FLOW RELEASES DOWNSTREAM OF KATSE AND MUELA RESERVOIRS

(OCTOBER 1995 TO MARCH 2002)

TOWER ON MALIBAMATSO RIVER @ KAO

APRIL 2002

OPERATIONS AND MAINTENANCE GROUP

Operations Planning Branch
HYDROLOGY SECTION

TABLE OF CONTENTS

Page

List of Figures:

List of Tables:

1. INTRODUCTION

The Katse Reservoir was impounded in October 1995 when the two diversion tunnels that were used to pass water downstream were closed permanently. Construction was still in progress then, so the water level was made to rise at a pace lagging behind construction. After commissioning, the water level in the reservoir was controlled by the downstream discharge facilities on the Katse Dam.

The facilities at Katse Dam are composed of a ten (10) bay spillway designed to Probable Maximum Flood of 6252 m^3/s at a surcharge level of 7.2m above its crest. There are two (2) Low - Level Outlets (LLO), each with a capacity of 415m^3/s. Each LLO has one emergency gate and one radial gate installed in series. A third discharge facility consists of a compensation pipe capable of discharging between 300 to 800 litres per second through a sleeve valve.

At the ‘Muela Reservoir there is one compensation pipe, an LLO and a spillway.

LHDA has been requested to provide an accounting of all water that has gone downstream of Katse and 'Muela dams since impoundment. An earlier report was issued which was based on calculations made without the rating tables for the compensation pipe and the LLO (Radial Gates) at Katse. This report is an update of the earlier report and is now based on the rating tables of the compensation pipe and LLO (Radial Gates), which have become available since the issuing of the earlier report. It also revises the previous estimates that were made for the volume of LLO (Radial Gates) discharge and spill flow over the Katse Dam.

Most of the data for this exercise was obtained from the Dam Safety and Surveillance Branch, which is the custodian Branch for the data, collected at the Katse Dam as well as from the Engineering Group. Part of the data was also obtained from the Operations and Maintenance Branch who have been operating the outlets at the 'Muela Dam and a mini-hydro at Katse Dam.

This report provides information on the quantity of water that has been discharged downstream of the Katse and 'Muela Reservoir systems since impoundment to March 2002. First a summary of results is presented then the methodology. A chronology of events follows before the results are presented accompanied by tables and graphs. Conclusions and recommendations are finally discussed.

2. SUMMARY

Katse Dam has spilled through the Spillway four times since impoundment. The periods of spill are:

PERIOD	DISCHARGE
- 09th Mar. 1998 to 21st Apr. 1998	127.24 MCM (0.62m^3/s)
- 17th Apr. 2001 to 17th May 2001	155.96 MCM (0.761 m^3/s)
- 24th Nov. 2001 to 10th Jan. 2002	167.61 MCM (0.82 m^3/s)
- 25th Jan. 2002 to 12th Feb. 2002	156.67 MCM (0.764 m^3/s)

It should also be noted that the LLO (Radial Gates) have been used to draw down the level of the Katse reservoir especially during periods immediately preceding a spill event to fill up the stilling basin, and sometimes used to avoid spillage altogether.

The guaranteed minimum compensation discharge at Katse is 0.500 m^3/s, which converts to a Volume of 102.60 MCM for the period October 1995 to March 2002. The actual amount of water discharged through the compensation and mini-hydro outlets is 157.4 MCM (equivalent to 0.768 m^3/s) for the same period.

The amount of water released downstream of the 'Muela Reservoir from October 1997 to March 2002 is about 54.17 MCM (0.38 m^3/s). This amount exceeds 21.6 MCM (0.15 m^3/s), which is the average annual flow from the Nqoe River.

3. METHODOLOGY

There are no flow meters on the pipes and gates of the LHWP Dams. Therefore to determine the discharge from the LLO (Radial Gates) and compensation pipes, rating tables that were derived by the consultant on the project, were used as the basis for the derivation of flows. Spillway discharges were obtained from spillway discharge equations that were developed by the Consultant.

The monthly flows were then compiled from the computed hourly and daily averages for the reporting period.

4. CHRONOLOGY OF EVENTS (History)

During the construction of the arch dam, river water was impounded behind a cofferdam and was diverted through two diversion tunnels on the left bank reaches of the river.

The diversion tunnels were closed in October 1995 to commence the impoundment of the Katse Reservoir. The required compensation was passed downstream through a by-pass pipe that was attached to Diversion Tunnel No 2. The releases were scheduled to be at 0.92 m^3/s during the dry season and at 0.40 m^3/s during the wet season.

The compensation pipe leading from the intake structure in the middle of the dam wall at Katse was opened as soon as the water level reached Minimum Operating Level (MOL). The rate of impounding was however faster than originally anticipated, hence, the reservoir level had to be controlled so that

it would not interfere with the construction process. The water level was therefore controlled through the use of the LLO (Radial Gates) whose intake is at elevation 1938 masl.

The water level of the Katse Reservoir reached the MOL of 1989 masl on the 9th August 1996. The O & M manuals specify that the amount of water discharged downstream is a function of reservoir level and valve opening. The sleeve valve was designed to discharge between 0.3 and 0.8 m^3/s for reservoir levels ranging from MOL to Full Supply Level (FSL). To achieve this, the sleeve valve opening was set at 35% from August 1996.

The LLO (Radial Gates) have been occasionally opened for short durations of time, example 20 minutes, for operational purposes, while the compensation releases downstream continued in a steady manner. From January 2000 the mini hydro at Katse Dam became operational and the corresponding discharges downstream became part of the compensation flow.

5. RESULTS

5.1 Katse Outflows

5.1.1 Spill Flow

The spill discharges over the Katse Dam during the four periods are as shown below (see table 1).

PERIOD	DISCHARGE
- 09th Mar. 1998 to 21st Apr. 1998	127.24 MCM (0.62m^3/s)
- 17th Apr. 2001 to 17th May 2001	155.96 MCM (0.761 m^3/s)
- 24th Nov. 2001 to 10th Jan. 2002	167.61 MCM (0.82 m^3/s)
- 25th Jan. 2002 to 12th Feb. 2002	156.67 MCM (0.764 m^3/s)

The total amount of spill over the Katse Dam since impoundment is therefore 607.48 MCM (2.96 m^3/s).

5.1.2 Compensation and Mini Hydro Flows

From the Katse Reservoir, about 157.4 MCM (0.768 m^3/s) of water has been released downstream from October 1995 to March 2002, made up of 153.1 MCM (0.747 m^3/s) from the compensation pipe and 4.3 MCM (0.021 m^3/s) from the mini hydro discharges.

This compares with the treaty required guaranteed minimum compensation discharge volume of 102.60 MCM (0.500 m^3/s) for the period October 1995 to March 2002.

5.1.3 Low – level Outlets (LLO)

A total of about 576.1 MCM (2.81 m^3/s) of water has been released through the LLO (Radial Gates).

5.1.4 Total Flow

In total about 1,340.96 MCM (which is equivalent to 6.54 m^3/s) has been released downstream of the Katse Reservoir as seen from table 1 below.

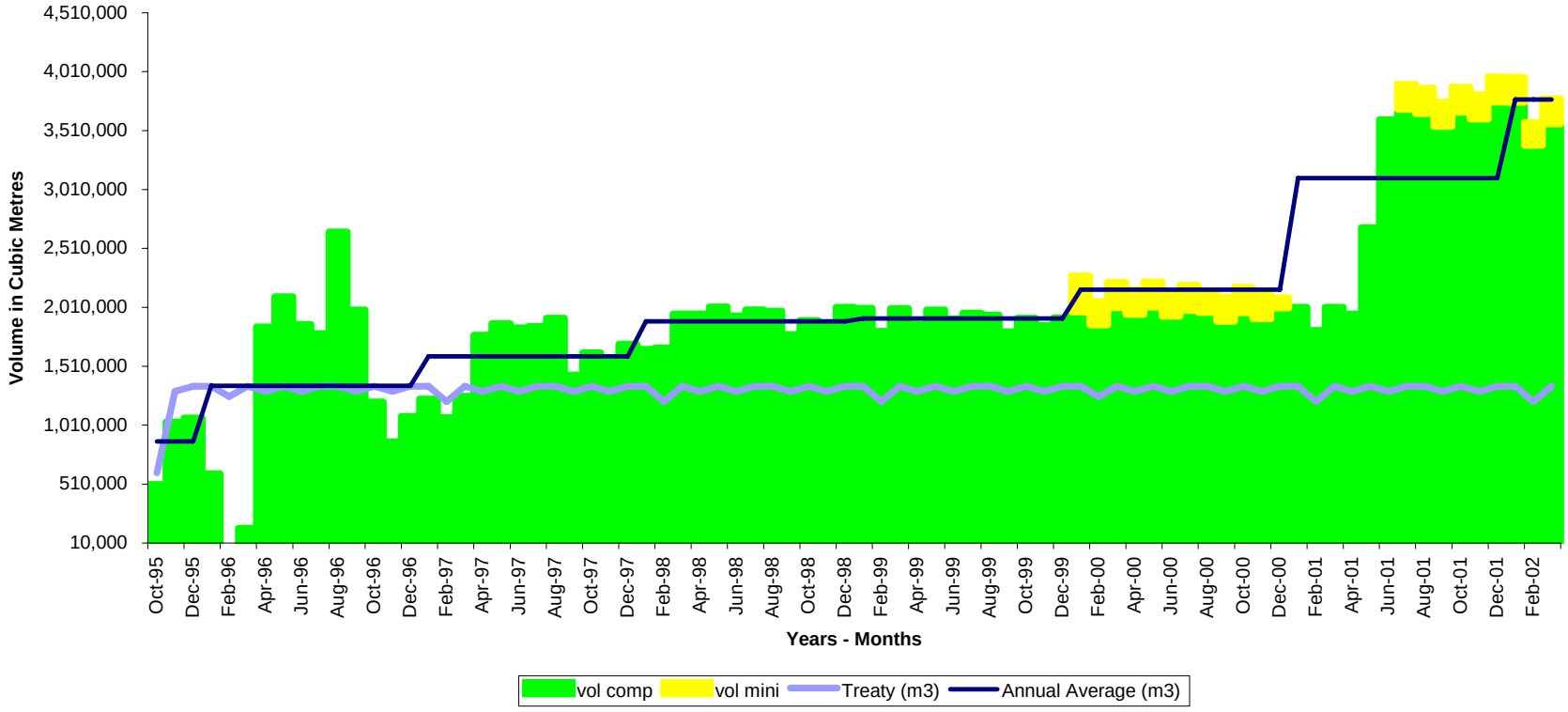
Table 1: Katse Flows

Table 1 below gives the volumes of water released downstream of the Katse Reservoir since impoundment to March 2002 for each month. It also gives the totals for each year and the overall total at the end of the period.

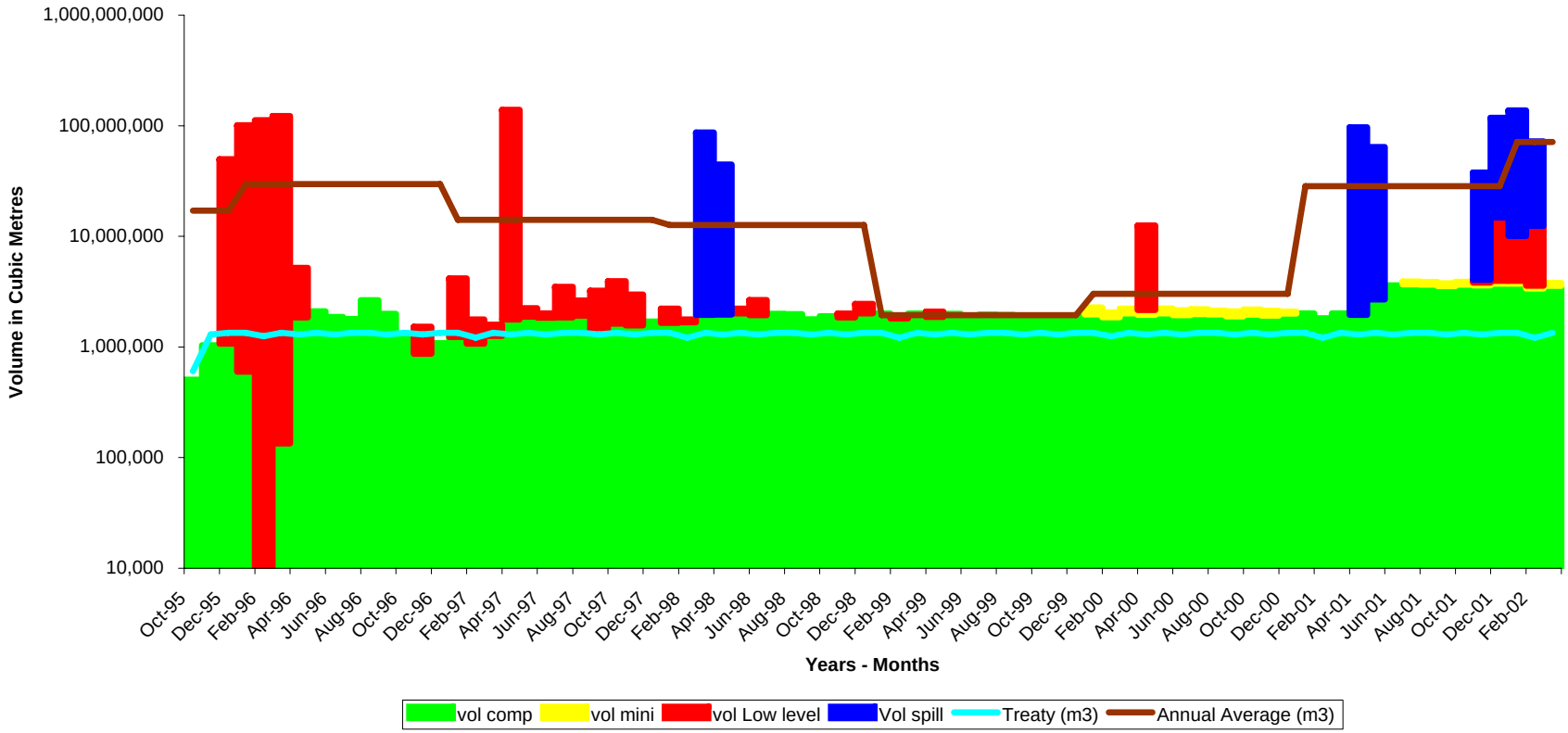
Months – Years Since Impoundment	Low – level Outlet (Radial Gates) Volume in Cubic Metres	Compensation Volume in Cubic Metres	Mini – Hydro Volume in Cubic Metres	Spillway Volume in Cubic Metres	Monthly total in Million Cubic Metres (MCM)	Yearly Total in MCM
Oct-95	-	506,880	-	-	0.51	
Nov-95	-	1,036,800	-	-	1.04	
Dec-95	48,720,587	1,071,360	-	-	49.79	51.34
Jan-96	100,366,740	597,312	-	-	100.96	
Feb-96	111,977,412	-	-	-	111.98	
Mar-96	122,282,982	134,352	-	-	122.42	
Apr-96	3,354,390	1,844,640	-	-	5.20	
May-96	-	2,099,520	-	-	2.10	
Jun-96	-	1,866,240	-	-	1.87	
Jul-96	-	1,788,480	-	-	1.79	
Aug-96	-	2,649,888	-	-	2.65	
Sep-96	-	1,987,200	-	-	1.99	
Oct-96	-	1,207,584	-	-	1.21	
Nov-96	653,626	869,526	-	-	1.52	
Dec-96	-	1,084,550	-	-	1.08	354.76
Jan-97	2,932,800	1,232,064	-	-	4.16	
Feb-97	700,800	1,073,088	-	-	1.77	
Mar-97	333,900	1,256,256	-	-	1.59	
Apr-97	137,528,533	1,773,827	-	-	139.30	
May-97	366,826	1,873,580	-	-	2.24	
Jun-97	176,400	1,837,293	-	-	2.01	
Jul-97	1,647,340	1,849,003	-	-	3.50	
Aug-97	714,600	1,919,121	-	-	2.63	
Sep-97	1,783,500	1,435,157	-	-	3.22	
Oct-97	2,299,968	1,626,299	-	-	3.93	
Nov-97	1,414,422	1,563,267	-	-	2.98	
Dec-97	-	1,697,283	-	-	1.70	169.04
Jan-98	564,516	1,654,850	-	-	2.22	
Feb-98	106,560	1,666,706	-	-	1.77	
Mar-98	-	1,953,237	-	84,743,424	86.70	
Apr-98	-	1,955,199	-	42,497,892	44.45	
May-98	204,480	2,013,279	-	-	2.22	
Jun-98	725,232	1,937,191	-	-	2.66	
Jul-98	-	1,990,062	-	-	1.99	
Aug-98	-	1,979,026	-	-	1.98	

Months – Years Since Impoundment	Low – level Outlet (Radial Gates) Volume in Cubic Metres	Compensation Volume in Cubic Metres	Mini – Hydro Volume in Cubic Metres	Spillway Volume in Cubic Metres	Monthly total in Million Cubic Metres (MCM)	Yearly Total in MCM
Sep-98	-	1,779,216	-	-	1.78	
Oct-98	-	1,899,880	-	-	1.90	
Nov-98	150,450	1,852,464	-	-	2.00	
Dec-98	441,882	2,011,252	-	-	2.45	152.13
Jan-99	-	2,002,074	-	-	2.00	
Feb-99	74,184	1,807,337	-	-	1.88	
Mar-99	-	2,000,180	-	-	2.00	
Apr-99	219,396	1,866,584	-	-	2.09	
May-99	-	1,987,675	-	-	1.99	
Jun-99	-	1,913,418	-	-	1.91	
Jul-99	-	1,961,394	-	-	1.96	
Aug-99	-	1,945,025	-	-	1.95	
Sep-99	-	1,803,939	-	-	1.80	
Oct-99	-	1,918,160	-	-	1.92	
Nov-99	-	1,854,437	-	-	1.85	
Dec-99	-	1,920,822	-	-	1.92	23.27
Jan-00	-	1,970,209	308,376	-	2.28	
Feb-00	-	1,860,185	200,448	-	2.06	
Mar-00	-	2,007,468	214,272	-	2.22	
Apr-00	10,368,000	1,950,370	207,360	-	12.53	
May-00	-	2,011,275	214,272	-	2.23	
Jun-00	-	1,935,544	207,360	-	2.14	
Jul-00	-	1,983,426	214,272	-	2.20	
Aug-00	-	1,965,240	172,800	-	2.14	
Sep-00	-	1,891,194	207,360	-	2.10	
Oct-00	-	1,964,190	214,272	-	2.18	
Nov-00	-	1,913,393	207,360	-	2.12	
Dec-00	-	2,004,447	85,392	-	2.09	36.28
Jan-01	-	2,011,695	-	-	2.01	
Feb-01	-	1,813,658	-	-	1.81	
Mar-01	-	2,011,402	-	-	2.01	
Apr-01	-	1,954,126	-	94,685,596	96.64	
May-01	-	2,687,144	-	61,277,845	63.96	
Jun-01	-	3,602,336	-	-	3.60	
Jul-01	-	3,689,828	211,824	-	3.90	
Aug-01	-	3,654,058	214,272	-	3.87	
Sep-01	-	3,545,211	207,360	-	3.75	
Oct-01	-	3,665,260	214,272	-	3.88	
Nov-01	238,950	3,607,406	207,360	33,749,513	37.80	
Dec-01	10,818,470	3,751,190	214,272	103,282,605	118.07	341.32
Jan-02	6,095,841	3,749,298	214,272	127,594,312	137.65	
Feb-02	8,803,830	3,384,688	193,536	59,648,669	72.03	
Mar-02	-	2,965,739	179,712	-	3.15	212.83
	576,066,617	153,103,961	4,310,424	607,479,856		
Volume in MCM	**576.067**	**153.104**	**4.310**	**607.480**	**1,340.961**	**1,340.961**
Total water gone downstream of Katse Dam					**1,340.961**	**MCM**

FIGURE 1 - Historic Flow Releases - Katse Reservoir
Actual vs Treaty guaranteed Minimum Flows



GRAPH 2:- Historic Flow Releases - Katse Reservoir



5.2 'MUELA OUTFLOWS

The 'Muela compensation flows are shown below in table 2 in MCM. They span the period from October 1997 to March 2002. Prior to October 1997, the flows indicated in the same table are Nqoe River flows. From October 1997, the flows are discharges from the compensation pipe at 'Muela except the period April 2000 during which part of the flow was from the LLO at Muela.

5.2.1 Spill Flow

During commissioning, 'Muela Dam was allowed to spill for a short duration of time in order to test the performance of the spillway.

5.2.2 Compensation Flow

For the period October 1997 to March 2002, an amount of 48.34 MCM (0.34 m^3/s) was discharged as compensation flow.

5.2.3 Low Level Outlets (LLO)

A release of 5.83 MCM (0.04 m^3/s) was made during April 2000. This amount has been included in table 2 as part of compensation.

5.2.4 Total Flow

The total downstream releases from the 'Muela Reservoir from October 1997 to March 2002 was about 54.17 MCM (which is equivalent to 0.38 m^3/s) as seen from Table 2.

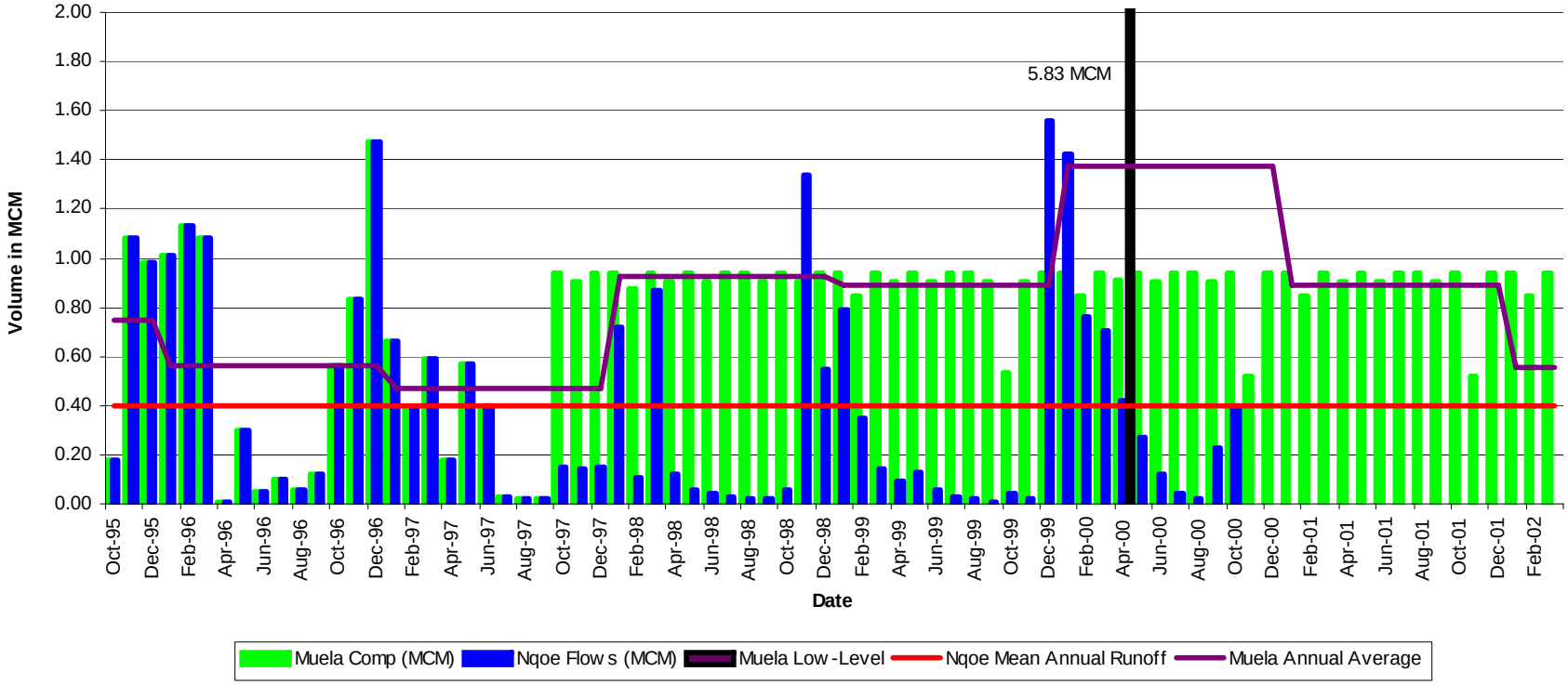
Table 2: ‘Muela Flows

Table 2 below gives the monthly volumes of water released downstream of ‘Muela Reservoir from January 1995 to March 2002. The values from January 1995 to September 1997, when the ‘Muela Reservoir was not yet in operation, represent the flows from the Nqoe River. From October 1997 to March 2002 the values shown are regulated outflows from the ‘Muela Reservoir for compensation.

	Jan.	Feb.	Mar	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec	Total
													MCM
1995	0.20	0.24	0.70	0.20	0.13	0.02	0.06	0.04	0.02	0.18	1.08	0.98	3.85
1996	1.01	1.13	1.08	0.01	0.30	0.05	0.10	0.06	0.12	0.56	0.83	1.47	6.72
1997	0.66	0.39	0.59	0.18	0.57	0.40	0.03	0.02	0.02	0.94	0.91	0.94	**5.64**
1998	0.94	0.88	0.94	0.91	0.94	0.91	0.94	0.94	0.91	0.94	0.91	0.94	**11.07**
1999	0.94	0.85	0.94	0.91	0.94	0.91	0.94	0.94	0.91	0.54	0.91	0.94	**10.64**
2000	0.94	0.85	0.94	6.74	0.94	0.91	0.94	0.94	0.91	0.94	0.52	0.94	**16.21**
2001	0.94	0.85	0.94	0.91	0.94	0.91	0.94	0.94	0.91	0.94	0.52	0.94	**10.65**
2002	0.94	0.85	0.79										**2.57**
Total water gone downstream of ‘Muela Dam (from October 1997)													**54.17**

FIGURE 6- Muela Dam Releases from compensation pipe and Nqoe Mean Annual Runoff (MAR)

(Compensation vs Nqoe MAR)



5.3 COMPENSATION FLOWS

5.3.1 Katse

The chart in Graph 1 compares the Treaty required guaranteed minimum flow with the flow from the Katse compensation pipe. It is seen that the outflow from the compensation pipe has consistently been more than that required by the Treaty.

Graph 2 shows the different outlet flows at Katse and how they compare with the Treaty required guaranteed minimum flow and the annual average of the total outflows.

Please note that this graph has a vertical logarithmic scale, which tends to compress the vertical scale especially as it moves upward.

5.3.2 'Muela

In Graph 3, flows from the 'Muela Dam outlets are compared with those from the Nqoe River. The annual averages of these two flows are also shown on the graph. It is observed that the 'Muela outflows are consistently higher than the average Nqoe flows.

6. CONCLUSION

There have been various discharges downstream of the Katse and 'Muela Dams. The flow through the compensation pipe at Katse has consistently been above the required Treaty guaranteed minimum flow of 500 litres per second.

The flow downstream of the 'Muela Dam has also been consistently higher than the annual average flow from the Nqoe River.

7. RECOMMENDATIONS

It is recommended that the compensation valve at Katse be maintained at 0.75 m^3/s pending a recommendation on the IFR policy in October 2002. This recommended release level of 0.75 m^3/s is more than the stipulated treaty guaranteed minimum compensation of 0.500 m^3/s.

The effect of passing down more than the average annual flow downstream of 'Muela should be examined in terms of the downstream effects. In the mean time, the flows downstream of 'Muela should be reduced to approximate the average annual flow from the Nqoe River.