	151	164	265	278	123	14	-	1098
1987/88	3	7	99	169	389	350	397	20	-	1435
1988/89	-	19	153	148	307	243	234	42	-	1144
1989/90	-	19	105	310	124	151	88	67	34	897
1990/91	-	1	19	179	301	127	185	53	8	872
1991/92	-	34	94	202	299	101	181	10	-	921

EVAPOTRANSPIRATION

MONTH	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	YEARLY TOTAL
	93	123	154	162	114	108	97	84	98	90	95	82	1300

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Run-off values were calculated for each month of each year and aggregated to give yearly figures. Direct up-take by the dam surface was calculated annually. Total run-off figures so determined are as follows, with precipitation and net land up-take figures also given.

YEAR	PRECIPITATION (mm)	NET LAND UPTAKE (mm)	RUN - OFF MEGALITRES
1972/73	785	219	19600
1973/74	1032	389	33700
1974/75	1364	809	67900
1975/76	1419	884	74000
1976/77	1257	670	56600
1977/78	1304	712	60100
1978/79	991	401	34600
1979/80	1072	469	40200
1980/81	1011	451	38700
1981/82	1128	507	43300
1982/83	1256	636	53900
1983/84	1179	662	55700
1984/85	1108	495	42300
1985/86	1519	918	76900
1986/87	1098	481	41200
1987/88	1435	919	76700
1988/89	1144	583	49400
1989/90	897	296	26000
1990/91	872	404	34600
1991/92	921	396	34100
MEAN	1141	565	48000

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Data on tailings inflow to the dam was available from the mine management in the form of daily records of tailings pumped from the concentrator plant. This was summarised volumetrically for each year of the long-term study period, giving the following results:-

TAILINGS INFLOW

YEAR	ANNUAL VOLUME OF TAILINGS IN MEGALITRES
1972/73	5413
1973/74	5187
1974/75	6351
1975/76	5571
1976/77	5011
1977/78	5121
1978/79	5420
1979/80	5627
1980/81	5309
1981/82	5300
1982/83	5928
1983/84	5088
1984/85	4751
1985/86	4812
1986/87	4535
1987/88	4265
1988/89	3741
1989/90	3512
1990/91	4149
1991/92	4568

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B. OUTFLOWS from the DAM

Outflows from the dam comprise the following :-

1. Water drawn for domestic use at Konkola Township.
2. Water drawn off to waste via the decanting tower.
3. Evaporation
4. Seepage through the embankment.

Continuous records of items 1 & 2 are not maintained. The domestic water is pumped from the Mingomba River at the point where it joins the dam, by means of two electricity-driven submersible pumps running for 24 hours per day. Measurement of the discharge from the rising main made during October 1992 showed the output to be 2520 Lit./minute., equivalent to 3.63 Megalitres/day = 1325 Megalitres/annum.

The discharge from the decanting tower is piped under the dam embankment and the adjoining road into a lined canal ("No.3 Canal") discharging to the Lubengele River catchment some 1.5km downstream of the dam. At the time of the study a measurement of the flow in the canal had been made by the mine management using the area-velocity method, giving a discharge of 232 Lit/sec. It was understood that normally the tower discharged continuously throughout the year, so for the purposes of calculation the given discharge figure was used, equivalent to 7320 Megalitres/annum.

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Published information on evaporation was available for the three Government weather stations previously referred to, and also, for the period 1966 to 1970 only, for a station in the Luano Forest Reserve located some 25km. south-east of the dam. These stations recorded the following mean annual evaporation rates:-

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Station	Distance from Lubengele Dam	Period of Records	Mean Annual Evaporation
Solwezi	150km	30 years (1950 to 1980)	1 664mm
Kafironda	45km	30 years (1950 to 1980)	2 072mm
Ndola	110km	30 years (1950 to 1980)	2 046mm
Luano Forest	25km	5 years (1966 to 1970)	1 762mm

These stations all lie at considerable distances from the dam; they also lie almost on a straight line so that Thiessen polygons cannot be applied. It was decided therefore to instal an evaporation pan adjacent to the rain gauge at Shaft 3. This would yield useful records in the long term, and for the short period of the study would give information which could be compared with that from the other stations. The pan is the U.S. Weather Bureau Type A pan, and was built and installed by the mine workshop. Daily readings from the pan taken from 21 September to 16 October 1992 indicated free water evaporation of 167mm. in 25 days, equivalent to a monthly (30-days) rate of 200mm/month. Figures for the period mid-September to mid-October abstracted from the long-term records of the four stations previously referred to are as follows:-

Solwezi :	181mm
Kafironda :	255mm
Ndola :	252mm
Luano Forest :	195mm
Shaft 3 :	200mm

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The figures show that the evaporation at Shaft 3 is numerically close to the at the Luano Forest Reserve, being only 2.5% higher. Allowing that the annual average values at the two sites are similarly close, an annual value for open-water evaporation of 1800mm. was used throughout the calculations of evaporation from the Lubengele Dam.

A further factor that had to be considered in determining the evaporation quantities was the variation in the shape and area of the dam water surface. Three survey plans of the dam, made by the mine management, were available, and a further survey was made by the study team during September 1992. The water surface areas were measured on the survey plans with the following results:-

Date	Surface Area
March 1977	2.96 sq.km.
June 1989	2.96 sq.km.
February 1991	3.29sq.km.
September 1992	2.84 sq.km.

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The fourth visible outflow from the dam is the seepage through the earth embankment. A large marsh area exists below the embankment, which drains into the original downstream course of the Lubengele River. To assess this loss a channel was cleaned out at a suitable point as near to the dam as possible, and the rate of flow measured using a propellor-type current meter and measurement of the cross-sectional dimensions of the channel. Measurements were taken daily mid-September to mid-October from which a mean rate of flow of 11.4 Lit./sec. was determined. This is equivalent to a loss of 0.985 Megalitres/day = 360 Megalitres/annum. Since this loss is principally a function of the depth of water in the dam it would only vary significantly if large changes in the dam water level occurred. Records kept by the mine management indicate that the variation in depth was not great over the long-term study period. Since also the seepage is a relatively small item in the calculations, a constant rate of embankment seepage throughout the period was assumed.

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C. CHANGES IN DAM STORAGE

In addition to the inflows and outflows, a further factor affecting the calculation of loss through the floor of the dam is that of changes in the volume of water stored in the dam. The mine management has been measuring the water levels since the dam was first constructed; annual records were available for the period 1964 to 1979, and bi-annual records thereafter. The changes in level are illustrated in Figure 2. Volumetric changes were calculated using these level changes and the surface areas previously quoted.

D. WATER BALANCE

The calculations of annual losses for the 20-year period 1972 to 1992 are presented in the following table. These show the following results :-

Mean Annual Loss : 38 G.Lit/an. = 103 M.Lit./day

Maximum Annual Loss:66 G.Lit/an. = 181 M.Lit./day

Minimum Annual Loss: 8 G.Lit./an = 23 M.Lit./day

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UNACCOUNTED WATER LOSS

	ANNUAL INFLOW			ANNUAL OUTFLOW			(7)	(8)	UNACCOUNTED WATER LOSS	
YEAR	(1) RUN-OFF	(2) TAILINGS	(3) TOTAL (1) + (2)	(4) DRAW-OF & SEEPAGE	(5) EVAP'ION	(6) TOTAL (4) + (5)	ANNUAL NET INFLOW (3)-(6)	ANNUAL CHANGE IN DAM STORAGE	(9) ANNUAL (7)-(8)	(10) DAILY
	G. Lit	G. Lit	G. Lit	G. Lit	G. Lit	G. Lit	G. Lit	G. Lit	G. Lit	M. Lit
1972/73	19.6	5.41	25.01	9.01	5.33	14.34	10.67	2.22	8.45	23.16
1973/74	33.7	5.19	38.89	9.01	5.33	14.34	24.55	7.61	16.94	46.40
1974/75	67.9	6.35	74.25	9.01	5.33	14.34	59.91	1.27	58.64	160.66
1975/76	74.0	5.57	79.57	9.01	5.33	14.34	65.23	1.51	63.72	174.58
1976/77	56.6	5.01	61.61	9.01	5.33	14.34	47.27	0.36	46.91	128.52
1977/78	60.1	5.12	65.22	9.01	5.33	14.34	50.88	-0.73	51.61	141.40
1978/79	34.6	5.42	40.02	9.01	5.33	14.34	25.68	3.41	22.27	61.01
1979/80	40.2	5.63	45.83	9.01	5.33	14.34	31.49	-0.60	32.09	87.91
1980/81	38.7	5.31	44.01	9.01	5.33	14.34	29.67	-0.60	30.27	82.93
1981/82	43.3	5.30	48.60	9.01	5.33	14.34	34.26	1.23	33.03	90.49
1982/83	53.9	5.93	59.83	9.01	5.33	14.34	45.49	1.23	44.26	121.25
1983/84	55.7	5.09	60.79	9.01	5.33	14.34	46.45	-1.76	48.21	132.08
1984/85	42.3	4.75	47.05	9.01	5.33	14.34	32.71	-1.76	34.47	94.44
1985/86	76.9	4.81	81.71	9.01	5.33	14.34	67.37	3.03	64.34	176.28
1986/87	41.2	4.53	45.73	9.01	5.33	14.34	31.39	3.03	28.36	77.71
1887/88	76.7	4.27	80.97	9.01	5.33	14.34	66.63	0.45	66.18	181.32
1988/89	49.4	3.74	53.14	9.01	5.33	14.34	38.80	0.45	38.36	105.09
1989/90	26.0	3.51	29.51	9.01	5.33	14.34	15.17	0.60	14.57	39.92
1990/91	34.5	4.15	38.65	9.01	5.63	14.64	24.01	0.60	23.41	64.13
1991/92	34.0	4.57	38.57	9.01	5.53	14.54	24.03	-0.74	24.77	67.86
MEAN	48.0	4.98	52.95	9.01	5.36	14.37	38.68	1.04	37.64	102.86

NOTES :-

Draw Offs & Seepage :

Decant Tower	:	7.32 G. Lit./annum
Ming'omba Pumping Station	:	1.33 G. Lit./annum
Embarkment Seepage	:	0.36 G. Lit./annum
Total	:	9.01 G. Lit./annum

Evaporation : 1800 mm/annum over measured water surface.

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SHORT-TERM STUDY

A. INFLOWS TO THE DAM

For the short-term study, which was carried out during September and October 1992 when rainfall was absent, the inflows comprised :-

1. Tailings inflow
2. River inflows.

Records of the daily pumping of tailings were available up to 30 September 1992. From these the average daily input from 14 September to 30 September was calculated to be 11.65 M.Lit./day.

River inflows were measured in the field, using a propellor-type current meter and measurement of the cross-sectional dimensions of the stream. Flows were only measured in the Mingomba, Lubengele and Michelo Rivers, the Kasapa and Kaviri Rivers being dry. At the start of this work it was apparent that certain difficulties existed in achieving meaningful results. In its lower reaches, the Lubengele River runs through a dambo, or marsh area, so that a channel suitable for measurement could only be found some 2km. upstream from its point of entry to the dam. A similar situation existed with the Michelo River. True inputs to the inputs to the dam therefore were likely to be greater than those measured. The second problem was the seasonally small size of the streams which necessitated great care in the positioning and use of the current meter to obtain velocity readings.

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Readings were taken daily from 14 September to 16 October 1992, but since the tailings flows were known only up to 30 September the average river flows were calculated for the period 14 to 30 September, with the following results:-

Lubengele River :	40.5 Lit/sec.	
Michelo River :	5.2 Lit/sec.	
Mingomba River :	8.1 Lit/sec.	
Total Inflow:	53.8 Lit/sec.	= 4.65 M.Lit/day

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B. OUTFLOWS from the DAM

Of the four outflow components previously described, only the domestic water draw-off and the embankment seepage rates remained unchanged for the purpose of the short-term assessment of water balance. Draw-off via the decanting tower had been stopped on 1 September. The evaporation rate varies significantly throughout the year, the highest values occurring during the hot dry weather of September/October. The actual rate at this time had to be used therefore in place of the long-term average. Information yielded by the new evaporation pan, namely 167mm. in 25 days (as previously stated), converts to an average loss from the dam surface of 18.93 M.Lit./day for the period of the short-term study.

C. CHANGES IN DAM STORAGE

The dam water level was also monitored daily from 16 September to 16 October 1992, and showed a fall of 95mm in 30 days. This converts to an average daily reduction in stored water of 8.99 M.Lit./day.

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D. WATER BALANCE

The calculation of daily unaccounted loss is as follows (average daily rates in Megalitres per Day):-

Inflows :	Catchment Run-Off :	4.65	
	Tailings :	11.65	16.30
Outflows :	Mingomba Pump Station:	3.63	
	Embankment Seepage:	0.99	
	Evaporation:	18.93	23.55
Net Outflow:			7.25
Reduction in Stored Water			8.99
Unaccounted Water Loss, per day:			1.74M.Lit/day

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CONCLUSIONS

It can seen that the two studies yielded very different results :-

Long-term Study (20 years) :-

Mean Daily Loss : 103 M.Lit./day.

Short-term Study (1 month, dry season, no decanting):-

Mean Daily Loss : 1.74 M.Lit./day.

In trying to account for the different result, the uncertainties and accuracy of each method were first examined. These can be summerised as follows :-

Long-Term Study

Inflows

Catchment Run-Off & Direct Precipitation.

Based on long-term meteorological records adjusted for the Lubengele Dam area. Moderately reliable.

Tailings

Based on mine managements daily records. High reliability.

Outflows

Mingomba Pumping Station.

Based on a single measurement. Believed to be constant throughout the year with both pumps running 24 hours per day.

Decanting Tower

Based on a single measurement and assumed constant throughout the year. Variation possible, including shut-down.

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Embankment Seepage

Based on velocity measurements in small stream.

Of doubtful accuracy.

Evaporation

Based on long-term meteorological records.

Moderately reliable.

<u>Changes in Dam Storage</u>

Based on annual, or bi-annual records of water level, but more infrequent surface area surveys. Not very reliable overall.

<u>Short-Term Study</u>

<u>Inflows</u>

Catchment Run-Off

Based on daily velocity measurements in a small stream.

Validity of results doubtful.

Tailings

High reliability (as for long-term study)

<u>Outflows</u>

Mingomba Pumping Station

Believed constant (as for long-term study)

Embankment Seepage

Of doubtful accuracy (as for long-term study study)

Evaporation

Based on evaporation pan in the locality. High accuracy.

<u>Change in Dam Storage</u>

Based on daily water level measurements and a survey of the water surface area. High accuracy.

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Reference to the water balance calculation for the short-term study indicates the sensitivity of the calculation to the run-off and embankment seepage values; for example a 100% increase in the run-off value would increase the loss more than three and a half times, to 6.39 M.Lit./day.

In the long-term study data it was noted that the annual loss values vary largely in sympathy with the catchment run-off values. This is unlikely to represent the true situation. The apparent relationship between the values is caused by the use of constant or near-constant values from year to year for all of the data except the run-off. It seems reasonable to suspect, however, that draw-off from the Decanting Tower would have been increased during years of above-average rainfall, either by increasing the rate of draw-off or by lengthening the period of draw-off, or both.
If this had been so then the calculated loss values might vary substantially from those shown, with a reduction in the higher values.

Whilst these reservation concerning the calculations might lead to a belief in a higher daily loss arising from the short-term study and a lower daily loss arising from the long-term study, a considerable discrepancy between the figures might still exist. The conclusion drawn and reported to the mine management on completion of these studies was that the true loss figures were likely to be somewhere between the two extremes, and that additional measurement and record-keeping was necessary before a more accurate analysis could be undertaken.

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ADDITIONAL INFORMATION

During 1993 the mine management obtained certain additional data relevant to investigation. The new data is as follows, with the earlier values stated alongside for comparison.

	Values used in original studies G.Lit/annum cu.m./day	cu.m./day	31 March 1993 cu.m./day	May/June 1993
Decanting Tower	7.32	20 055	124 506	117 000
Mingomba Pumps	1.33	3 643	3 630	3 630
Dam Water Level above local datum		21.8m	25.2m	-

Although limited in scope, the new data shows two rates of draw-off through the Decanting Tower during the first half of 1993 that are both much higher than the value used in the original long-term study. The figures given indicate that the draw-off rate is much higher near the end of the rains (in March 1983), reducing slightly thereafter (in May/June 1983). Rainfall in the Copperbelt over the 1992/93 season was some 8% above the long-term average, whilst over the 1991/92 season it was 16% below average. The figures seem to suggest therefore that the rate of draw-off is adjusted from time to time to suit the prevailing conditions. The effect of this on the calculations can be shown by an example. If the draw-off rate in a typical year peaks at 115 000 cu.m./day at the end of the rains, and touches 0 at the end of the dry season, then the typical average rate of draw-off would be 57 500 cu.m./day, as compared with the value of 20 100 cu.m./day used in the long-term analysis. The calculated daily unaccounted loss rates would then fall by 37.4 M.Lit./day.

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The second factor of significance shown by the new data is the rise in the dam water level of 3.4m between October 1992 and March 1993. The rise took place during the rains, and occurred despite the increased rate of draw-off through the Decanting Tower. If such a rise represents typical seasonal behaviour of the dam, then seasonal variation in the rate of loss through the floor of the dam would occur, since the loss is primarily a function of the height of the water in the dam. It appears that the level probably rises each year during the rains, reaching a peak when they end in April, and thereafter falls to a minimum in October before the next rains start. Higher daily rates of loss during the rains would to some extent account for the mean daily rates given by the long-term study being higher than the daily loss calculated during the short-term study of the dry months of September/October 1992.

The temporary rise in water level would be accompanied by a temporary increase in the water surface area, and a corresponding increase in the amount of water lost by evaporation.

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To summarise, the additional information has indicated that seasonal variations in the operation and behaviour of the dam probably exist that were not known at the time of the original study. The effects of these on the water balance calculations would be probably as follows:-

a) Considerable increase in the annual draw-off through the Decanting Tower
b) Increase in the annual loss by evaporation, due to temporary increase in the dam surface area.
c) Considerable reduction in the annual unaccounted loss values consequent upon a) and b) above.

It should be noted also that revised daily unaccounted loss figures based on annual calculations could not be compared strictly with the results of the short-term study here presented. The short-term study result is not representative of the average loss over the year since it is related to minimum water level in the dam. Furthermore the inaccuracies in certain data used for that study render the result to some extent unreliable.

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