3 WELL OBSERVATION

3.1 Selection of Observation Wells

To clarify the relationship between the river water level and shallow groundwater level, nineteen (19) observation well shown in Table-3.1 were selected near the hydrometric stations.

One well was designated near hydrometric station, but around two (2) hydrometric stations; St. Lubungu and St. Luangwa Bridge, there were no available well. The locations of well are shown in Fig.-3.1.

Table-3.1 List of Observation Wells

Observation Well	Hydrometric Stations	Diameter(m)	Depth (m)	Distance btw Well & St.
(1) Kanylilaba	1-150 Zambezi	1.30	11.77	8.50 km
(2) Kanyayibmu	1-650 Kabompo B	1.30	14.00	6.00 km
(3) Watopa	1-950 Watopa P	1.30	11.79	0.80 km
(4-1) Luanchama	2-030 Lukulu	1.40	3.66	7.00 km
(4-2) Lishawa	2-030 Lukulu	1.30	4.20	30.00 km
(5) Machatanga	2-250 Kalabo	1.40	3.29	4.20 km
(6-1) Milne Farm	2-400 Senanga	1.30	2.21	4.10 km
(6-2) Litoya	2-400 Senanga	1.30	4.35	20.00 km
(7) Kansofu	4-050 Raglam Farm	1.30	7.99	9.10 km
(8) Mwambashi	4-120 Mwambashi	1.00	4.82	0.07 km
(9) Kabulanda	4-130 Smith's B.	1.00	5.36	0.70 km
(10) Mpatamato	4-200 Mpatamato	0.50	1.60	0.54 km
(11) Machiya	4-280 Machiya F	0.98	6.33	0.35 km
(12) Chilenga	4-350 Chilenga	1.30	2.25	1.50 km
(14) Lupemba	4-560 Chifumpa P	1.20	10.81	30.00 km
(15) Kafue H/B	4-669 Kafue F/B	5.15	7.54	0.50 km
(16) U Kaleya Dam	4-941 Kaleya D/S	1.40	10.50	6.50 km
(17) Uruaff Farm	4-958 Uruaff Farm	1.20	4.50	1.60 km
(18) Mutamina	5-030 Exchange F	1.20	3.90	0.60 km

Well No.	NAME	Dia.(m)	Depth(m)	Ele.(m)	Hydrometric St.	Dis.(km)
1	Kanyilaba	1.30	11.77	1068.55	1-150 Zambezi	8.50
2	Kanyayimba	1.30	14.00	1074.33	1-650 Kabompo	6.00
3	Natopa	1.30	11.79	1038.96	1-950 Natopa P.	0.80
4-1	Luanchama	1.40	3.66	1046.90	2-030 Lukulu	7.00
4-2	Lishawa	1.30	4.20	1062.60	2-030 Lukulu	30.00
5	Machatanga	1.40	3.2	1031.92	2-250 Kalabo	4.20
6-1	Milne Farm	1.30	2.21	1024.21	2-400 Senanga	4.10
6-2	Litoya	1.30	4.35	1038.21	2-400 Senanga	20.00
7	Kansofu	1.30	7.99	1305.96	4-050 Raglan F.	9.10
8	Hwambashi	1.00	4.82	1179.51	4-120 Hwambashi	0.07
9	Kabulanda	1.00	5.36	1176.10	4-130 Smith's B.	0.70
10	Mpatamato	0.50	1.60	1170.80	4-200 Mpatamato	0.54
11	Machiya F.	0.98	6.33	1128.65	4-280 Machiya F.	0.35
12	Chilenga	1.30	2.25	1120.65	4-350 Chilenga	1.50
14	Lupemba	1.20	10.81	1147.00	4-560 Chifumpa	30.00
15	Kafue H/B	5.15	7.54	1075.48	4-669 Kafue H/B	0.50
16	U.kaleya Dam	1.40	10.50	1319.40	4-941 Kaleya D/S	6.50
17	Urunff Farm	1.20	4.50	1031.12	4-958 Urunff F.	1.60
18	Hutamina	1.20	3.90	1120.27	5-030 Exchange F	0.60

Fig.-3.1 Location Map of Observation Wells

3.2 Observation of Well Water Level

(1) Observation Rule and Method

The well water level is measured two (2) times a day, every morning and evening by the observer employed at each observation well. Measurement time in morning is fixed at 6:00 hour and evening at 18:00 hour. The measurement was done using a 10 meter-length of vinyl tape with a minimum reading of 1 cm, attaching a small iron sinker at the one end of tape. As the observation wells are so shallow that observer can see clearly the well water surface, observer can easily measure the depth from the measuring point to the well water surface.

(2) Observation Data

In Table-3.2, the monthly mean well water level and river water level at the hydrometric station are shown. All the observation data are compiled in the Data Book.

3.3 Analysis of Well Water Level

(1) Relationships between Well and River Water Levels

The pattern taken from the relationship charts between the river and well water levels can be classified as follows shown in Fig.-3.2. As is seen from the morning and evening water levels in the well water level fluctuation charts, evening water levels generally reflect levels after water used in daily life, etc., has been pumping out of the well. From this, the morning water levels are thought to show the actual groundwater levels while evening water levels are provided as reference data. For the relationship charts with river water levels, the morning water levels are used.

1) Linked Relationship (Type A)

Groundwater level fluctuations occur in unison with river water level fluctuations. In cases where the rivers and wells are close, it is thought that they are connected. Observation wells No.9 and No.12 are examples of this case.

2) Delayed Relationship (Type B)

Groundwater level fluctuations occur with a time lag after fluctuations in river water levels. Groundwater levels show gradual increases after increases in river water levels or gradual decreases after decreases in the river water levels. A time lag of 1 month is common for water level highs and lows. Observation wells No.1, 2, 3, 7, 8, 11 and 18 are examples of this case.

Table-3.2 Monthly Mean Well Water Level and River Water Level

No.	Stations		JUN'90	JUL	AUG	SEP	OCT	NOV	DEC	JAN'91	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	A/AVG
	1-150 Zambezi P/M	River Mean	2.05	1.43	1.07	0.72	0.58	0.58	1.18	3.07	7.73	6.39	5.56	3.10	1.76	1.17	0.79	0.62	2.36
(1)	KANYILABA	Well Morning	35.02	34.62	34.03	33.54	33.10	32.69	32.38	32.87	36.17	36.91	36.94	36.39	35.80	35.14	34.46	33.91	34.62
		Well Evening	34.79	34.28	33.62	33.09	32.72	32.23	32.05	32.64	36.04	35.78	36.77	36.19	35.47	34.68	34.04	33.33	34.29
	1-650 Kabompo Boma	River Mean	2.01	1.84	1.75	1.63	1.59	1.54	1.88	2.57	3.21	3.16	2.92	2.20	1.99	1.91	1.84	1.70	2.11
(2)	KANYAIMOU	Well Morning	15.56	THERE WAS NO SUFFICIENT PERSON FOR							15.36	15.76	15.74	15.51	15.37	15.21	14.98	14.78	13.83
		Well Evening	15.56	READING TAPE.							15.30	15.57	15.43	15.36	15.13	14.77	14.53	14.10	13.57
	1-950 Matopa Pontoon	River Mean	2.22	2.05	1.94	1.78	1.73	1.68	2.05	3.37	4.66	3.99	3.69	2.53	2.38	2.27	1.95	1.79	2.51
(3)	MATOPA PONTOON	Well Morning	2.24	2.09	1.94	1.74	1.57	1.37	1.21	1.19	1.98	2.33	2.33	2.17	1.96	1.78	1.57	1.37	1.80
		Well Evening	2.11	2.09	1.94	1.74	1.57	1.36	1.22	1.20	1.99	2.33	2.32	2.17	1.95	1.77	1.57	1.37	1.79
	2-030 Lukulu	River Mean	1.48	1.05	0.83	0.62	0.58	0.57	0.99	2.34	4.96	4.48	3.88	2.65	1.61	0.90	0.71	0.53	1.76
(4-1)	LUANCHUMA	Well Morning	27.19	27.11	26.98	26.74	26.66	26.55	26.71	27.68	28.28	28.19	27.94	27.64	27.46	27.36	27.25	27.05	27.31
		Well Evening	27.19	27.10	26.97	26.70	26.53	26.36	26.62	27.85	28.23	28.11	27.85	27.50	27.34	27.28	27.16	26.98	27.24
(4-2)	LISHUMA	Well Morning	42.08	41.96	41.84	41.63	41.44	41.36	41.48	42.11	42.73	42.56	42.39	42.11	41.99	41.78	41.67	41.42	41.91
		Well Evening	41.26	41.15	41.00	40.94	40.76	40.68	41.08	41.79	42.36	42.21	42.10	41.71	41.44	41.40	41.13	41.06	41.38
	2-250 Kalabo	River Mean	1.91	1.40	1.00	0.77	0.58	0.39	0.39	0.55	1.99	3.04	2.76	2.15	1.70	1.28	0.97	0.69	1.35
(5)	MUCHATANGA	Well Morning	13.28	13.27	13.27	13.24	13.17	13.22	13.25	13.51	14.13	14.05	14.09	13.75	13.73	13.96	13.50	13.27	13.54
		Well Evening	12.99	13.01	12.95	12.92	12.91	12.87	12.93	13.52	13.93	13.62	13.71	13.22	13.40	12.65	12.95	12.65	13.14
	2-400 Senanga	River Mean	2.51	1.45	1.02	0.76	0.66	0.62	0.94	1.71	3.02	4.17	4.00	3.58	2.24	1.24	0.95	0.74	1.85
(6-1)	MILNE FARM	Well Morning	23.02	23.01	22.99	22.92	22.85	22.80	23.01	23.09	23.45	23.37	23.29	23.23	23.22	23.21	23.18	23.08	23.11
		Well Evening	23.02	23.01	22.98	22.91	22.84	22.79	23.01	23.08	23.44	23.37	23.29	23.23	23.22	23.21	23.18	23.08	23.10
(6-2)	LITOYA	Well Morning		36.34	36.35	36.31	36.32	36.33	36.32	36.32	36.32	36.31	36.32	36.18	36.21	35.91	36.07	36.31	36.26
		Well Evening		36.07	36.00	35.90	35.90	35.90	35.92	35.97	35.95	35.97	36.16	35.97	35.91	35.57	35.79	36.13	35.94
	4-050 Raglan Farm	River Mean	1.33	0.89	0.69	0.51	0.42	0.40	0.55	1.37	3.00	3.24	3.02	2.01	1.27	0.93	0.76	0.56	1.31
(7)	KANSOFU	Well Morning	41.66	41.55	41.31	41.10	40.84	40.59	40.59	41.40	42.70	42.73	43.50	42.89	42.40	42.16	41.90	41.77	41.82
		Well Evening	41.67	41.50	41.25	40.99	40.71	40.40	40.44	41.38	42.70	42.74	43.52	42.88	42.38	42.13	41.92	41.73	41.77
	4-120 Mwanbashi	River Mean	1.02	0.91	0.86	0.78	0.69	0.67	0.96	2.23	2.66	2.63	2.13	1.36	1.04	0.97	0.96	0.87	1.30
(8)	MWAMBASHI	Well Morning	7.15	6.82	6.58	6.38	6.19	6.02	5.97	7.82	8.61	8.45	8.32	7.92	7.61	7.34	7.34	6.76	7.20
		Well Evening	7.14	6.81	6.57	6.38	6.18	6.03	5.93	7.83	8.60	8.44	8.31	7.94	7.61	7.34	7.34	6.76	7.20
	4-130 Smith's Bridge	River Mean	2.76	1.51	1.24	1.04	0.91	0.86	1.27	3.45	4.81	5.01	4.44	3.13	2.15	1.72	1.45	1.15	2.31
(9)	KABALAMBA	Well Morning	10.30	10.22	9.90	9.73	9.42	9.39	9.89	11.35	12.79	12.32	12.07	11.12	10.58	10.35	10.11	10.03	10.60
		Well Evening	10.26	10.16	9.85	9.69	9.39	9.39	9.87	11.37	12.77	12.31	12.05	11.10	10.56	10.34	10.07	10.00	10.57
	4-200 Mpatamato	River Mean	1.42	1.02	0.75	0.61	0.53	0.49	1.20	3.62	5.09	4.45	3.74	2.42	1.66	1.26	1.03	0.76	1.88
(10)	MPATAMATO	Well Morning	5.57	5.57	5.57	5.57	5.95	6.62	6.62	6.62	6.62	6.62	6.62	6.60	6.56	6.24	5.55	5.47	6.15
		Well Evening	5.53	5.53	5.53	5.53	5.95	6.62	6.62	6.62	6.62	6.62	6.62	6.60	6.50	6.01	5.54	5.41	6.11
	4-280 Machiya Ferry	River Mean	3.08	2.70	2.57	2.42	2.32	2.17	2.53	4.52	6.59	5.89	5.55	3.99	3.20	2.89	2.73	2.55	3.48
(11)	MACHIYA FERRY	Well Morning	2.70	2.40	1.92	1.54	1.48	1.46	1.43	2.68	4.78	4.89	4.87	4.39	3.84	3.27	2.82	2.44	2.93
		Well Evening	2.56	2.25	1.74	1.51	1.45	1.46	1.42	2.69	4.77	4.88	4.84	4.36	3.74	3.19	2.74	2.32	2.87
	4-350 Chilenga	River Mean	2.18	1.63	1.36	1.17	1.03	0.94	1.27	3.37	5.38	5.42	5.19	3.66	2.39	1.86	1.61	1.28	2.48
(12)	CHILENGA	Well Morning	5.82	5.62	5.22	5.20	4.99	4.74	5.67	6.31	6.55	6.85	6.68	6.33	6.05	5.82	5.61	5.36	5.80
		Well Evening	5.79	5.59	5.22	5.17	4.95	4.72	5.66	6.31	6.66	6.85	6.66	6.32	6.04	5.79	5.59	5.34	5.79
	4-560 Chifunpa Pon.	River Mean	0.72	0.62	0.55	0.45	0.40	0.34	0.49	1.30	2.37	1.83	1.43	0.87	0.69	0.60	0.53	0.45	0.85
(14)	LUPEMBA	Well Morning		32.51	32.24	31.48	30.84	30.57	31.04	34.33	35.24	34.95	34.59	33.83	33.11	32.63	32.28	31.79	32.76
		Well Evening		32.27	31.79	30.91	30.40	30.39	30.90	34.34	35.22	34.97	34.54	33.78	33.04	32.52	32.02	31.63	32.58
	4-669 Kafue Hook B.	River Mean	1.99	1.81	1.72	1.63	1.55	1.49	0.49	0.73	3.02	3.01	2.82	2.34	2.02	1.84	1.77	1.67	1.87
(15)	KAFUE HOOK BRIDGE	Well Morning		5.27	5.00	4.97	5.02	4.93	5.26	5.98	6.16	6.16	5.92	5.60	5.23	5.24	5.00	4.97	5.38
		Well Evening		4.63	4.39	4.31	4.41	4.34	4.77	5.42	5.68	6.52	6.56	6.24	5.87	5.88	5.64	5.61	5.35
	4-941 Kaleya D/S	River Mean	0.37	0.36	0.35	0.35	0.34	0.35	0.34	0.34	0.37	0.36	0.31	0.34	0.34	0.34	0.33	0.34	0.35
(16)	UPPER KALEYA DAM	Well Morning	73.99	73.35	72.58	72.33	71.69	71.65	71.48	72.47	72.75	72.71	72.34	71.43	70.85	70.35	70.02	69.76	71.86
		Well Evening	73.93	73.26	72.49	72.01	71.34	71.33	71.21	72.12	72.45	72.40	72.10	71.20	70.56	70.10	69.81	69.40	71.61
	4-958 Uruaff Farm	River Mean	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.07	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
(17)	URUAFF FARM	Well Morning	8.18	7.89	7.39	6.87	6.74	6.67	5.96	6.73	7.03	7.05	6.96	6.93	6.94	7.02	6.36	6.20	6.93
		Well Evening	8.16	7.88	7.34	6.87	6.80	6.79	6.18	6.74	7.17	7.13	7.18	7.19	7.18	7.19	6.35	6.20	7.02
	5-030 Exchange Farm	River Mean	0.09	0.07	0.06	0.02	0.07	0.00	0.05	0.45	0.40	0.26	0.18	0.11	0.09	0.09	0.09	0.05	0.13
(18)	MUTAMINA	Well Morning	1.81	1.80	1.78	1.82	1.71	1.68	1.63	2.01	2.36	1.97	2.01	1.89	1.72	1.83	1.77	1.73	1.85
		Well Evening	1.73	1.75	1.78	1.80	1.70	1.66	1.62	2.02	2.37	1.96	2.02	1.89	1.72	1.83	1.77	1.73	1.83

3) Preceding Relationship (Type C)

Groundwater levels decrease, preceding decreases in river water levels. In mountain areas, groundwater levels increase due to the effects of rain, etc., and when decreases in river water levels occur groundwater levels also decrease after a time lag. Observation wells No.5 and No.15 are examples of this case.

4) Combined Relationship (Type D)

Type D1 (A/B combination): Linkage relationship is indicated when the river water levels are high and a delayed link is indicated when the river water levels are low. When river water levels decrease, there is a delay before the groundwater levels decrease. Observation wells No.4-2 and no.14 are examples of this case.

Type D2 (B/C combination): Preceding relationship is indicated when the river water levels are high and a delayed linkage relationship is indicated when the river water levels are low. In mountain areas groundwater levels increase quicker that river water levels due to the effects of rain, etc., and compared to the decrease in river water levels, there is a delay in the decrease of groundwater levels. Observation wells No.4-1 and No.6-1 are examples of this case.

5) Irregular Relationship (Type E)

Type E1 (Stable water levels - temporary water level drop): Groundwater levels are normally stable regardless of river water levels but occasionally show small temporary decreases. Observation well No.6-2 is and example of this case.

Type E2 (Overall decrease trend - temporary increase): Showing a general decrease in water levels for the period from June, 1990 to September, 1991 but show partial recovery during the rainy season. Observation wells No.16 and No.17 are examples of this case.

Type E3 (Flooded): Flooded during the rainy season. Shows a preceding relationship when the river water levels are low. Observation well No.10 is an example of this case.

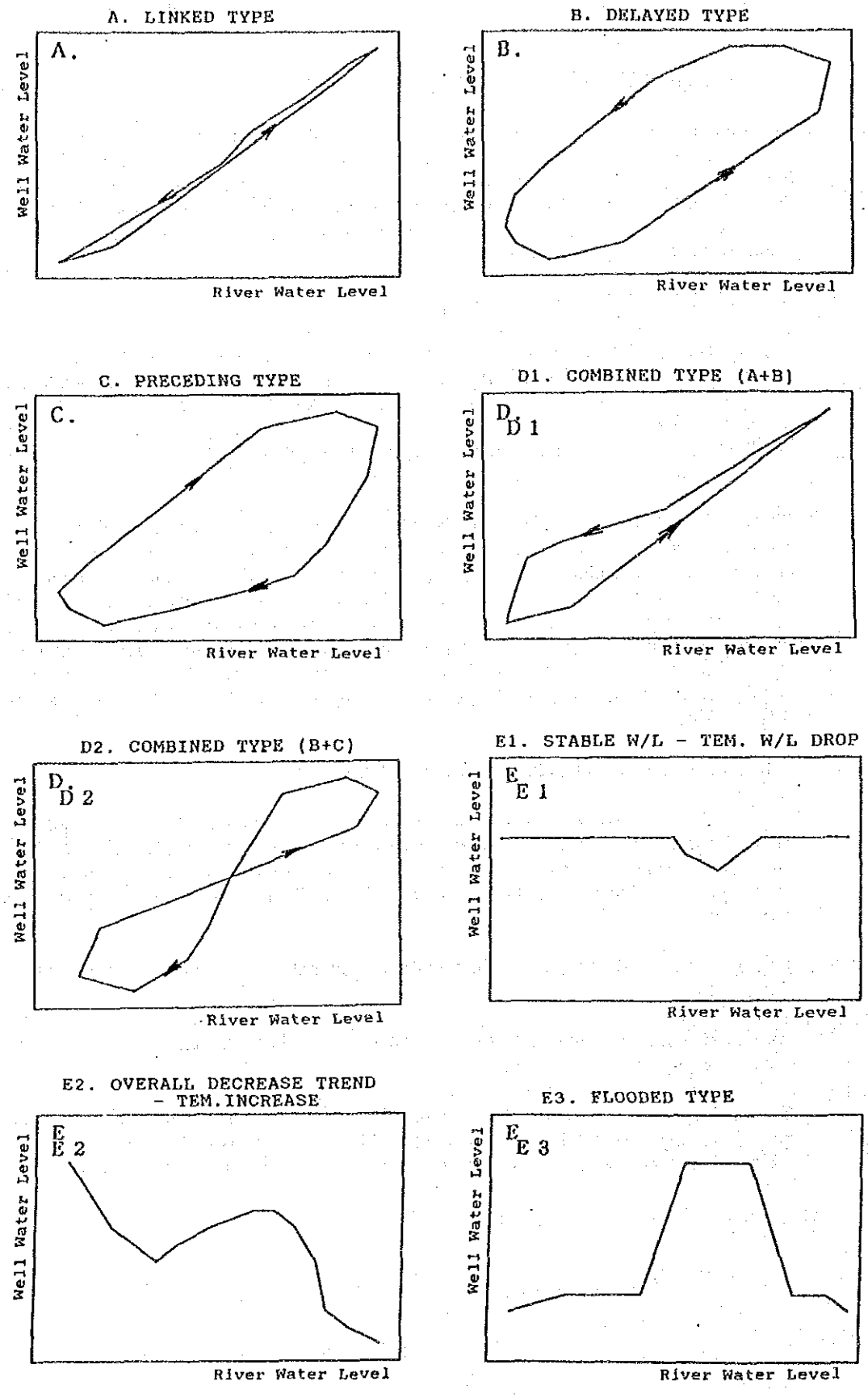


Fig.-3.2 Correlation Pattern between River W/L and Well W/L

(2) Trends in Well Water Level Fluctuation

Table-3.3 summarizes the topographical geology and water level fluctuation trends for the observation wells. The following trends apply to shallow wells surrounding rivers.
Refer to Fig.-3.3.
The following considerations are for each observation well;

< Well No. 1 >:

The well water level fluctuates following the patterns of the river water level. The highest and lowest well water levels occur with a one month delay compared to river water levels. December is the time with the lowest water levels and March to April is the time of the highest water levels. The water level fluctuation range is 4.5 m.

< Well No. 2 >:

These recordings were made starting in February 1992. March is the high water level period following the river water level with a delay of one month.

< Well No. 3 >:

The well water level fluctuates following the patterns of the river water level. The highest and lowest well water levels occur with a one month delay compared to river water levels. January is the time with the lowest water levels and March to April is the time of the highest water levels. The water level fluctuation range is 1.1 m.

< Well No. 4-1 >:

Where there are increases in the water level, the well water level increase precedes the increase in the river water level and when there are decreases in the water level, the well water level decrease lags behind the decrease in the river water level. November is the time with the lowest water levels and February is the time of the highest water levels. The water level fluctuation range is 1.7m.

< Well No. 4-2 >:

When the water level is high a linkage relationship can be seen while when the water level is low the decrease in the well water level is delayed. November is the time with the lowest water levels and February is the time of the highest water levels. The water level fluctuation range is 1.4m.

Table-3.3 Characteristics of Well Water Level Fluctuation

Well No.	Dis.*1 (km)	Height (m)*2	Geology	Fluctuation Pattern	Hmax. Month	Hmin. Month	dH *3 (m)
1	8.5	28	Sand of Kalahari group	B	Mar	Dec	4.5
2	6.0	21		B	Mar	-	-
3	0.8	2	Alluvium	B	Mar	Jan	1.1
4-1	7.0	17	Sand of Kalahari group	D2	Feb	Nov	1.7
4-2	30	32		D1	Feb	Nov	1.4
5	4.2	11		C	Feb	Nov	0.9
6-1	4.1	14		D2	Feb	Nov	0.65
6-2	20	28		E1	-	Jul	0.4
7	9.1	41	Alluvium	B	Apr	Nov	2.6
8	0.07	4		B	Feb	Dec	2.7
9	0.54	4		A	Feb	Dec	3.4
10	0.35	1.5		E3	-	Aug	1.1
11	1.5	4		B	Mar	Dec	3.5
12	30	0		A	Mar	Dec	2.1
14	0.5	32	*4	D1	Feb	Nov	4.6
15	5.4	2.6	*5	C	Mar	Nov	1.2
16	6.5	183	Alluvium	E2	Feb	Dec	4.0
17	1.6	3.5	*6	E2	Jun	Dec	1.0
18	0.6	1.9	Alluvium	B	Feb	Dec	0.8

[Note]
*1 : Distance between well and Hydro.St.,
*2 : Height from river bench mark up to well observation point
*3 : Max. fluctuation range of well water level
*4 : Weathered shales of Kundelungu group
*5 : Alluvium and Siltstones of the Upper Karoo
*6 : Weathered Calc-Silicate Rocks of the Pre-Katanga

< Well No. 5 >:

The well water level precedes the river water level in fluctuations. With both water level highs and lows, well water levels precede river water levels by one month. There is considerable fluctuation each month and this may be because of water usage. October to November is the time with the lowest water levels and February is the time of the highest water levels. The water level fluctuation range is 0.9m.

< Well No. 6-1 >:

The well water level precedes the river water level in water level increases and lags behind the river water level in water level decreases. November is the time with the lowest water levels and February is the time of the highest water levels. The water level fluctuation range is 0.65m.

< Well No. 6-2 >:

There is almost no fluctuation in the water level, however, the lowest level was during the period from May to August, 1991. July is the time with the lowest water levels and the water level fluctuation range is 0.4m.

< Well No. 7 >:

The well water level fluctuates following the level of the river water level. There is a one month lag between the well water level and the river water level at the highest and lowest water level periods. November is the time with the lowest water levels and April is the time of the highest water levels. The water level fluctuation range is 2.6m.

< Well No. 8 >:

The well water level fluctuates following the level of the river water level. The highest well water level occurs at the same time as the highest river water level while the lowest well water level occurs with a one month lag after the lowest river water level. December is the time with the lowest water levels and February is the time of the highest water levels. The water level fluctuation range is 2.7m.

< Well No. 9 >:

Fluctuation in the well water level is linked to the fluctuation in the river level. Close examination shows a slight lag in the increase of water levels during the high water level season. December is the time with the lowest water levels and February is the time of the highest water levels. The water level fluctuation range is 3.4m.

< Well No. 10 >:

The well is situated in the flood plains near the Kafue river and is flooded from November to April. The increase in the well water level precedes the river water level and lags behind the river water level for decreases. August to September is the time with the lowest water levels and the water level fluctuation range is 1.1m.

< Well No. 11 >:

The well water level fluctuates following the fluctuations in the river water level. There is a lag of one month between the river water level and the well water level during the high water and low water seasons. December is the time with the lowest water levels and March is the time of the highest water levels. The water level fluctuation range is 3.5m.

< Well No. 12 >:

Fluctuations of the well water level are linked to fluctuations of the river water level. Close examination shows a slight lag in the increase of water levels during the high water level season and something close to a preceding relationship in the low water season when the water level increases. November is the time with the lowest water levels and March is the time of the highest water levels. The water level fluctuation range is 2.1m.

< Well No. 14 >:

During the high water periods there is a linked fluctuation and during the low water periods there is a lag in the decrease of the well water level. December is the time with the lowest water levels and February is the time of the highest water levels which are the same as the river water levels. The water level fluctuation range is 4.6m.

< Well No. 15 >:

Well water level fluctuation precedes that of the river water level. For both the high and low water levels the well water level precedes the river water level by one month. November is the time with the lowest water levels and March is the time of the highest water levels. The water level fluctuation range is 1.2m.

< Well No. 16 >:

The water level shows an overall decreasing trend. There was a drop of 4.0m in the period from June 1990 to September 1991although there was a temporary increase of about 1.2m during the rainy season from January to April. This is thought to have been affected by the lack of rain in 1991.

< Well No. 17 >:

Compared to the water level in June 1990, the 1991 level was low. The 1991 water level fluctuation range was about 1.0m with December being the lowest and March being the highest. There are months where the water level is higher during the evening, possibly due to the way the water is used.

< Well No. 18 >:

The well water level fluctuates following the fluctuations of the river water level. During the high and low water periods the is a fluctuation lag of one month. December is the time with the lowest water levels and February is the time of the highest water levels. The water level fluctuation range is 0.75m.

(3) Consideration

It is clear that the level of groundwater near the river is closely related with the river water level although there are some types of water level fluctuation according to the topography,geology and permeability of ground. It is clarified that the groundwater recharged with rainfall is flowing into the river because the well water level is higher than the river water level at each observation station. It seems that groundwater development is a promising mean for the development of water resources if the development scale is suitable. More detailed and extensive investigation is required to prepared the development plan of groundwater.

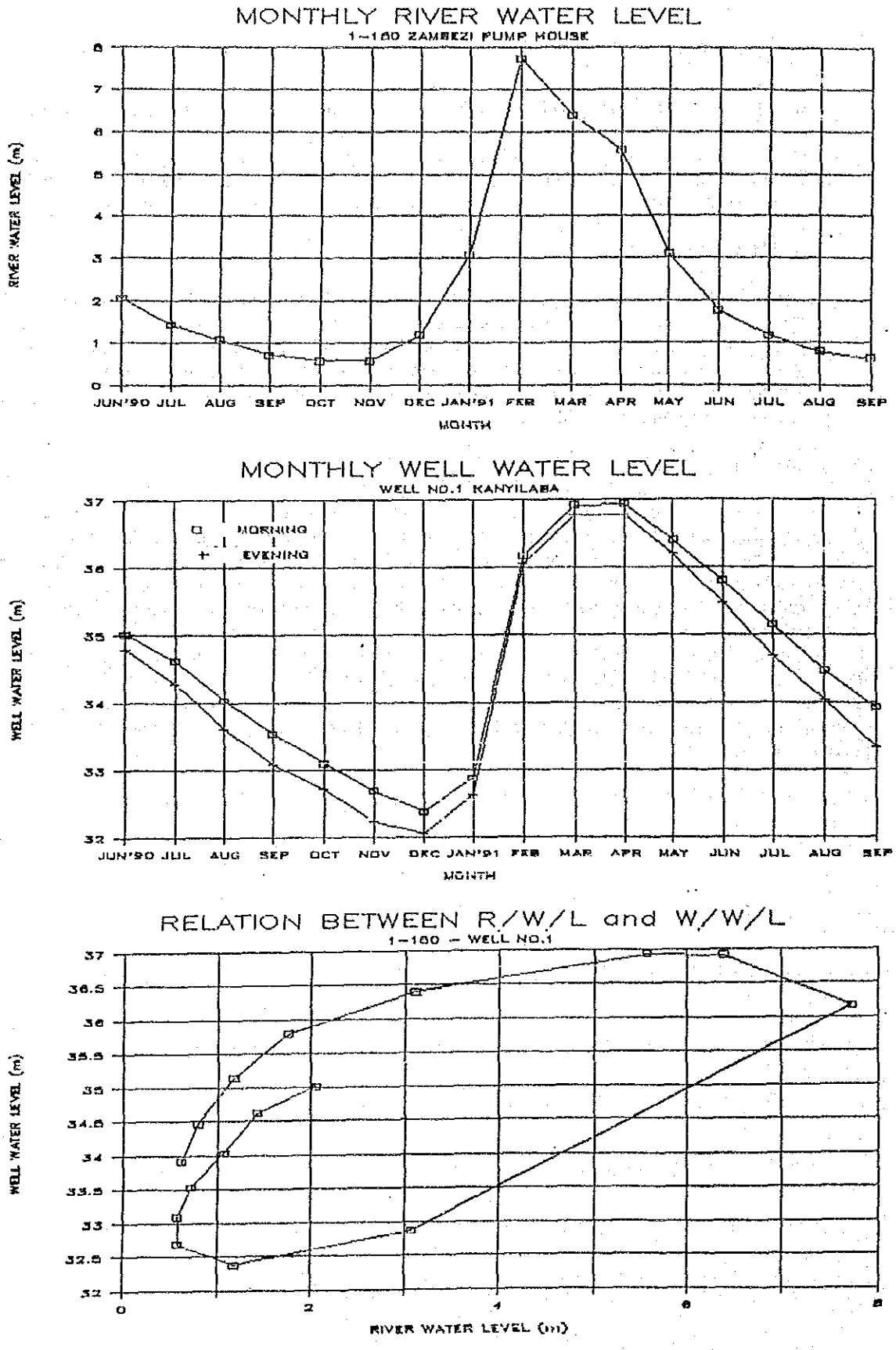


Fig.-3.3(1) Monthly Water Level Fluctuation (No. 1 Kanyilaba)

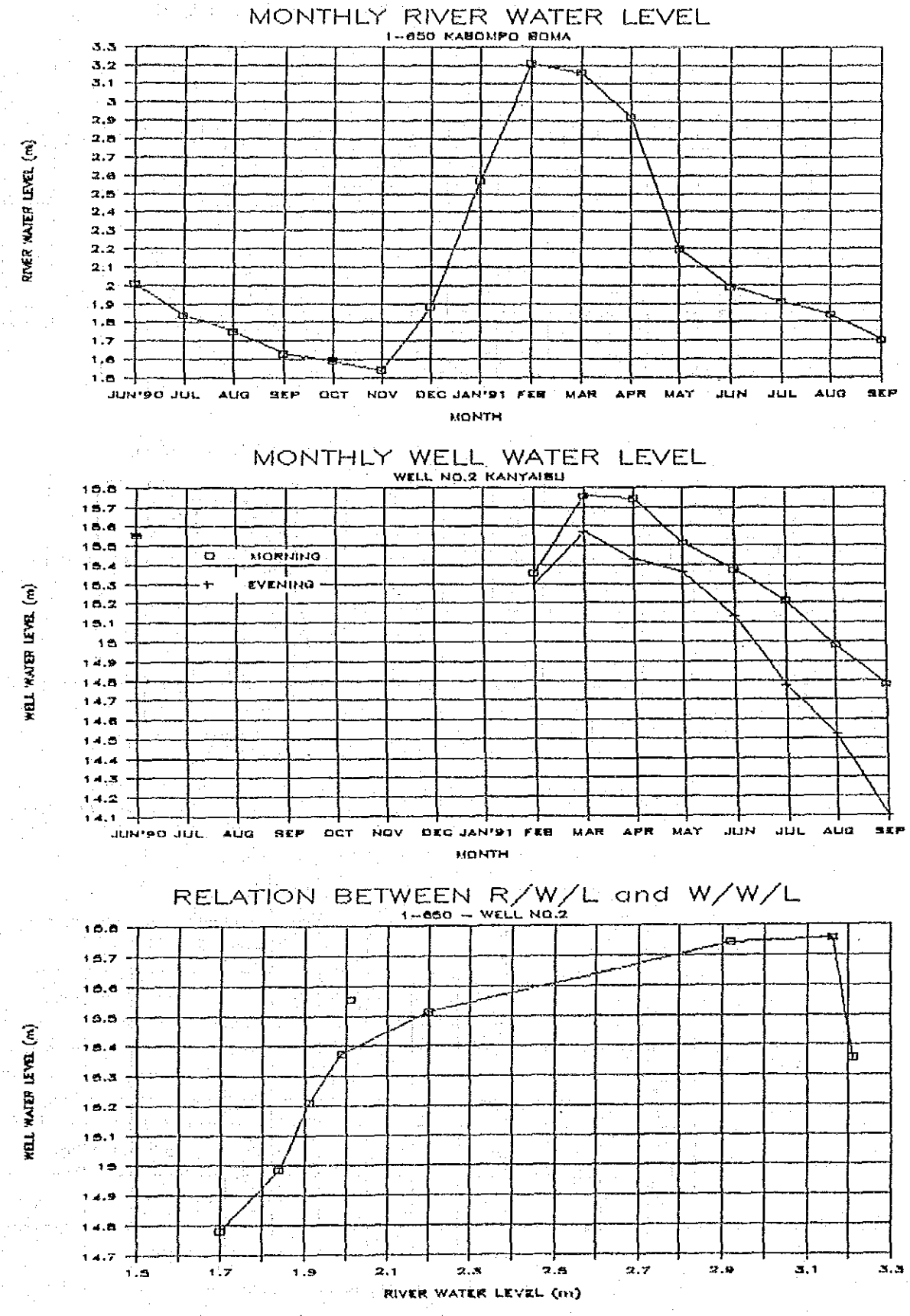
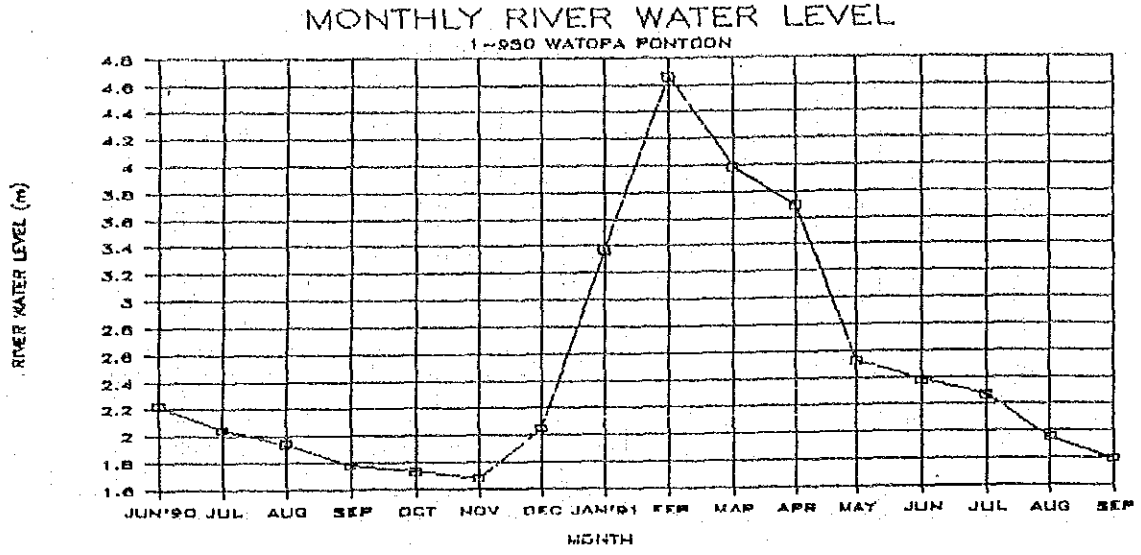
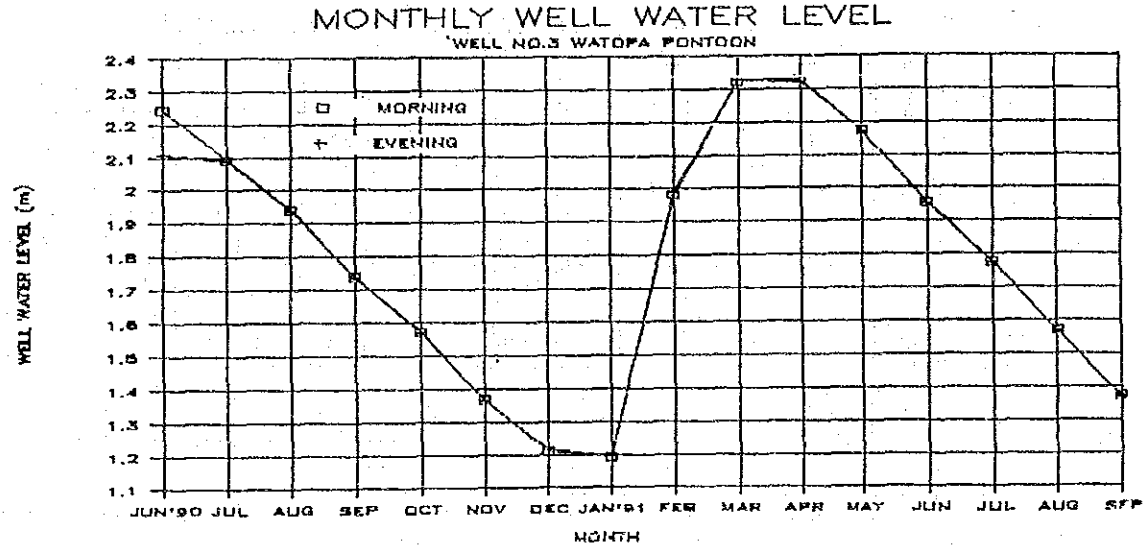


Fig.-3.3(2) Monthly Water Level Fluctuation (No. 2 Kanyaimba)





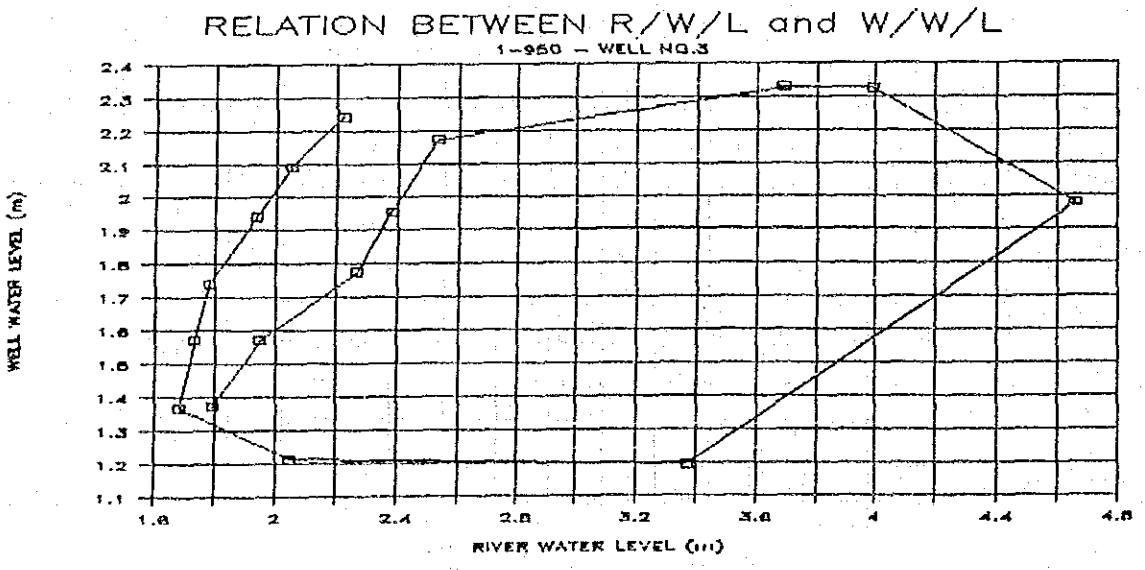


Fig.-3.3(3) Monthly Water Level Fluctuation
(No. 3 Watopa Pontoon)

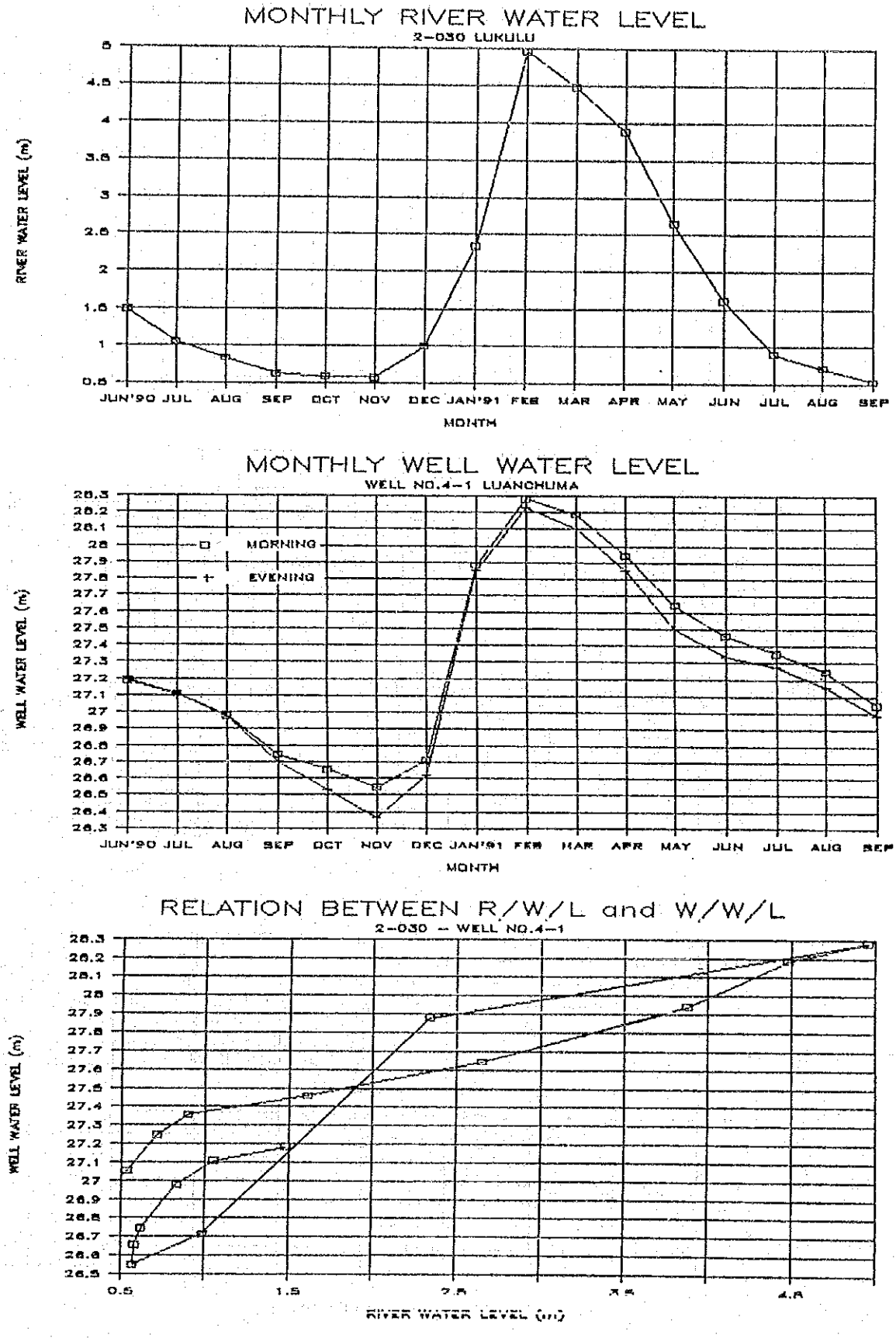


Fig.-3.3(4) Monthly Water Level Fluctuation (No. 4-1 Luanchuma)

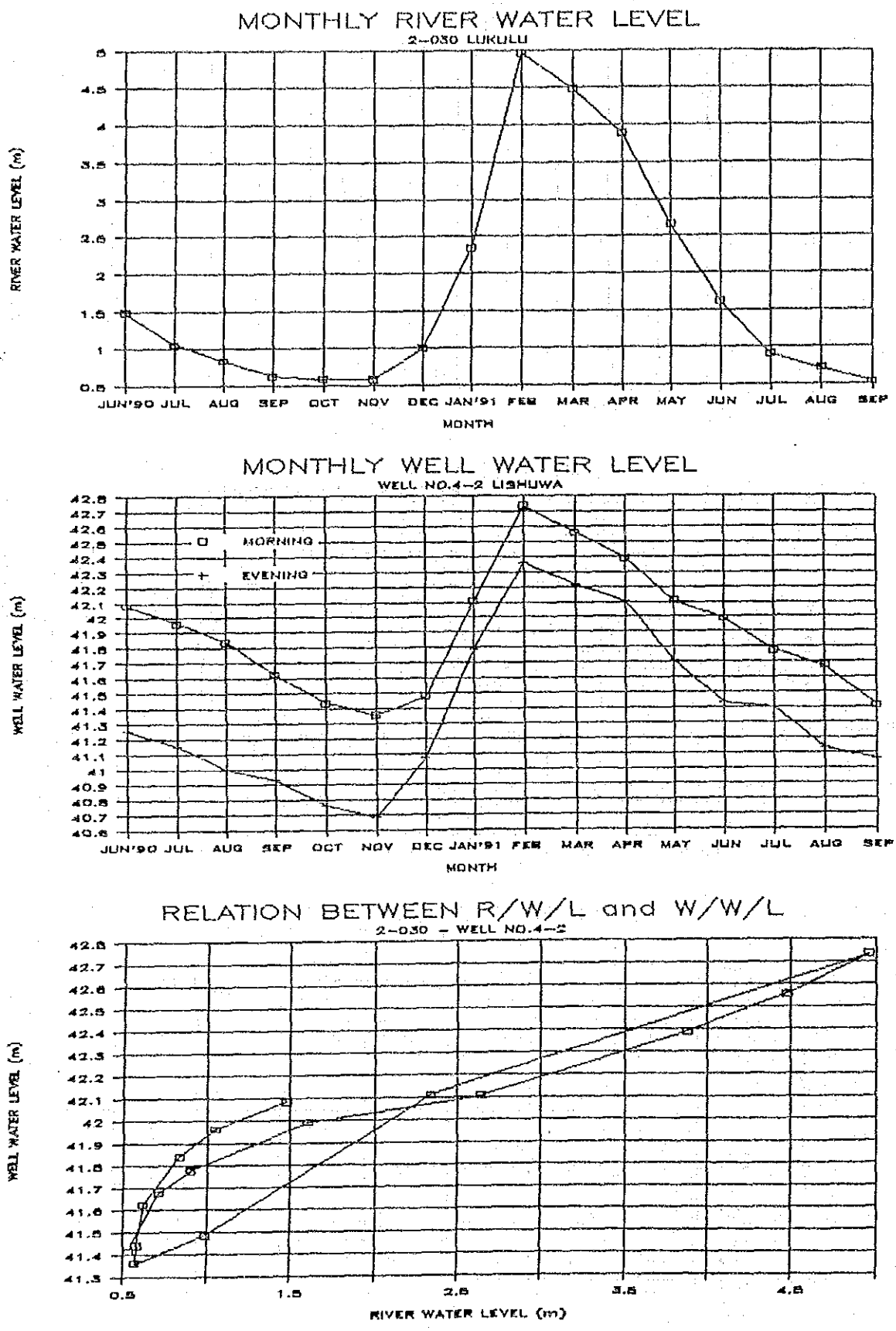


Fig.-3.3(5) Monthly Water Level Fluctuation (No. 4-2 Lishuwa)

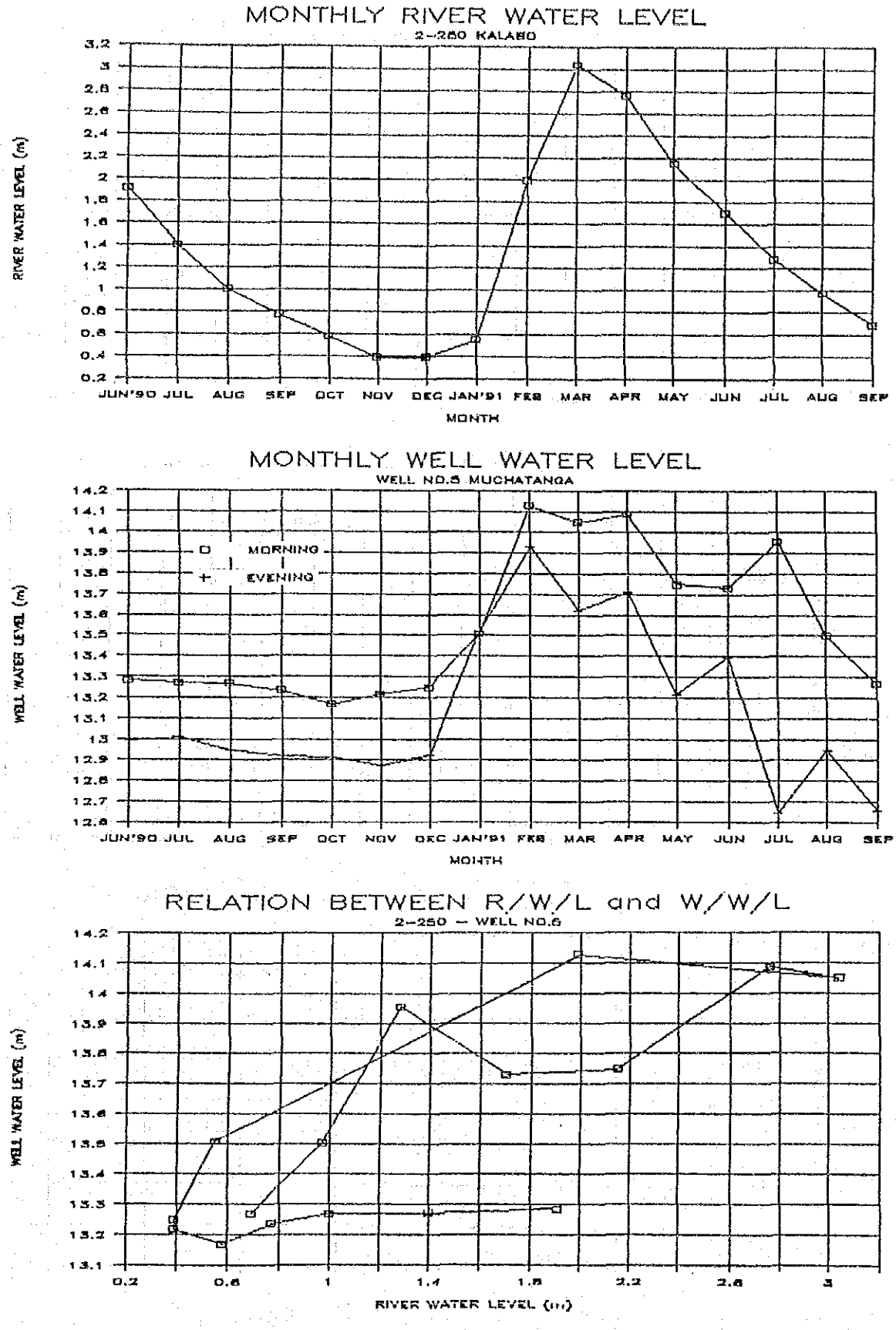
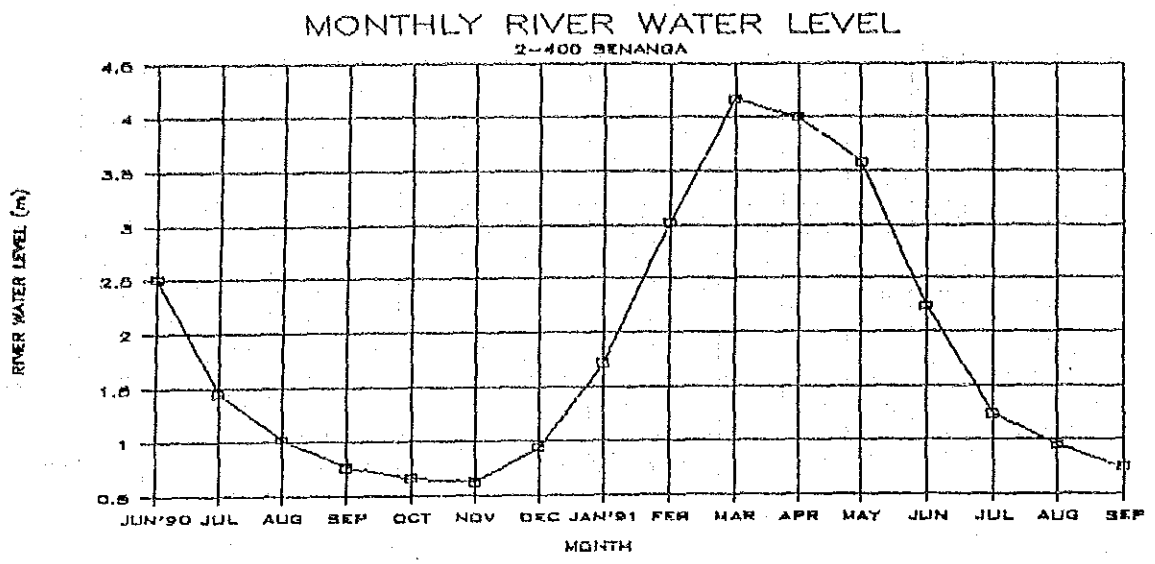
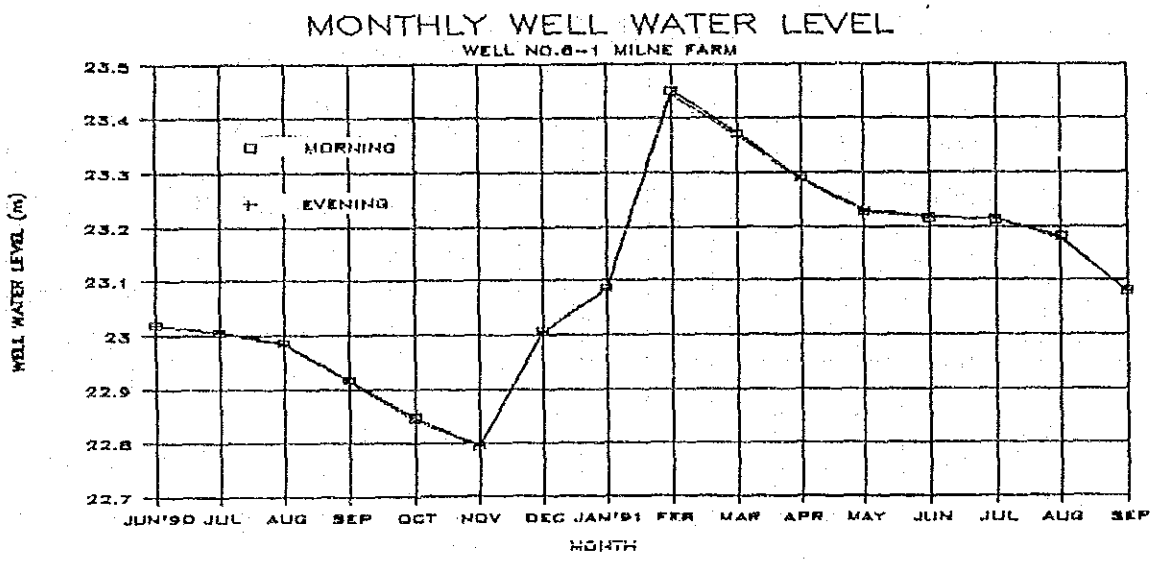


Fig.-3.3(6) Monthly Water Level Fluctuation (No. 5 Muchatanga)





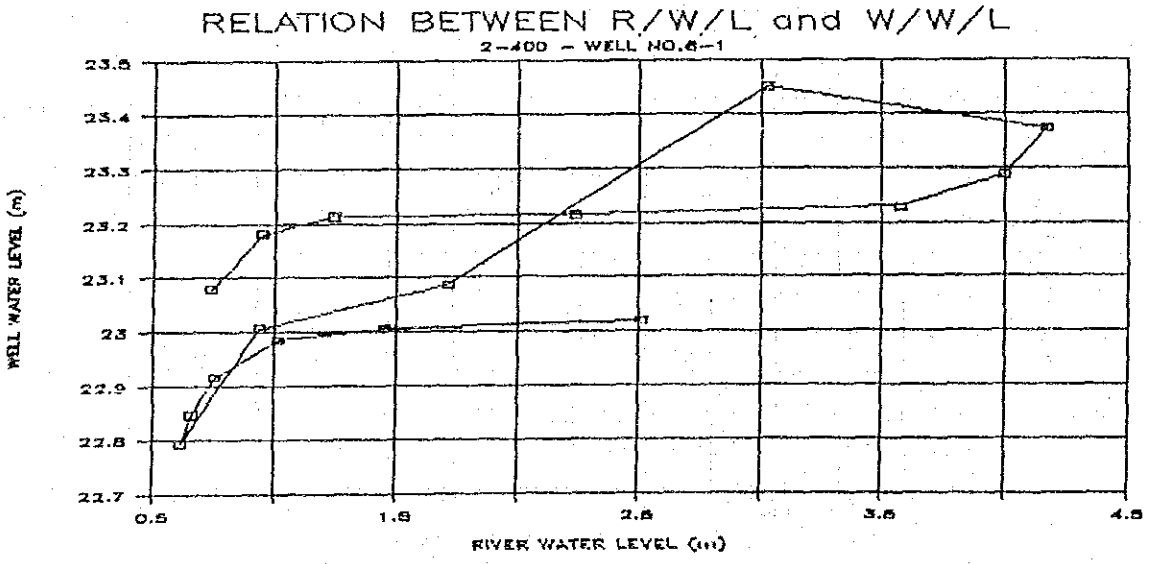


Fig.-3.3(7) Monthly Water Level Fluctuation (No. 6-1 Milne Farm)

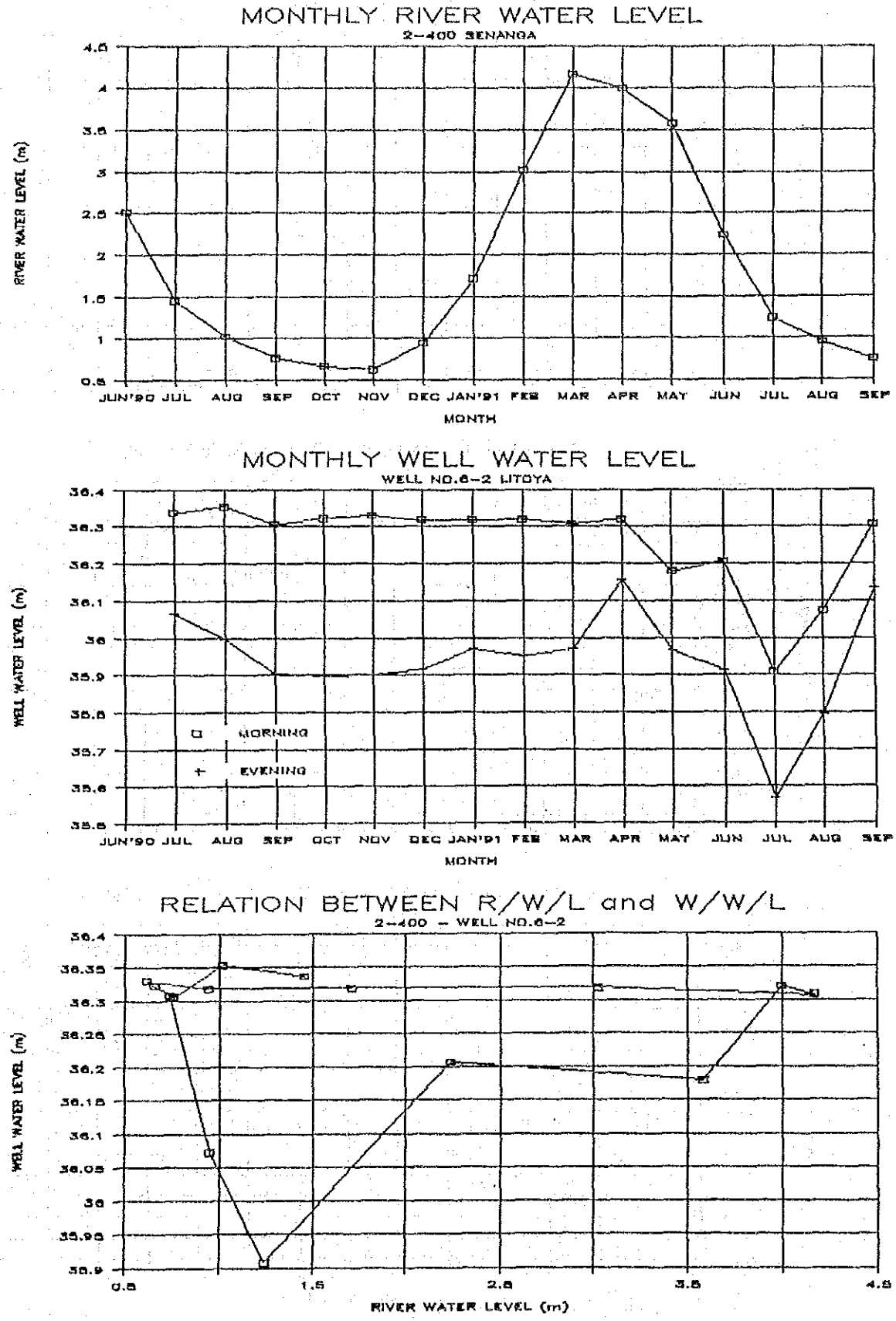
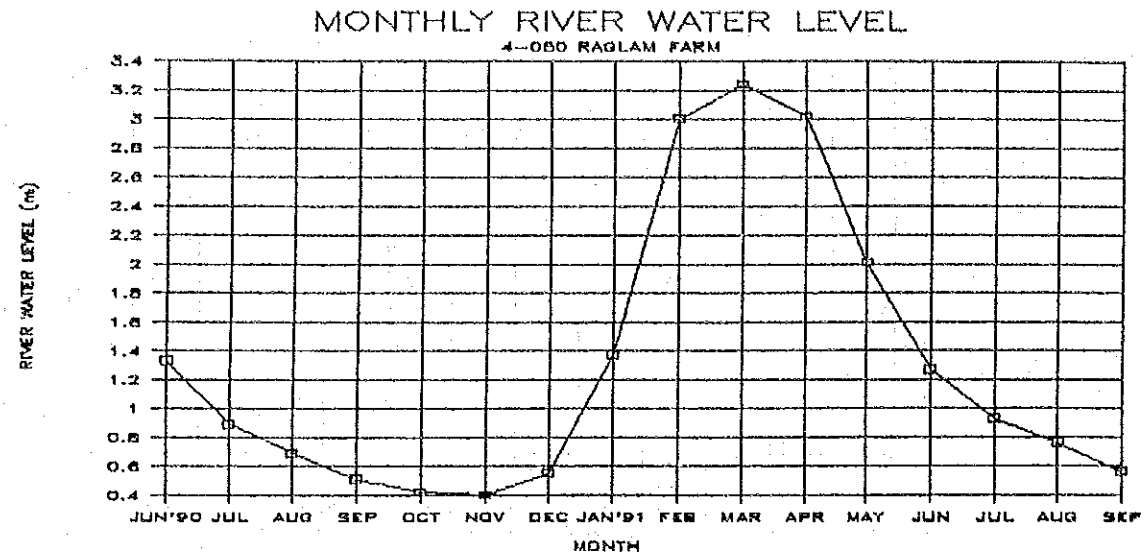
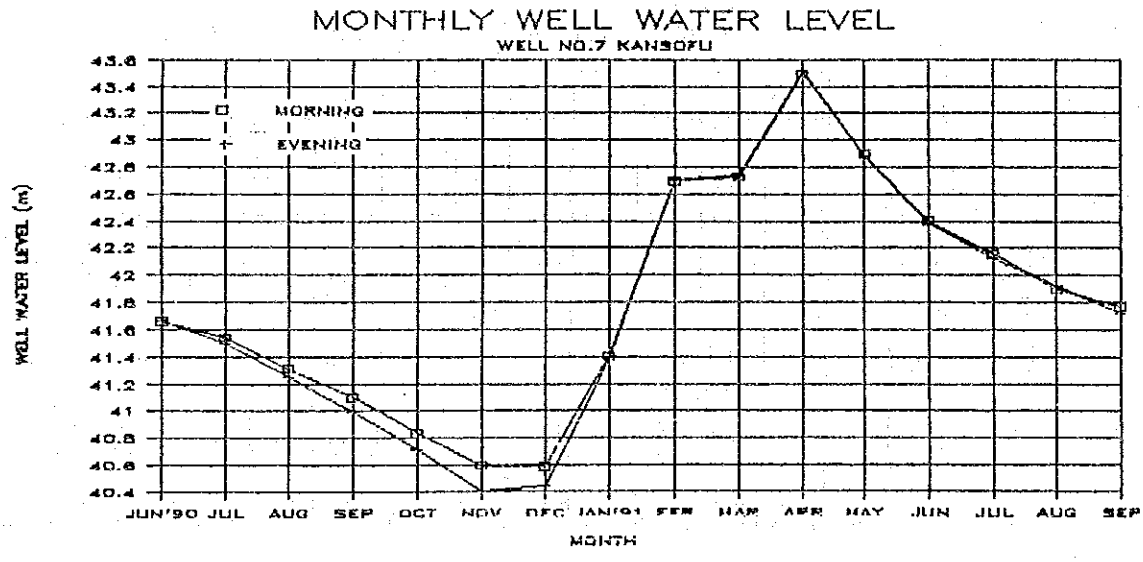


Fig.-3.3(8) Monthly Water Level Fluctuation (No. 6-2 Litoya)





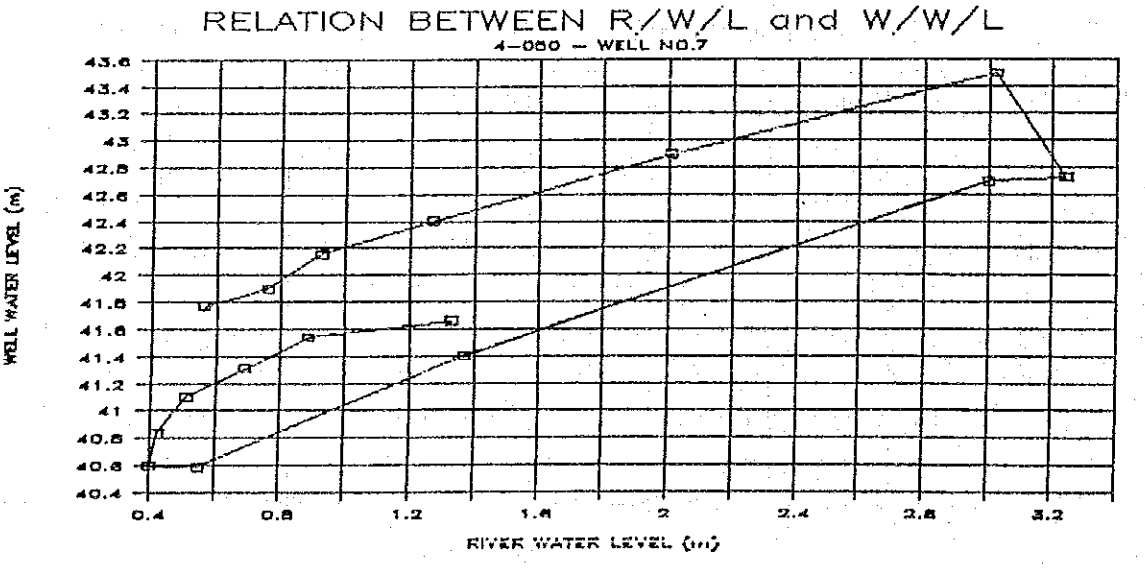


Fig.-3.3(9) Monthly Water Level Fluctuation (No. 7 Kansofu)

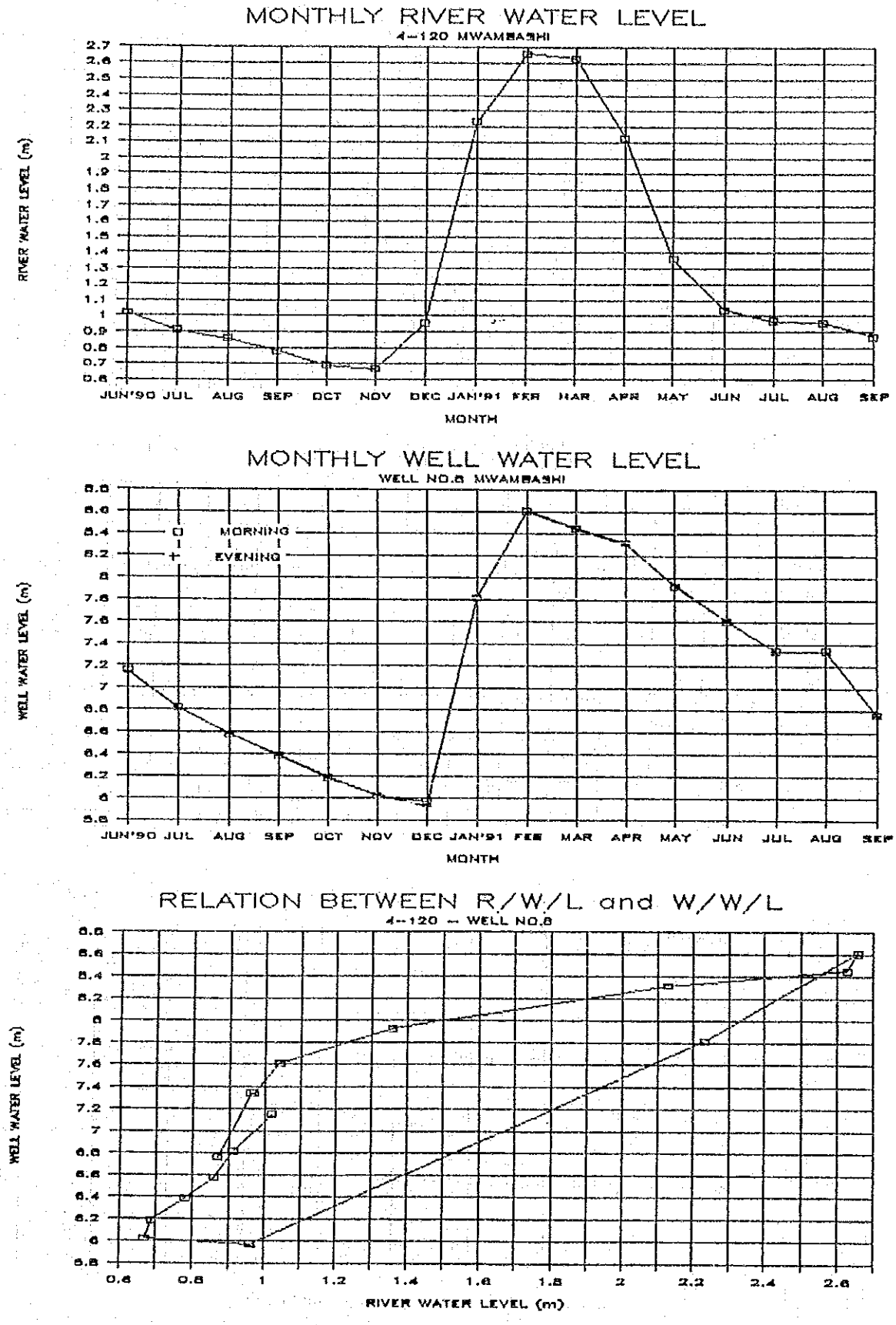


Fig.-3.3(10) Monthly Water Level Fluctuation (No. 8 Mwambashi)

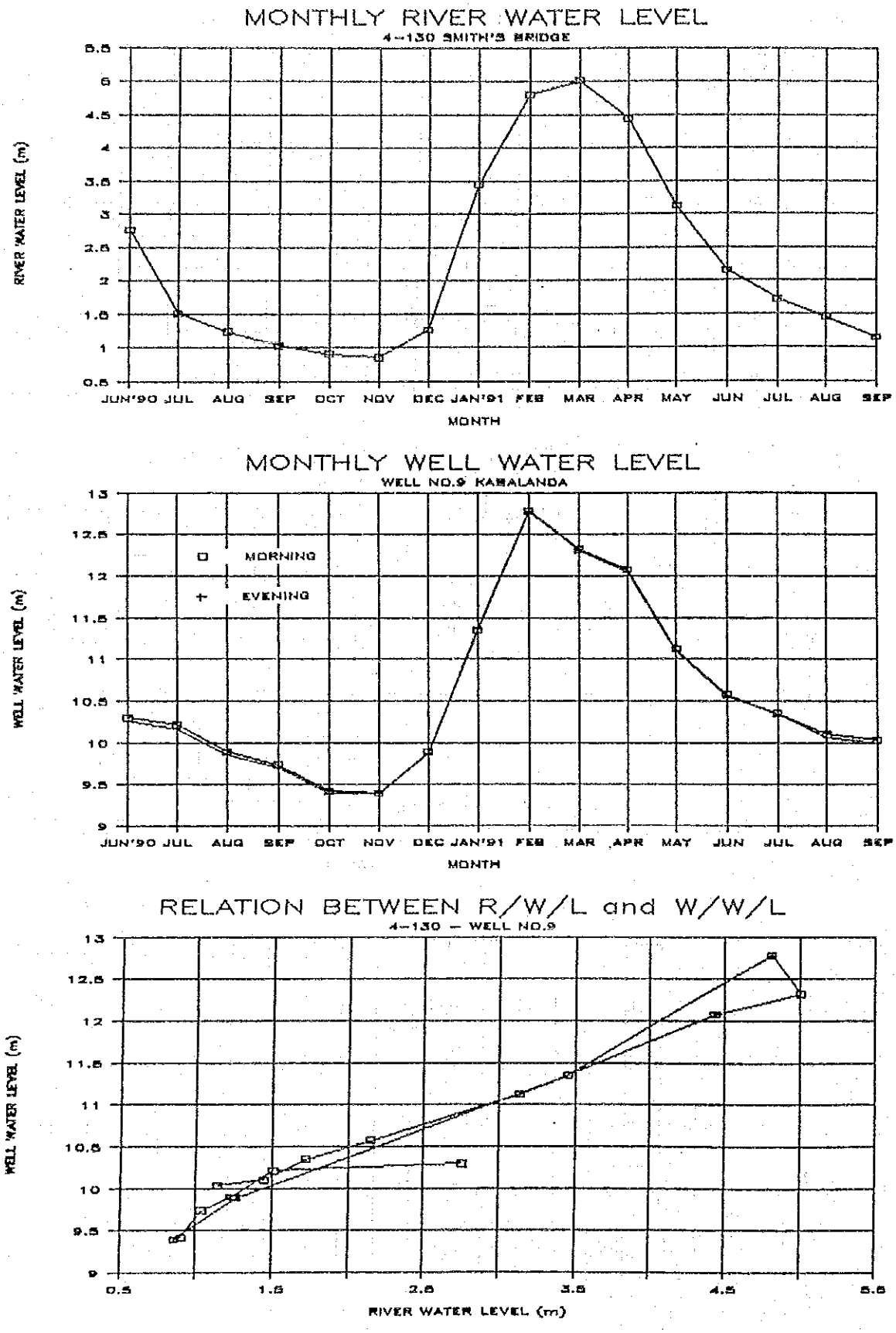
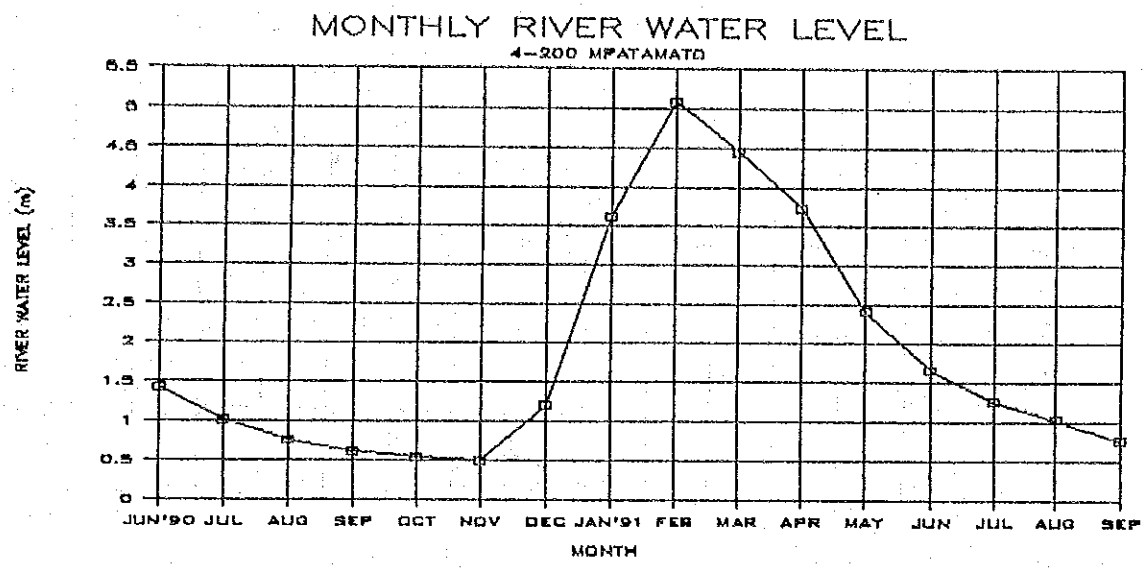
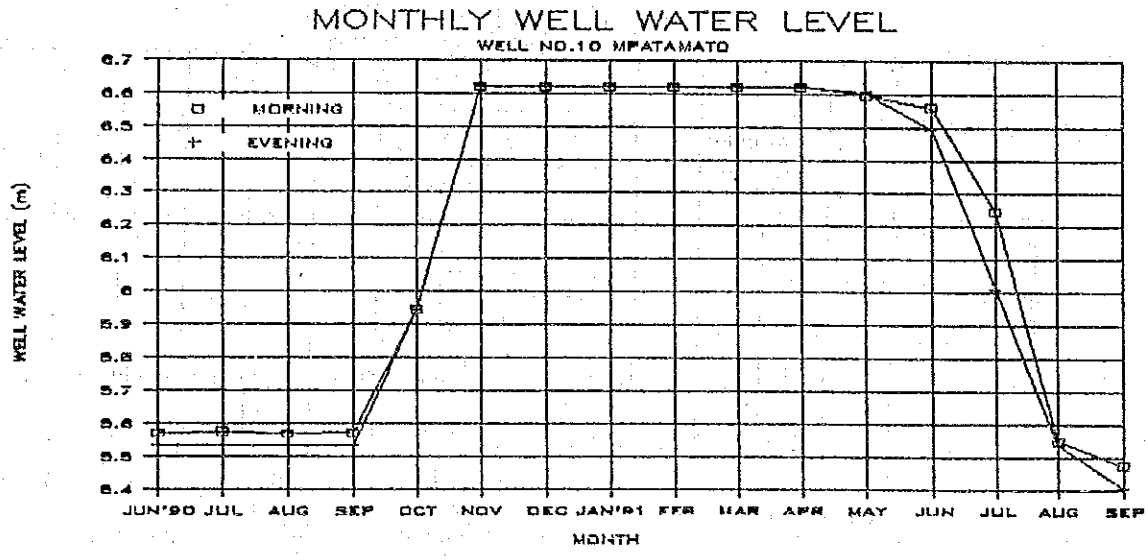


Fig.-3.3(11) Monthly Water Level Fluctuation (No. 9 Kabalanda)





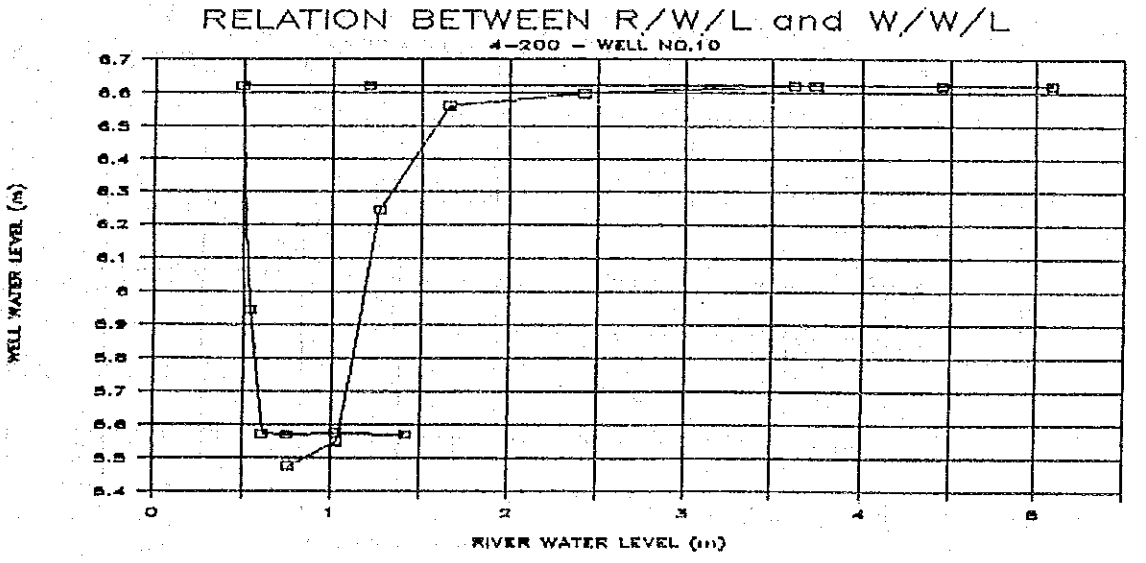
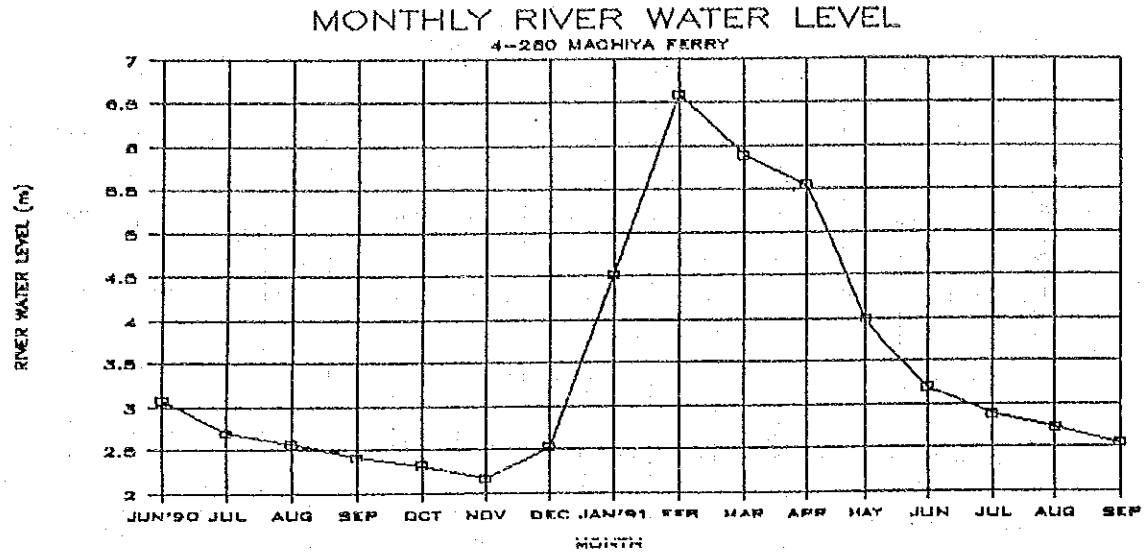
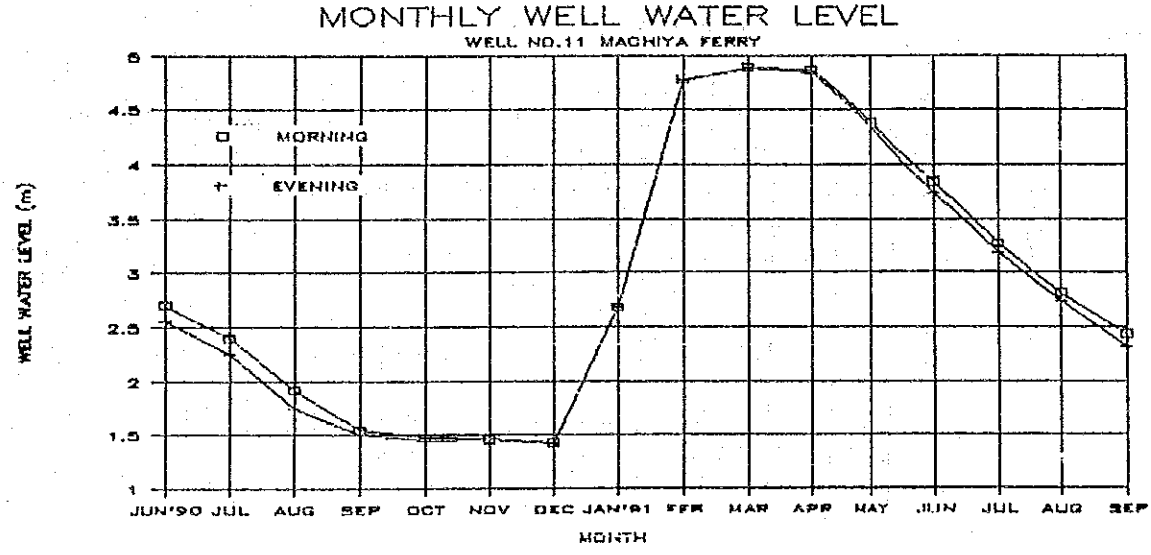


Fig.-3.3(12) Monthly Water Level Fluctuation (No. 10 Mpatamato)





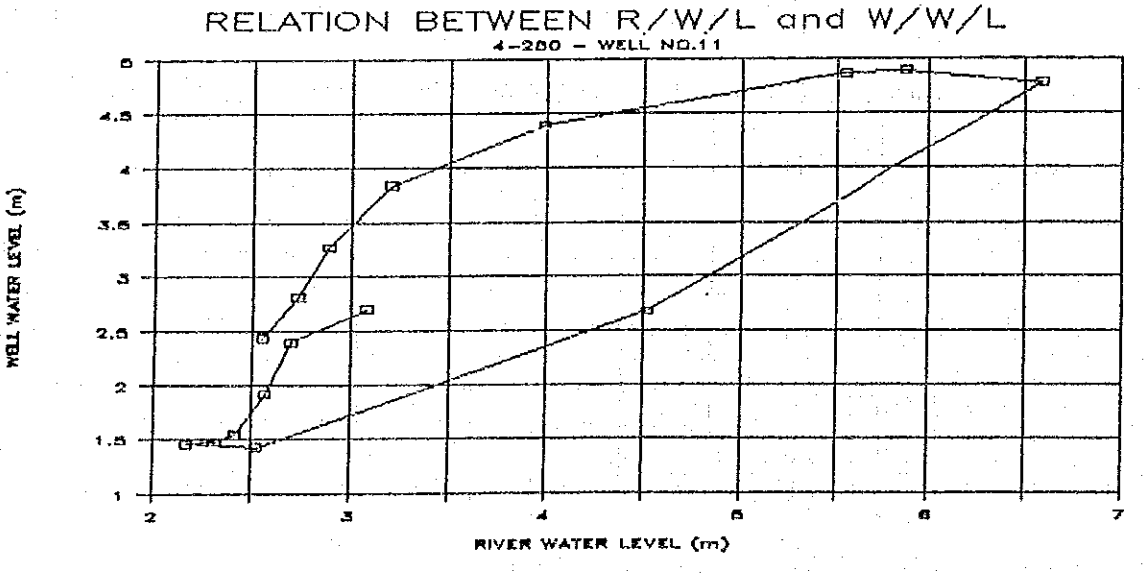


Fig.-3.3(13) Monthly Water Level Fluctuation
(No. 11 Machiya Ferry)

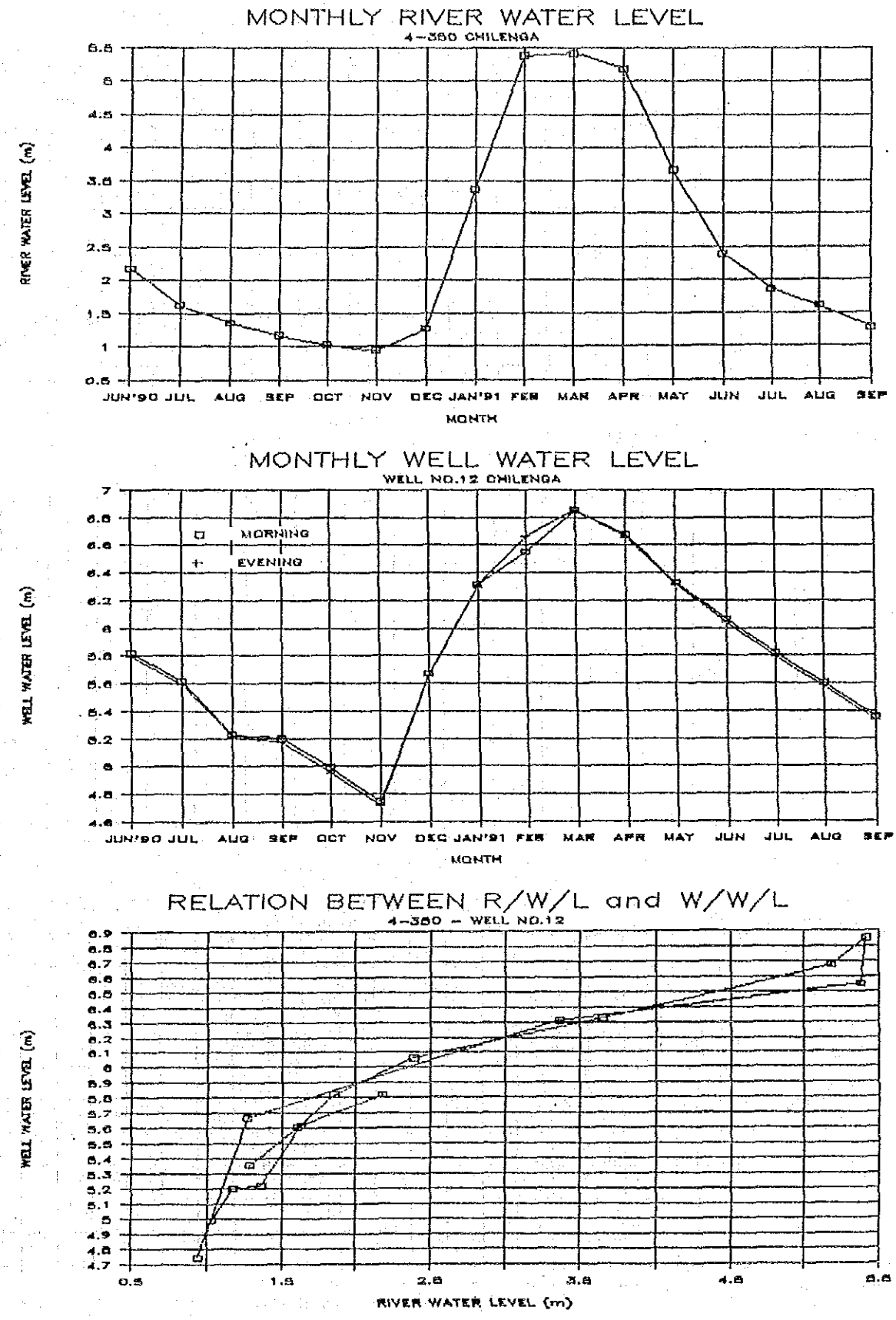
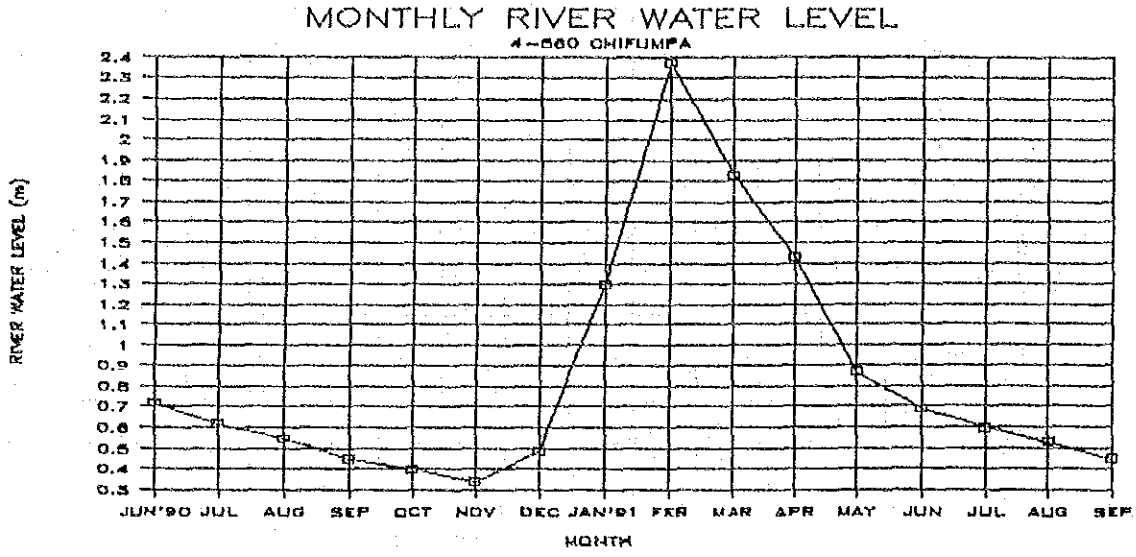
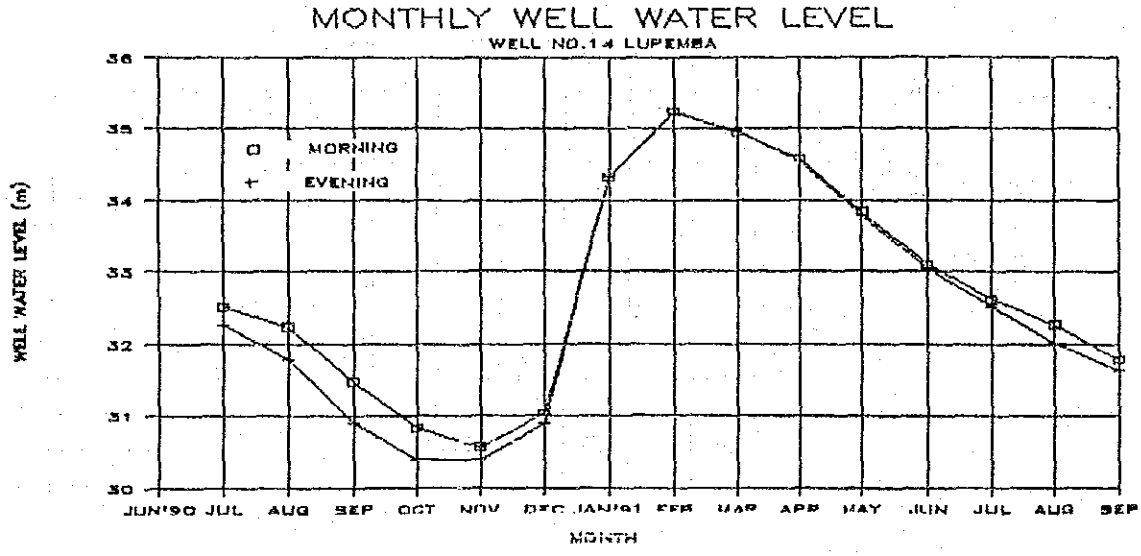


Fig.-3.3(14) Monthly Water Level Fluctuation (No. 12 Chilenga)





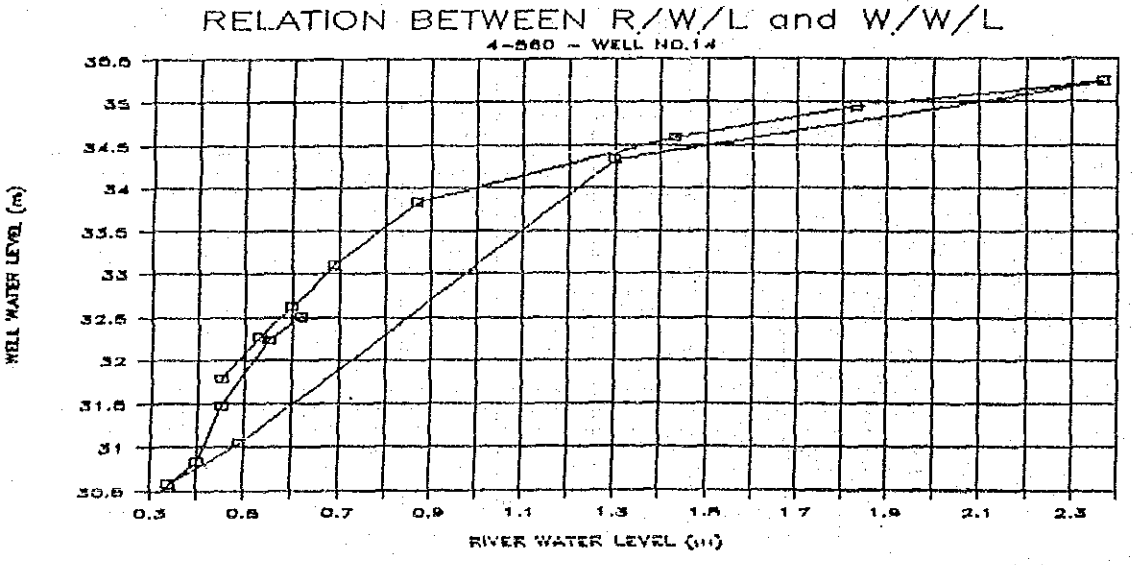
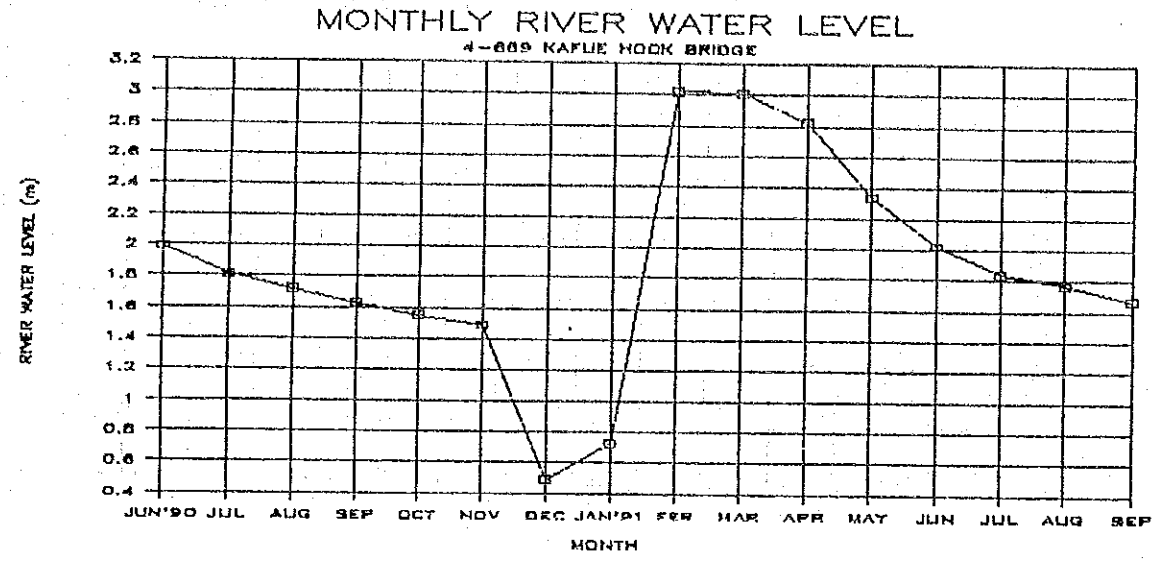
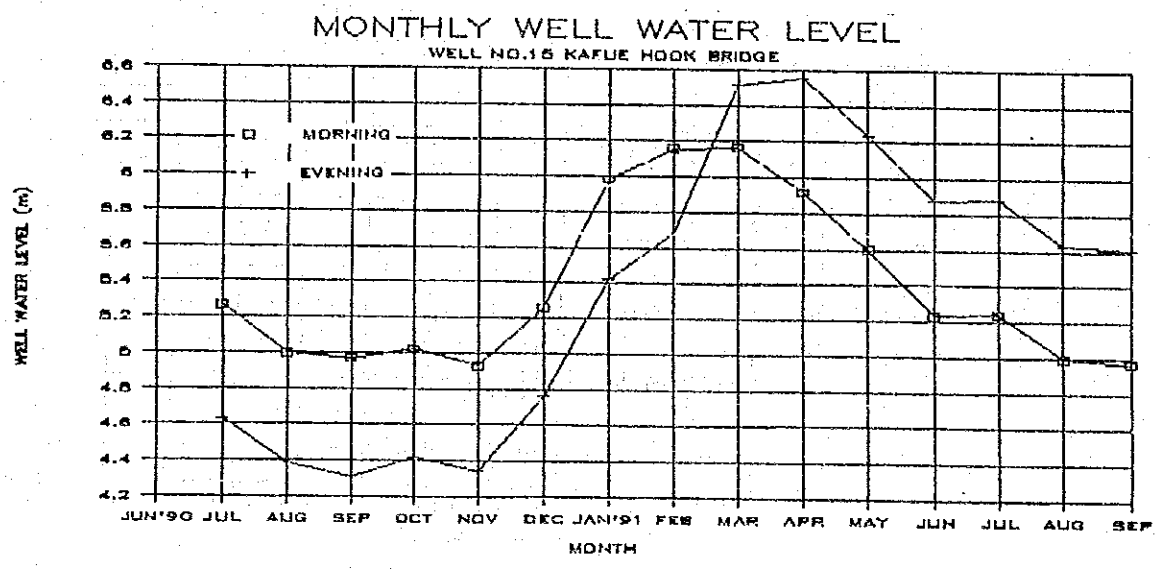


Fig.-3.3(15) Monthly Water Level Fluctuation (No. 14 Lupemba)





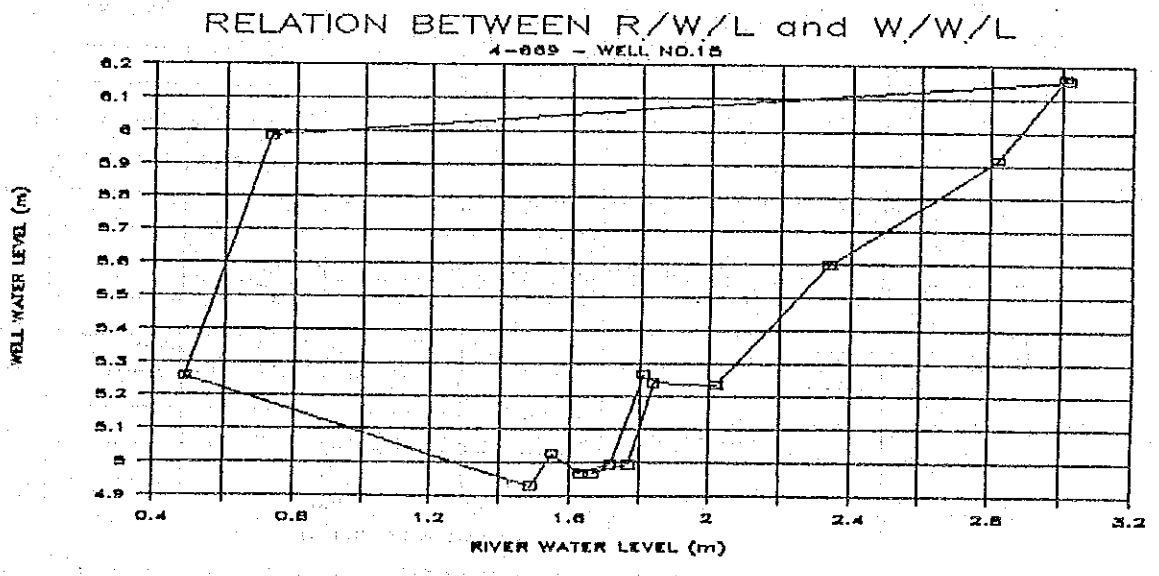
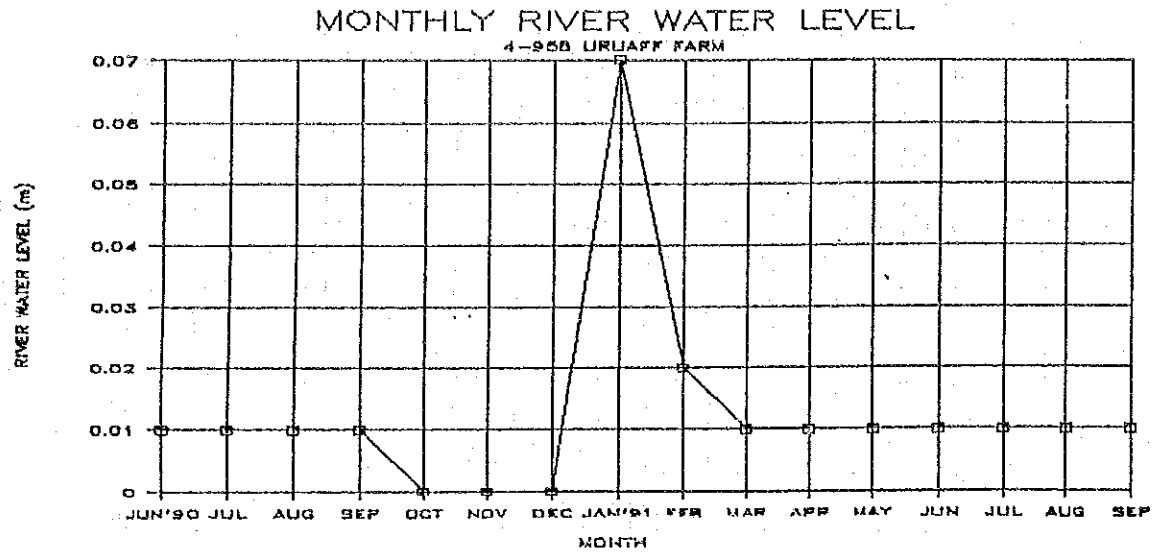
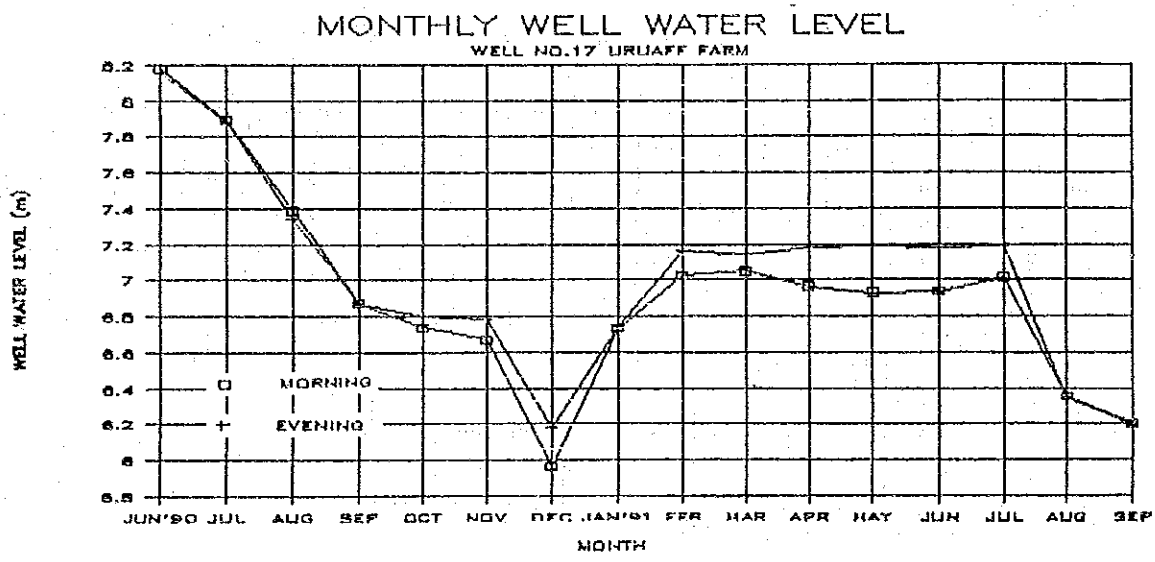


Fig.-3.3(16) Monthly Water Level Fluctuation
(No. 16 Kafue Hook Bridge)





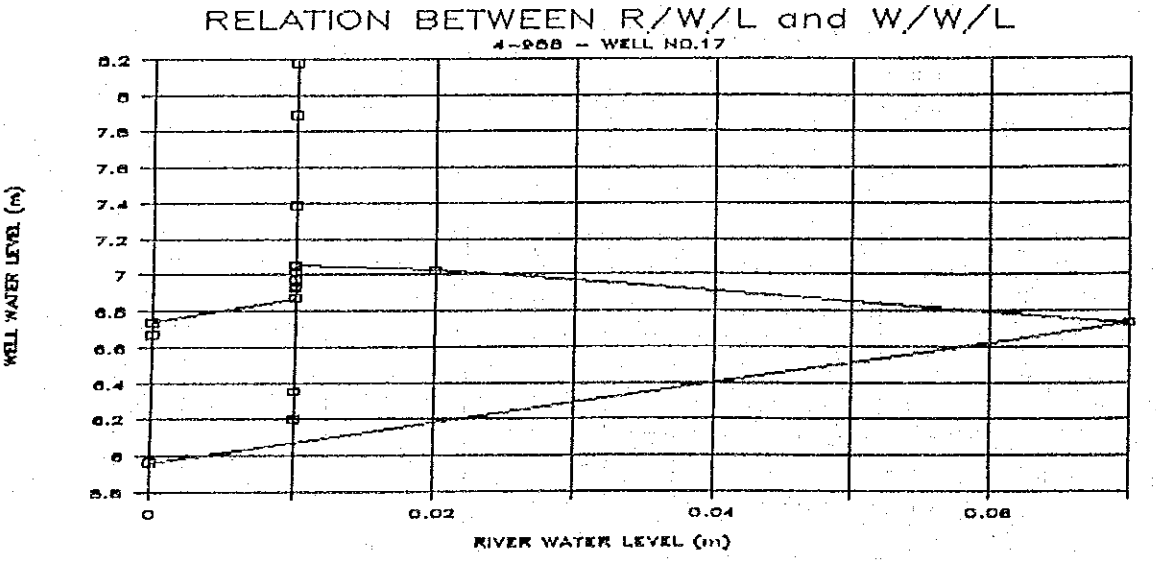


Fig.-3.3(17) Monthly Water Level Fluctuation (No. 17 Kanyilaba)

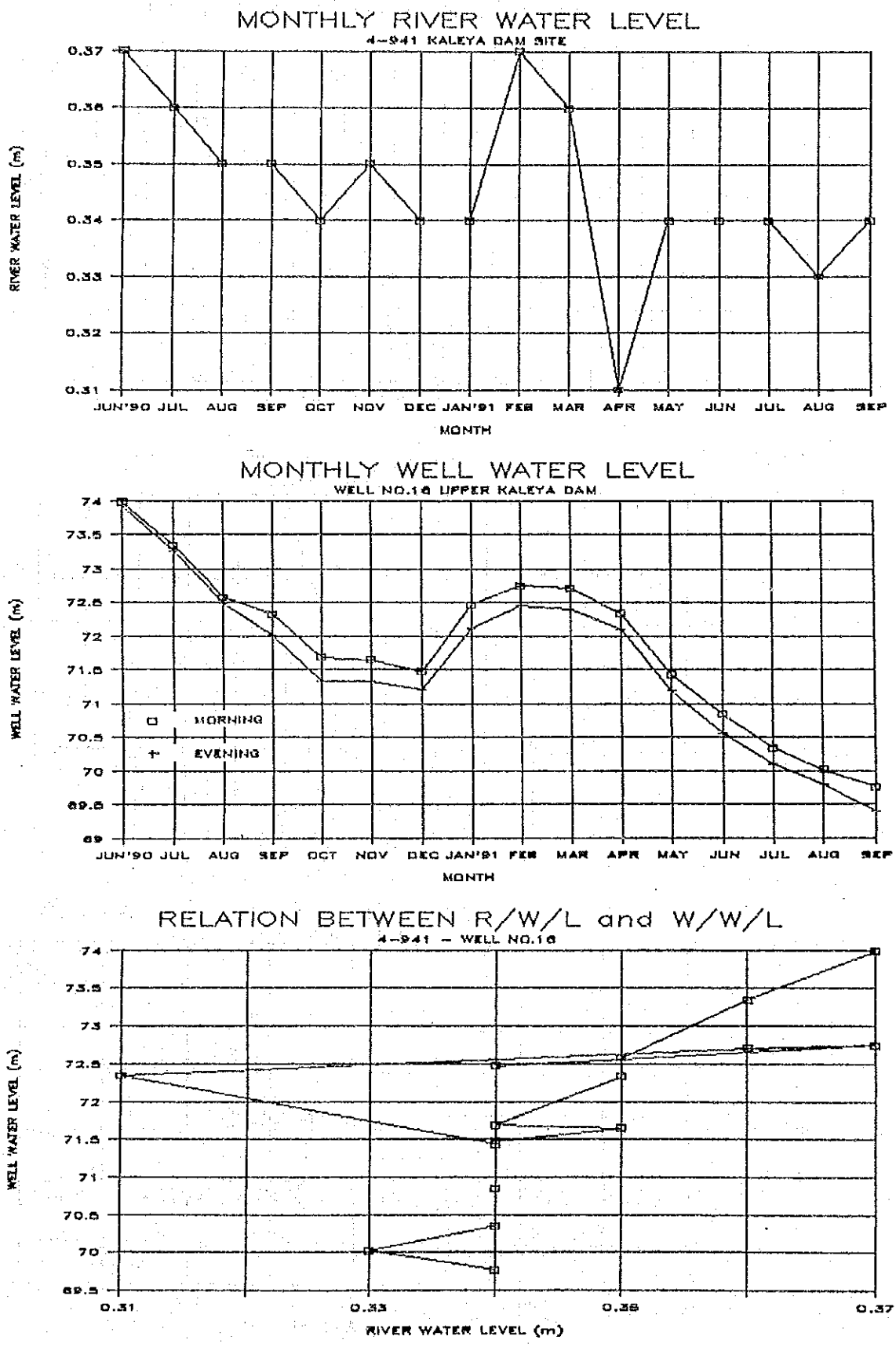


Fig.-3.3(18) Monthly Water Level Fluctuation (No. 18 Uruaff Farm)

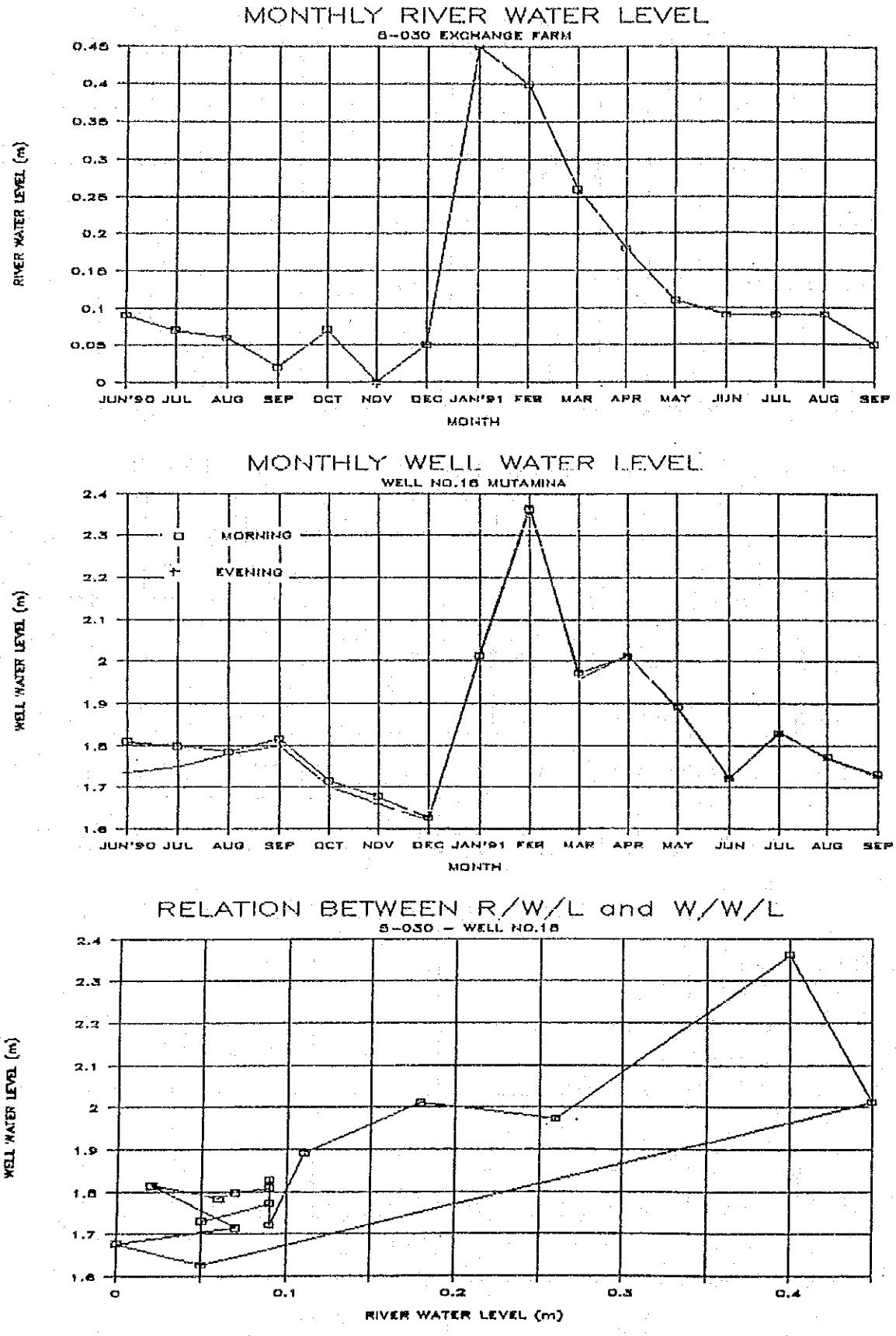


Fig.-3.3(19) Monthly Water Level Fluctuation (No. 19 Mutamina)

4 WATER QUALITY INVESTIGATION

4.1 Water Sampling

(1) Time Schedule of Sampling

To generally comprehend the water quality of main streams, the programs for water sampling and testing were executed through the following three (3) seasons.

1) 1st Program: (1990,Jun. and Jul.)
   in Dry Season
2) 2nd Program: (1990,Dec., 1991,Jan. and Feb.)
   in Rainy Season
3) 3rd Program: (1991,Aug. and Sep.)
   in Dry Season

The 1st Program was the original program proposed at the beginning of this Study. However, in response to a request from the Counterpart the 2nd and 3rd Program were additionally formulated, in order to study the pollutant loads from mining operations in rainy season that the 1st program could not detect during the dry season.

(2) Sampling Points

The water sampling and testing were carried out at the following points.

1) 56 points on the Kafue River
   including the following 6 Hydrometric Stations
   + Point No.2 : Raglam Farm (4-050)
   + Point No.30 : Mpatamato (4-200)
   + Point No.43 : Machiya Ferry (4-280)
   + Point No.45 : Chilenga (4-350)
   + Point No.50 : Chifumpa Pontoon (4-560)
   + Point No.51 : Lubungu (4-450)

2) 2 points on the Luangwa River
   including the following Hydrometric Station
   + Point No.102: Luangwa Bridge (5-940)

3) 8 points at the main stream of the Zambezi River
   including the following 6 Hydrometric Stations
   + Point No.201: Zambezi Pump House (1-150)
   + Point No.202: Kabompo Boma (1-650)
   + Point No.203: Watopa Pontoon (1-950)
   + Point No.204: Lukulu (2-030)
   + Point No.205: Kalabo (2-250)
   + Point No.206: Senanga (2-400)

The locations of the points are shown in Fig.-4.1. The locations of hydrometric stations are referred to in Chapter-2.

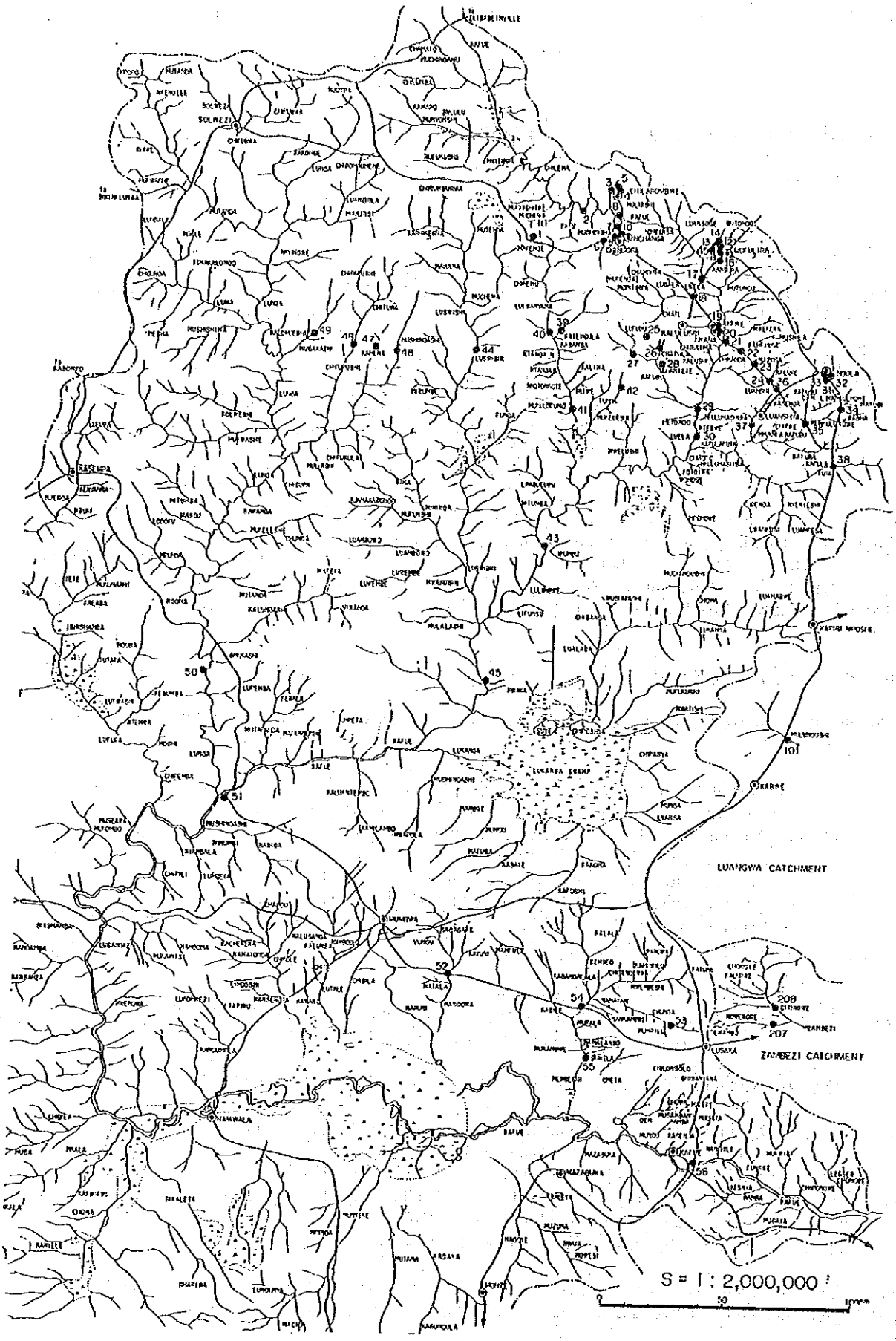


Fig-4.1 Sampling Points of Water Quality Test

4.2 Water Quality Tests

4.2.1 Test Items

General items and special items as shown in Table-4.1 were tested in water quality test programs.

Water quality tests for general items were carried out at all the points mentioned above. However, test for special items were made at the selected points.

Table-4.1 Test Items for Water Quality

Test Items	Unit	1st Program	2nd Program	3rd Program
<< General Items >>				
1) Temperature (Temp)	Deg.C	O	O	O
2) Turbidity (Turb)	mg/lit.	O	O	O
3) Hydrogen Ion (pH)	-	O	O	O
4) Ele.Conductivity (EC)	mv/cm	O	O	O
5) Dissolved Oxygen (DO)	mg/lit.	O	O	O
6) Chloride Ion (Cl-)	mg/lit.	O	O	O
7) Copper Ion (Cu2+)	mg/lit.	O	O	O
8) Manganese Ion (Mn2+)		-	O	O
<< Special Items >>				
1) Total Iron (Fe)	mg/lit.	O	-	-
2) Total Copper (Cu)	mg/lit.	O	-	-
3) Total Manganese (Mn)	mg/lit.	O	-	-
4) Arsenic (As)	mg/lit.	O	-	-
5) Cadmium (Cd)	mg/lit.	O	-	-
6) Lead (Pb)	mg/lit.	O	-	-

[Note] O: done, -: not done

4.2.2 Test Methods

(1) General Items

Regarding five (5) items (Temperature, Turbidity, Hydrogen Ion, Electric Conductivity and Dissolved Oxygen), just after sampling, the water samples were measured in the field by the Water Checker (Horiba Co.,Ltd.,Japan). Furthermore, the water samples were measured again in the laboratory to determine changes in the water quality.

In the 1st Program, chloride ions and copper ions of the same water sample were analyzed by the Ion Meter (Horiba Co.,Ltd.,Japan). The quantitative limit of the Ion Meter for analyzing both ions is 0.15 mg/lit. In the 2nd and 3rd Program, copper and manganese ions were analyzed by the German-made Photometer (quantitative limit: 0.1 mg/lit.). Also in 2nd and 3rd pograms chloride ions were analyzed by the Volumetric Titration Method (quantitative limit: 0.3 mg/lit.).

(2) Special Items

The water samples were analyzed by a simplified detecting tube ("Yoshitest", Yoshitomi Seiyaku Co., Ltd., Japan). The quantitative limits for total iron, total copper, total manganese and arsenic were 0.5 mg/lit., and for cadmium, 0.1 mg/lit. Because chemical constituents change to insoluble salts, such as hydroxides, after sampling and are suspended in insoluble matter, the water samples were acidified with sulfuric acid before being analyzed.

4.2.3 Test Results

All the test results of water quality are shown in Table-4.2 and 4.3 for general items and 4.4 for special items. The summaries of test results are as follows.

1) A total number of 279 water samples were tested, including 66 tests in the laboratory.
2) The main pollutant source (organic and non-organic) to rivers in the Copperbelt areas is the waste water produced by the mining work and related activities. The contamination caused by this pollutant source was found at some points in these areas.
3) Judging from the test results, the pollution caused at the upper Kafue River does not affects the middle and lower stream due to self purification system of Kafue River.
4) In some tributaries around Lusaka affected by the municipal waste water, there is active overgrowth of plants and algae. The water is contaminated with organic pollution causing the eutrophication at some dead water areas.
5) The water quality of the main streams of Zambezi and Luangwa River is good.
6) The water quality in rainy season shows higher turbidity

than that in dry season. On the contrary, chloride ion in rainy season is lower than that in wet season, generally.

7) Ions of copper and manganese etc. are found in the waste water form mining and some points of river water affected by this in the Copperbelt areas. But these ions are not found in the middle and lower reaches of the Kafue River.

Table-4.2 Test Results of General Items

Test Items	Data Items	Test Results			
		1-Pgm	2-Pgm	3-Pgm	Total
1) Temperature [Temp] (Deg.C)	Nu.of Sample	121	98	60	279
	Max.	25.4	33.9	31.7	33.9
	Min.	14.7	17.0	17.2	14.7
	Average	19.9	23.8	20.0	21.3
2) Turbidity [Turb] (mg/lit)	Nu.of Sample	109	98	60	267
	Max.	257	399	330	399
	Min.	2	2	1	1
	Average	12	44	24	26
3) pH value [pH]	Nu.of Sample	120	97	59	276
	Max.	8.6	9.5	8.6	9.5
	Min.	5.9	5.4	6.2	5.4
	Average	7.5	7.9	8.0	7.7
4) Ele.Conductivity [EC] (mv/cm)	Nu.of Sample	110	97	60	267
	Max.	1.9	2.9	2.0	2.9
	Min.	0.1	0.2	0.2	0.1
	Average	0.9	1.0	0.8	0.9
5) Dissolved Oxygen [DO] (mg/lit)	Nu.of Sample	111	96	42	249
	Max.	12.3	18.0	10.7	18.0
	Min.	0.7	0.1	0.5	0.1
	Average	7.4	5.2	6.6	6.4
6) Chloride Ion [Cl-] (mg/lit)	Nu.of Sample	41	93	6	140
	Max.	53.6	18.0	3.0	53.6
	Min.	0.6	0.0	0.6	0.0
	Average	6.4	1.0	2.4	2.7
7) Copper Ion [Cu2+] (mg/lit)	Nu.of Sample	42	93	60	195
	Max.	6.3	51.0	38.0	28.0
	Min.	0.0	0.0	0.0	0.0
	Average	0.3	0.8	2.4	0.4
8) Manganese Ion [Mn2+] (mg/lit)	Nu.of Sample	-	93	59	152
	Max.	-	28.0	27.0	28.0
	Min.	-	0.0	0.0	0.0
	Average	-	0.3	0.5	0.4

	Sampling Year/Month	'90/Jun	'91/Feb	'91/Aug	Average
Average Monthly Discharge (m3/s)	4-050 Raglam Farm	12.9	57.5	3.9	30.4
	4-200 Mpatamato	31.9	245.6	21.2	92.1
	4-280 Machiya Ferry	47.0	341.5	32.4	105.8
	4-350 Chilenga	60.6	336.3	36.8	167.1
	4-450 Lubungu	67.9	290.3	38.5	168.4
	4-560 Chifumpa Pon.	41.6	220.7	30.4	110.0

Table-4.3 Water Quality Test Results (General Items) - 1/7

River Basin	NO.	Sampling Points	Sample No.	Sampling Date D:M:Y	Sampling Time h:m	Test Date D:M:Y	Temp. deg. C	Turb. mg/l	pH	E.C. mV/cm	DO mg/l	cl mg/l	Cu2+ mg/l	Mn2+ mg/l
Kafue	1	Muchishi R.	1-a-1	20:06:90	10:10	on spot	18.1	7	7.8	0.5	6.7	-	-	-
			1-a-2	20:06:90	10:10	04:07:90	21.2	11	8.2	0.8	8.2	1.0	0.0	-
			1-b-1	05:12:90	12:45	on spot	23.0	9	8.6	0.8	3.2	0.0	0.0	0.0
			1-c-1	06:08:91	12:45	on spot	22.0	42	7.1	0.6	-	-	0.0	0.0
	2	Raglam Farm (St. 4-050)	2-a-1	06:06:90	16:30	on spot	23.0	2	7.7	1.0	7.7	-	-	-
			2-a-2	06:06:90	16:30	14:06:90	17.7	4	8.0	0.8	7.6	3.3	0.0	-
			2-b-1	05:12:90	12:04	on spot	24.0	4	8.3	0.9	6.2	2.5	0.0	0.0
			2-b-2	14:02:91	12:47	on spot	26.5	50	7.6	0.9	2.9	0.0	0.0	0.0
			2-c-1	06:08:91	13:15	on spot	24.0	25	8.6	0.7	-	-	0.0	0.0
	3	Man Made Channel	3-a-1	20:06:90	11:50	on spot	19.1	3	8.3	1.1	9.0	-	-	-
			3-b-1	05:12:90	12:15	on spot	20.0	4	8.4	1.4	7.1	0.0	0.0	0.0
			3-b-2	14:02:91	11:06	on spot	24.5	28	8.3	0.8	6.0	0.0	0.0	0.0
			3-c-1	06:08:91	15:39	on spot	22.0	30	8.5	0.8	-	-	19.0	0.0
	4	Konkola Slime Dam	4-a-1	20:06:90	11:40	on spot	20.5	7	7.8	1.0	7.8	-	-	-
			4-b-1	05:12:90	12:20	on spot	22.0	9	9.1	2.2	6.5	0.0	0.0	0.0
			4-b-2	14:02:91	11:13	on spot	24.9	40	8.5	0.9	4.7	0.0	0.0	0.0
			4-c-1	06:08:91	15:50	on spot	20.0	21	7.4	1.1	-	-	12.0	0.0
	5	Stream (from Slime Dam)	5-a-1	20:06:90	11:40	on spot	19.0	6	7.6	1.1	7.6	-	-	-
			5-b-1	05:12:90	12:30	on spot	23.0	68	8.2	2.9	6.3	0.0	0.0	0.0
			5-b-2	14:02:91	11:00	on spot	23.5	70	7.6	0.8	4.4	0.0	0.0	0.0
			5-c-1	06:08:91	16:50	on spot	18.0	55	8.0	0.7	-	-	15.0	0.0
	6	Mushishima R	6-a-1	20:06:90	09:30	on spot	14.9	3	8.0	1.0	7.4	-	-	-
			6-a-2	20:06:90	09:30	04:07:90	21.1	7	7.4	0.9	7.8	0.9	0.0	-
			6-b-1	05:12:90	10:16	on spot	17.0	41	7.8	1.1	7.1	0.0	0.0	0.0
			6-b-2	14:02:91	12:00	on spot	23.0	34	7.0	0.7	4.9	18.0	0.0	0.1
			6-c-1	06:08:91	16:45	on spot	19.0	31	7.8	0.8	-	-	0.0	0.0
	7	Stream (Waste Water)	7-a-1	20:06:90	10:45	on spot	25.1	257	7.8	1.9	7.0	-	-	-
			7-a-2	20:06:90	09:30	28:06:90	23.8	-	6.7	1.8	5.8	14.0	6.3	-
			7-b-1	05:12:90	09:45	on spot	29.4	270	7.1	2.0	8.2	1.2	51.0	28.0
			7-b-2	14:02:91	14:48	on spot	28.7	9	5.4	2.6	5.2	0.0	0.0	0.0
			7-c-1	06:08:91	12:30	on spot	21.0	22	6.2	1.8	-	-	38.0	27.0
	8	Kafue R (Chililabombwe Rd. Bridge)	8-a-1	06:06:90	15:30	on spot	23.3	19	8.0	1.1	8.0	-	-	-
			8-a-2	06:06:90	15:30	14:06:90	17.7	15	7.5	1.0	7.6	-	-	-
			8-a-3	06:06:90	15:30	04:07:90	21.0	19	8.0	0.8	9.3	-	1.2	-
			8-a-4	20:06:90	11:00	on spot	21.4	67	8.3	1.2	7.0	2.5	-	-
			8-a-5	20:06:90	11:00	28:06:90	23.8	55	7.3	0.9	6.2	-	2.1	-
			8-b-1	05:12:90	11:54	on spot	25.2	22	8.5	1.1	0.5	0.0	1.0	0.2
			8-b-2	14:02:91	11:34	on spot	25.2	130	8.1	0.9	4.4	0.0	0.0	0.5
			8-c-1	06:08:91	11:30	on spot	20.7	29	8.4	1.1	-	-	0.2	0.3
	9	Stream (to Chingola R)	9-a-1	20:06:90	08:30	on spot	24.2	21	7.5	0.3	2.5	5.7	-	-
			9-a-2	20:06:90	08:30	04:07:90	20.8	8	6.7	0.2	5.9	-	0.0	-
			9-b-1	05:12:90	12:35	on spot	32.5	24	7.8	0.4	1.8	5.9	0.0	0.0
			9-b-2	14:02:91	11:45	on spot	25.6	40	7.8	0.7	4.9	0.0	0.0	0.0
			9-c-1	06:08:91	10:20	on spot	19.0	16	8.1	1.2	-	-	0.0	0.0

Table-4.3 Water Quality Test Results (General Items) - 2/7

River Basin	NO.	Sampling Points	Sample No.	Sampling Date D:M:Y	Sampling Time h:m	Test Date D:M:Y	Temp. deg. C	Turb. mg/l	pH	E.C. mv/cm	DO mg/l	cl mg/l	Cu2+ mg/l	Mn2+ mg/l
Kafue	10	Stream (near Nchanga Open Pit)	10-a-1	20:06:90	09:10	on spot	18.5	32	8.0	1.1	8.4	-	-	-
			10-a-2	20:06:90	09:10	01:07:90	24.1	22	7.3	1.0	5.7	9.1	0.4	-
			10-b-1	05:12:90	12:12	on spot	27.6	180	9.5	2.5	0.6	0.0	25.0	0.0
			10-b-2	14:02:91	15:25	on spot	25.8	46	7.5	0.8	5.6	0.0	0.0	0.0
			10-c-1	06:08:91	10:48	on spot	20.0	22	8.1	1.4	-	-	0.3	0.0
	11	Man Made Channel	11-a-1	20:06:90	13:50	on spot	25.4	34	8.7	1.2	6.2	-	-	-
			11-b-1	07:12:90	13:59	on spot	20.3	121	8.4	-	-	0.0	0.0	0.0
			11-b-2	14:02:91	15:25	on spot	28.1	47	8.2	0.9	5.3	0.0	0.0	0.0
			11-c-1	06:08:91	10:35	on spot	23.0	330	8.2	1.2	-	-	0.0	0.0
	12	Stream (to Mufulira R)	12-a-1	20:06:90	14:00	on spot	22.7	6	8.6	0.2	7.6	-	-	-
			12-a-2	20:06:90	14:00	25:06:90	22.0	3	7.4	0.1	4.8	-	-	-
			12-b-1	07:12:90	13:59	on spot	28.3	25	8.4	0.2	-	0.0	0.0	0.0
			12-b-2	13:02:91	12:12	on spot	30.5	25	8.5	0.2	4.3	15.0	0.2	0.0
			12-c-1	05:08:91	11:50	on spot	19.9	14	8.3	1.0	-	-	35.0	N.D.
	13	Stream (from Slime Dam)	13-a-1	20:06:90	14:00	on spot	21.0	9	8.4	1.2	8.7	-	-	-
			13-b-1	07:12:90	14:10	on spot	30.3	10	8.8	1.6	6.1	0.0	0.0	0.0
			13-b-2	13:02:91	12:20	on spot	25.7	15	7.9	0.4	5.2	0.0	0.3	0.0
			13-c-1	05:08:91	10:45	on spot	19.0	17	8.2	1.0	-	-	26.0	0.0
	14	Mufulira R	14-a-1	20:06:90	14:10	on spot	19.9	9	8.0	1.1	7.2	-	-	-
			14-b-1	07:12:90	09:40	on spot	30.3	8	8.1	1.2	7.2	0.0	0.0	0.0
			14-b-2	13:02:91	12:10	on spot	24.1	20	7.9	0.9	4.9	12.0	0.2	0.2
			14-c-1	05:08:91	11:32	on spot	19.8	15	8.0	1.0	-	-	0.0	0.0
	15	Mufulira R (after Confluence)	15-a-1	20:06:90	14:10	01:07:90	24.0	7	7.7	1.0	7.8	1.8	-	-
			15-b-1	07:12:90	09:27	on spot	31.2	4	7.3	0.7	2.4	0.0	0.0	0.0
			15-b-2	13:02:91	12:40	on spot	25.1	21	7.8	0.8	3.9	0.0	0.0	0.0
			15-c-1	05:08:91	12:15	on spot	22.0	12	8.5	2.0	-	-	0.0	0.0
	16	Kansunswa R	16-a-1	20:06:90	13:20	on spot	19.5	6	7.1	0.8	2.1	-	-	-
			16-a-2	20:06:90	13:20	04:07:90	21.2	7	5.9	0.8	6.6	3.2	-	-
			16-b-1	07:12:90	09:50	on spot	29.1	4	7.3	0.7	2.4	0.0	0.0	0.0
			16-b-2	13:02:91	11:34	on spot	25.2	19	6.8	0.9	3.6	0.0	0.0	0.2
			16-c-1	05:08:91	09:45	on spot	19.0	19	8.3	1.0	-	-	0.0	0.0
	17	Kafue R (near Kafironda)	17-a-1	07:06:90	08:30	on spot	21.1	7	8.1	1.1	8.6	-	-	-
			17-a-2	07:06:90	08:30	14:06:90	17.0	7	8.2	1.1	7.5	2.4	0.0	-
			17-a-3	20:06:90	13:10	on spot	20.7	4	8.2	1.1	6.5	-	-	-
			17-a-4	20:06:90	13:10	01:07:90	24.4	4	7.5	1.0	6.5	3.5	0.2	-
			17-b-1	07:12:90	08:35	on spot	29.2	42	7.5	0.7	4.7	0.0	0.0	0.0
			17-b-2	13:02:91	11:19	on spot	25.2	109	8.3	1.2	4.9	14	0.3	0.2
			17-c-1	05:08:91	10:39	on spot	18.3	20	-	1.0	-	-	0.0	0.0
	18	Mwambashi R	18-a-1	06:06:90	15:10	on spot	21.7	5	7.4	-	5.6	-	-	-
			18-a-2	06:06:90	15:10	14:06:90	17.4	3	7.9	0.6	7.8	4.1	0.0	-
			18-b-1	07:12:90	08:20	on spot	25.7	6	7.2	1.2	4.9	0.0	0.0	0.0
			18-b-2	13:02:91	11:00	on spot	23.1	5	7.7	0.7	4.4	0.0	0.0	0.0
			18-c-1	04:08:91	14:16	on spot	20.0	7	8.2	1.1	4.3	-	0.0	0.0

Table-4.3 Water Quality Test Results (General Items) - 3/7

River Basin	NO.	Sampling Points	Sample No.	Sampling Date D:M:Y	Sampling Time h:m	Test Date D:M:Y	Temp. deg. C	Turb. mg/l	pH	E.C. mv/cm	DO mg/l	Cl mg/l	Cu2+ mg/l	Mn2+ mg/l
Kafue	19	Kitwe R	19-a-1	20 06 90	08:10	on spot	18.7	40	7.4	0.9	3.5	-	-	-
			19-a-2	20 06 90	08:10	04 07 90	21.0	18	6.6	0.9	4.1	17.0	-	-
			19-b-1	06 12 90	11:10	on spot	20.8	46	8.1	1.1	4.6	0.0	0.0	0.0
			19-b-2	16 02 91	07:30	on spot	22.7	252	8.4	1.9	4.7	0.0	0.0	0.0
			19-c-1	04 08 91	13:55	on spot	21.0	30	8.4	1.0	2.5	-	0.0	0.0
	20	Stream (near Tailing Dam)	20-a-1	21 06 90	09:30	on spot	18.2	8	7.7	1.2	7.0	-	-	-
			20-a-2	21 06 90	09:30	04 07 90	21.6	6	7.0	1.0	8.5	7.8	0.0	-
			20-b-1	06 12 90	11:20	on spot	20.2	16	7.7	1.6	6.4	0.0	0.0	0.0
			20-b-2	16 02 91	07:45	on spot	22.4	18	8.3	1.2	5.3	0.0	0.0	0.0
			20-c-1	04 08 91	13:30	on spot	19.0	15	6.7	1.3	6.7	-	0.0	0.0
	21	Kafue R (Community Centre Br)	21-a-1	06 06 90	13:30	on spot	21.5	5	7.6	1.1	8.1	-	-	-
			21-a-2	06 06 90	13:30	14 06 90	17.8	5	7.5	1.0	7.3	-	0.0	-
			21-a-3	18 06 90	17:10	on spot	20.7	4	8.1	1.0	7.7	-	-	-
			21-a-4	18 06 90	17:10	25 06 90	22.6	2	6.8	1.0	8.2	7.0	0.3	-
			21-b-1	06 12 90	11:45	on spot	22.2	4	7.2	0.9	7.2	0.0	0.0	0.0
			21-b-2	16 02 91	08:20	on spot	24.4	35	8.2	0.7	4.9	13.0	0.0	0.1
			21-c-1	04 08 91	13:15	on spot	21.2	8	8.0	0.4	7.6	-	0.0	0.0
	22	Kamfinsa R	22-a-1	06 06 90	13:20	on spot	20.9	2	7.7	0.7	7.3	-	-	-
			22-a-2	06 06 90	13:20	14 06 90	18.0	3	6.9	0.4	7.7	-	0.0	-
			22-b-1	06 12 90	12:05	on spot	21.9	38	7.5	0.7	7.5	0.0	0.0	0.0
			22-b-2	16 02 91	08:33	on spot	22.3	22	8.4	0.2	4.5	0.0	0.0	0.0
			22-c-1	04 08 91	13:05	on spot	19.5	7	8.2	0.5	6.3	-	0.0	0.0
	23	Haposa R	23-a-1	08 06 90	11:00	on spot	17.2	9	7.8	0.7	8.6	-	-	-
			23-a-2	08 06 90	11:00	14 06 90	17.9	17	7.4	0.5	7.2	-	0.0	-
			23-b-1	06 12 90	12:20	on spot	20.9	61	7.8	0.6	7.7	0.0	0.0	0.0
			23-b-2	16 02 91	08:55	on spot	22.8	19	7.2	0.4	2.7	0.0	0.0	0.0
			23-c-1	04 08 91	12:30	on spot	18.9	6	8.5	0.4	5.2	-	0.0	0.0
	24	Baluba R	24-a-1	08 06 90	11:20	on spot	18.4	3	6.4	0.6	6.9	-	-	-
			24-a-2	08 06 90	11:20	14 06 90	17.6	4	6.7	0.4	7.1	-	0.0	-
			24-b-1	06 12 90	09:36	on spot	21.2	2	7.5	0.8	6.4	0.0	0.0	0.0
			24-b-2	16 02 91	09:02	on spot	22.6	15	7.3	0.2	4.1	0.0	0.0	0.0
			24-c-1	04 08 91	12:35	on spot	19.2	7	7.9	0.5	4.3	-	0.0	0.0
	25	Stream (upper Chapula)	25-a-1	19 06 90	08:30	on spot	16.4	6	7.4	0.4	8.6	-	-	-
			25-a-2	19 06 90	08:30	25 06 90	21.7	2	6.8	0.6	9.7	6.1	0.4	-
			25-b-1	08 12 90	09:30	on spot	21.5	4	7.6	0.8	7.2	0.0	0.0	0.0
			25-c-1	04 08 91	12:47	on spot	18.0	8	7.8	0.6	4.8	-	0.0	0.0
	26	Chapula (near St. Joseph)	26-a-1	19 06 90	15:50	on spot	21.2	9	7.8	1.0	7.8	-	-	-
			26-a-2	19 06 90	15:50	25 06 90	22.2	4	7.7	1.0	8.1	0.9	0.0	-
			26-b-1	08 12 90	10:45	on spot	20.9	6	7.9	0.8	6.9	0.0	0.0	0.0
			26-c-1	04 08 91	15:20	on spot	18.0	9	8.0	0.5	5.3	-	0.0	0.0
	27	Kafubu R	27-a-1	19 06 90	10:15	on spot	20.1	6	8.0	1.0	10.5	-	-	-
			27-b-1	05 12 90	08:20	on spot	19.8	63	7.3	0.6	5.1	0.0	0.0	0.0
			27-b-2	12 02 91	16:09	on spot	20.7	81	7.7	0.7	6.2	0.0	0.0	0.0
			27-c-1	04 08 91	11:30	on spot	17.9	8	8.4	1.0	8.2	-	0.0	0.0

Table-4.3 Water Quality Test Results (General Items) - 4/7

River Basin	NO.	Sampling Points	Sample No.	Sampling Date D:M:Y	Sampling Time h:m	Test Date D:M:Y	Temp. deg. C	Turb. mg/l	pH	E.C. mv/cm	DO mg/l	cl mg/l	Cu2+ mg/l	Mn2+ mg/l
Kafue	28	Chantete R	28-a-1	19.06.90	15:40	on spot	16.5	6	7.2	0.5	4.9	-	-	-
			28-a-2	19.06.90	15:40	04.07.90	21.1	3	7.5	0.9	8.2	2.9	0.0	-
			28-b-1	05.12.90	08:45	on spot	20.5	35	7.7	0.8	7.2	0.0	0.0	0.0
			28-c-1	04.08.91	14:25	on spot	19.0	5	7.8	0.8	7.6	-	0.0	0.0
	29	Kafue R (Emerald Mine)	29-a-1	19.06.90	17:00	on spot	20.7	5	8.8	1.1	8.7	-	-	-
			29-c-1	04.08.91	16:20	on spot	18.0	9	6.9	1.1	7.5	-	0.0	0.0
	30	Mpatamato (St. 4-200)	30-a-1	21.06.90	11:10	on spot	20.9	-	-	1.1	8.7	-	-	-
			30-a-2	21.06.90	11:10	01.07.90	24.1	7	7.3	1.0	7.8	2.7	0.0	-
			30-b-1	15.02.91	10:20	on spot	24.8	36	8.4	0.9	5.2	12.0	0.0	0.1
			30-c-1	07.08.91	10:05	on spot	19.2	9	8.3	0.9	7.6	-	0.0	0.0
	31	Stream (Ndola Mushishi Rd.)	31-a-1	18.06.90	15:50	on spot	20.6	5	8.4	1.0	5.0	-	-	-
			31-b-1	07.12.90	14:50	on spot	26.5	5	7.9	0.9	3.9	0.0	0.0	0.0
			31-b-2	16.02.91	10:50	on spot	26.2	10	8.2	2.1	6.0	0.0	0.0	0.0
			31-c-1	07.08.91	16:15	on spot	20.0	8	8.0	0.3	6.8	-	0.0	0.0
	32	Stream (Ndola Waste Water)	32-a-1	18.06.90	16:20	on spot	21.9	51	6.1	1.0	0.7	-	-	-
			32-b-1	07.12.90	16:20	on spot	25.9	57	6.7	0.8	0.6	0.0	0.0	0.0
			32-b-2	16.02.91	10:10	on spot	25.3	80	6.9	2.5	0.9	0.0	0.0	0.0
			32-c-1	07.08.91	16:30	on spot	22.0	48	6.2	1.2	0.5	-	0.0	0.0
	33	Ndola Dam (Kafubu)	33-a-1	18.06.90	16:10	on spot	21.0	6	8.7	1.0	12.3	-	-	-
			33-b-1	07.12.90	16:50	on spot	25.8	5	7.4	1.1	0.1	0.0	0.0	0.0
			33-b-2	16.02.91	10:33	on spot	24.6	7	8.3	2.0	18.0	0.0	0.0	0.0
			33-c-1	07.08.91	16:50	on spot	21.8	10	7.6	1.1	10.7	-	0.0	0.0
	34	Munkulungwe R	34-a-1	18.06.90	15:10	on spot	17.9	9	7.6	1.0	7.6	-	-	-
			34-b-1	07.12.90	17:50	on spot	23.7	6	7.6	0.9	0.3	0.0	0.0	0.0
			34-b-2	16.02.91	12:30	on spot	24.7	8	8.4	1.1	6.9	0.0	0.0	0.0
			34-c-1	07.08.91	15:02	on spot	20.0	8	8.1	0.8	6.7	-	0.0	0.0
	35	Kafubu R	35-a-1	06.06.90	12:50	on spot	19.4	3	7.7	1.1	8.1	-	-	-
			35-a-2	06.06.90	12:50	14.06.90	17.9	8	8.0	1.0	7.3	-	0.0	-
			35-b-1	07.12.90	18:30	on spot	22.0	40	8.2	1.2	0.7	0.0	0.0	0.0
			35-b-2	13.02.91	15:03	on spot	25.7	5	7.9	2.2	8.3	0.0	0.0	0.0
			35-c-1	07.08.91	13:25	on spot	20.0	8	8.5	0.7	7.6	-	0.0	0.0
	36	Luanshya R (Upper)	36-a-1	08.06.90	11:30	on spot	19.3	6	6.4	0.6	1.5	-	-	-
			36-a-2	08.06.90	11:30	14.06.90	18.3	10	7.7	0.4	7.1	-	0.0	-
			36-b-1	06.12.90	14:20	on spot	20.5	5	7.2	0.4	1.3	0.0	0.0	0.0
			36-b-2	16.02.91	09:10	on spot	22.7	15	7.5	0.2	4.7	0.0	0.0	0.0
			36-c-1	07.08.91	13:40	on spot	19.2	9	7.7	1.0	6.5	-	0.0	0.0
	37	Luanshya (near Makoma)	37-a-1	21.06.90	10:05	on spot	21.2	23	7.7	1.1	6.2	-	-	-
			37-a-2	21.06.90	10:05	01.07.90	24.4	12	7.2	1.0	6.7	4.6	0.0	-
			37-b-1	06.12.90	15:30	on spot	19.6	15	7.5	1.3	7.2	0.0	0.0	0.0
			37-b-2	16.02.91	09:45	on spot	23.2	18	7.6	0.3	4.6	0.0	0.0	0.0
			37-c-1	07.08.91	14:02	on spot	19.5	12	8.1	1.1	6.1	-	0.0	0.0
	38	Kafulafuta R	38-a-1	06.06.90	12:30	on spot	17.8	2	7.5	1.0	8.1	-	-	-
			38-a-2	06.06.90	12:30	14.06.90	17.5	6	7.8	0.8	7.5	-	0.0	-
			38-b-1	07.12.90	18:10	on spot	20.2	23	7.3	0.9	7.5	0.0	0.0	0.0
			38-b-2	16.02.91	13:30	on spot	26.2	7	8.4	0.7	6.8	0.0	0.0	0.0
			38-c-1	07.08.91	15:30	on spot	20.0	7	8.0	0.6	6.2	-	0.0	0.0

Table-4.3 Water Quality Test Results (General Items) - 5/7

River Basin	NO.	Sampling Points	Sample No.	Sampling Date D:M:Y	Sampling Time h:m	Test Date D:M:Y	Temp. deg. C	Turb. mg/l	pH	E.C. mv/cm	DO mg/l	cl mg/l	Cu2+ mg/l	Mn2+ mg/l
Kafue	39	Katembula R	39-a-1	07:06:90	08:50	on spot	17.6	11	8.1	1.1	8.8	-	-	-
			39-a-2	07:06:90	08:50	14:06:90	17.2	8	8.1	1.0	7.7	2.3	0.0	-
			39-b-1	08:12:90	11:30	on spot	19.5	10	7.9	1.2	7.6	0.0	0.0	0.0
			39-c-1	08:08:91	09:30	on spot	18.0	9	7.9	0.4	5.7	-	0.0	0.0
	40	Lufwanyama (Upper)	40-a-1	07:06:90	09:00	on spot	16.8	4	8.2	1.1	8.9	-	-	-
			40-a-2	07:06:90	09:00	14:06:90	17.4	9	8.4	1.1	7.7	2.0	0.0	-
			40-b-1	08:12:90	11:50	on spot	19.2	10	7.5	1.1	8.1	0.0	0.0	0.0
			40-c-1	08:08:91	09:48	on spot	18.9	6	7.8	0.4	5.5	-	0.0	0.0
	41	Lufwanyama (Middle)	41-a-1	19:06:90	13:00	on spot	19.3	4	7.1	1.0	7.5	-	-	-
			41-b-1	08:12:90	12:20	on spot	19.5	6	7.6	1.2	7.5	0.0	0.0	0.0
			41-c-1	08:08:91	10:15	on spot	19.0	5	8.2	0.4	6.2	-	0.0	0.0
	42	Mukeleshi R	42-a-1	19:06:90	10:15	on spot	20.1	6	8.0	1.0	10.5	-	-	-
			42-b-1	08:12:90	12:52	on spot	20.1	4	7.5	1.1	8.5	0.0	0.0	0.0
			42-c-1	08:08:91	10:48	on spot	19.5	5	8.0	0.5	9.1	-	0.0	0.0
	43	Hachiya Ferry (St. 4-280)	43-a-1	12:06:90	10:00	on spot	21.1	-	8.1	-	-	-	-	-
			43-a-2	12:06:90	10:00	25:06:90	22.0	4	7.8	1.0	8.6	2.2	0.0	-
			43-b-1	08:12:90	13:25	on spot	22.2	3	7.9	1.1	7.9	0.0	0.0	0.0
			43-c-1	08:08:91	16:50	on spot	18.3	8	7.0	0.9	7.3	-	0.0	0.0
	44	Luswishi R	44-a-1	07:06:90	10:30	on spot	19.0	3	6.0	1.1	8.8	-	-	-
			44-a-2	07:06:90	10:30	14:06:90	17.4	3	8.4	1.0	7.4	4.5	0.0	-
			44-b-1	08:12:90	13:52	on spot	20.0	22	7.6	1.6	7.8	0.0	0.0	0.0
			44-c-1	08:08:91	11:02	on spot	19.2	6	8.3	0.8	7.3	-	0.0	0.0
	45	Chilenga (St. 4-350)	45-a-1	12:06:90	10:00	on spot	21.1	-	7.8	-	-	-	-	-
			45-a-2	12:06:90	10:00	25:06:90	22.2	4	7.6	1.0	8.6	2.2	0.0	-
			45-b-1	08:12:90	14:30	on spot	21.0	29	8.1	1.5	8.0	0.0	0.0	0.0
			45-c-1	08:08:91	17:55	on spot	20.0	6	8.5	0.2	6.9	-	0.0	0.0
	46	Mushingashi R	46-a-1	07:06:90	11:10	on spot	18.4	7	7.6	1.1	7.8	-	-	-
			46-a-2	07:06:90	11:10	14:06:90	17.6	4	8.3	0.9	7.4	5.7	0.0	-
			46-b-1	08:12:90	14:48	on spot	19.1	6	7.3	1.2	7.0	0.0	0.0	0.0
			46-c-1	08:08:91	12:05	on spot	19.0	7	8.2	0.6	7.2	-	0.0	0.0
	47	Kamena R	47-a-1	07:06:90	11:20	on spot	15.9	4	7.3	1.0	7.7	-	-	-
			47-a-2	07:06:90	11:20	14:06:90	17.7	2	6.3	1.0	7.7	0.7	0.0	-
			47-b-1	08:12:90	15:23	on spot	19.2	3	7.5	1.0	6.9	0.0	0.0	0.0
			47-c-1	08:08:91	12:43	on spot	19.7	8	8.4	0.4	7.2	-	0.0	0.0
	48	Chipupushi R	48-a-1	07:06:90	11:40	on spot	17.5	4	7.6	1.1	8.1	-	-	-
			48-a-2	07:06:90	11:40	14:06:90	17.6	2	8.0	1.0	7.3	4.5	0.0	-
			48-b-1	08:12:90	15:49	on spot	18.2	2	8.1	1.1	7.7	0.0	0.0	0.0
			48-c-1	08:08:91	13:14	on spot	19.3	7	7.5	0.5	7.1	-	0.0	0.0
	49	Muzakazhi R	49-a-1	07:06:90	12:00	on spot	16.4	3	7.6	1.0	7.9	-	-	-
			49-a-2	07:06:90	12:00	14:06:90	17.5	2	8.2	0.9	7.6	0.7	0.0	-
			49-b-1	08:12:90	15:49	on spot	18.4	11	7.2	1.1	7.2	0.0	0.0	0.0
			49-c-1	05:08:91	08:20	on spot	17.2	6	8.3	0.3	6.3	-	0.0	0.0
	50	Chifumpa P. (St. 4-560)	50-a-1	03:07:90	13:00	on spot	23.4	-	7.1	-	-	-	-	-
			50-a-2	03:07:90	13:00	05:07:90	23.3	3	7.8	1.0	8.5	2.6	-	-
			50-b-1	08:12:90	16:25	on spot	19.8	21	7.3	2.0	8.3	0.0	0.0	0.0
			50-c-1	08:08:91	15:49	on spot	19.3	77	8.0	0.6	7.8	-	0.0	0.0

Table-4.3 Water Quality Test Results (General Items) - 6/7

River Basin	NO.	Sampling Points	Sample No.	Sampling Date D:H:Y	Sampling Time h:m	Test Date D:H:Y	Temp. deg. C	Turb. mg/l	pH	E.C. mv/cm	DO mg/l	cl mg/l	Cu2+ mg/l	Mn2+ mg/l
Kafue	51	Lubungu (St. 4-450)	51-a-1	03 07 90	16:00	on spot	21.3	-	8.0	-	-	-	-	-
			51-a-2	03 07 90	16:00	05 07 90	22.1	3.0	7.6	1.1	8.4	1.5	-	-
			51-c-1	08 08 91	13:38	on spot	18.9	8	7.9	0.6	7.1	-	0.0	0.0
	52	Nangoma R	52-a-1	06 07 90	11:50	on spot	16.5	4	7.2	0.7	9.5	-	-	-
			52-b-1	08 12 90	17:20	on spot	21.5	32	7.9	1.2	7.2	0.0	0.0	0.0
			52-b-2	16 02 91	07:54	on spot	23.2	10	-	0.7	4.1		-	-
	53	Chunga R (Kasup Mission)	53-a-1	06 07 90	09:40	on spot	16.3	12	6.6	0.5	5.7	-	-	-
			53-a-2	06 07 90	09:40	09 07 90	20.8	15	6.0	0.8	5.5	53.6	-	-
			53-b-1	03 01 91	15:50	on spot	23.7	25	7.7	0.9	2.9	0.0	0.0	0.0
			53-b-2	06 02 91	11:56	on spot	23.5	124	8.2	0.8	5	-	-	-
			53-c-1	08 08 91	14:10	on spot	20.0	7	7.5	0.3	6.8	-	0.0	0.0
			53-c-2	28 08 91	07:10	on spot	18.5	66	8.0	0.9	4.2	3.0	0.0	0.1
	54	Mwembeshi R (Road Bridge)	54-a-1	06 07 90	10:50	on spot	14.7	26	7.2	0.7	8.3	-	-	-
			54-a-2	06 07 90	10:50	09 07 90	21.3	20	6.5	0.9	7.7	32.3	-	-
			54-b-1	03 01 91	14:45	on spot	24.8	85	8.2	0.8	1.6	0.0	0.0	0.0
			54-b-2	06 02 91	10:04	on spot	23.8	117	8.0	0.9	3.7	-	-	-
			54-c-1	27 08 91	17:36	on spot	21.8	92	8.5	0.6	8.8	3.0	0.1	0.1
	55	Mwembeshi R (Shibuyunji)	55-a-1	06 07 90	13:00	on spot	19.1	18	7.2	0.8	7.9	-	-	-
			55-b-1	03 01 91	13:10	on spot	25.7	140	8.2	0.8	1.3	0.0	0.0	0.0
			55-b-2	05 02 91	14:00	on spot	26.2	42	8.1	0.9	3.0	-	-	-
			55-c-1	27 08 91	16:45	on spot	25.6	97	8.3	0.6	-	3.0	0.1	0.1
	56	Kafue R (Water Intake)	56-a-1	05 06 90	11:50	on spot	21.3	2	7.6	1.1	7.6	-	-	-
			56-b-1	02 01 91	12:45	on spot	27.0	12	8.9	0.5	2.8	0.0	0.0	0.0
			56-b-2	05 02 91	14:00	on spot	25.7	10	8.8	0.9	4.6	-	-	-
			56-c-1	27 08 91	11:20	on spot	22.0	1	7.9	0.2	7.0	0.6	0.1	0.2
Luangwa	101	Mulungushi R	101-a-1	06 06 90	11:20	on spot	18.7	4	7.5	1.0	8.8	-	0.0	-
			101-a-2	06 06 90	11:20	14 06 90	17.5	4	7.8	0.7	7.1	-	0.0	-
			101-b-1	09 12 90	15:50	on spot	20.7	3	7.9	1.2	8.2	0.0	0.0	0.0
			101-b-2	12 02 91	12:45	on spot	23.8	37	8.0	0.9	8.5	0.0	0.0	0.0
			101-c-1	04 08 91	10:30	on spot	19	3	7.9	0.9	7.6	-	0.0	0.0
	102	Luangwa Br. (St.5-940)	102-a-1	08 06 90	12:00	11 06 90	21.9	35	8.2	0.6	8.6	-	-	-
			102-a-2	08 06 90	12:00	14 06 90	19.9	32	8.0	0.6	6.6	-	-	-
			102-b-1	01 02 91	12:00	on spot	33.9	288	8.2	0.9	5.3	0.0	0.0	0.0
			102-c-1	05 09 91	11:30	on spot	31.7	28	8.2	0.5	7.5	-	0.0	0.0
Zambezi	201	Zambezi P/II (St.1-150)	201-a-1	23 06 90	09:00	on spot	20.0	-	6.3	-	-	-	-	-
			201-a-2	23 06 90	09:00	04 07 90	16.8	3	6.8	0.4	8.2	2.0	0.0	-
	202	Kabompo Boma (St.1-650)	202-a-1	23 06 90	11:50	on spot	20.8	-	8.1	-	-	-	-	-
			202-a-2	23 06 90	11:00	04 07 90	16.8	2	7.2	0.9	9.3	2.5	0.0	-
	203	Watopa P. (St.1-950)	203-a-1	23 06 90	16:00	on spot	21.0	-	8.0	-	-	-	-	-
			203-a-2	23 06 90	16:00	04 07 90	16.8	3	7.3	1.0	8.4	6.9	0.0	-
	204	Lukulu (St.2-030)	204-a-1	22 06 90	11:30	on spot	22.0	-	7.9	-	-	-	-	-
			204-a-2	22 06 90	11:30	04 07 90	16.9	2	7.0	0.9	8.2	2.0	0.0	-
	205	Kalabo (St.2-250)	205-a-1	20 06 90	17:30	on spot	20.8	-	6.0	-	-	-	-	-
			205-a-2	20 06 90	17:30	04 07 90	17.0	2	7.0	0.5	7.9	0.6	0.0	-
	206	Senanga (St.2-400)	206-a-1	25 06 90	09:30	on spot	20.0	-	6.8	-	-	-	-	-
			206-a-2	25 06 90	09:30	04 07 90	17.1	5	7.0	0.7	9.0	0.9	0.0	-

Table-4.3 Water Quality Test Results (General Items) - 7/7

River Basin	NO.	Sampling Points	Sample No.	Sampling Date D:M:Y	Sampling Time h:m	Test Date D:M:Y	Temp. deg. C	Turb. mg/l	pH	E.C. mv/cm	DO mg/l	cl mg/l	Cu2+ mg/l	Mn2+ mg/l
Zambezi	207	Ngwerere R (Bomanza Panch)	207-a-1	06 07 90	14:30	on spot	18.9	18	6.9	0.7	6.9	-	-	-
			207-a-2	06 07 90	14:30	09 07 90	20.9	16	6.8	0.9	8.4	32.5	-	-
			207-b-1	03 01 91	15:42	on spot	24.0	399	7.9	0.9	0.8	0.0	0.0	0.0
			207-b-2	06 02 91	14:00	on spot	22.6	137	9.1	0.8	3.2	0.0	0.0	0.0
			207-c-1	29 08 91	11:35	on spot	19.4	28	8.0	0.6	6.1	3.0	0.0	0.0
	208	Chongwe R (Route D176 Br)	208-a-1	06 07 90	14:50	on spot	19.8	4	7.3	0.6	6.0	-	-	-
			208-a-2	06 07 90	14:50	09 07 90	20.8	4	6.2	0.8	8.7	1.6	-	-
			208-b-1	03 01 91	08:30	on spot	22.7	26	8.3	0.8	1.1	0.0	0.0	0.0
			208-b-2	07 02 91	11:00	on spot	23.6	56	8.3	0.9	5.6	0.0	0.0	0.0
			208-c-1	29 08 91	12:22	on spot	20.3	20	8.3	0.5	9.2	2.0	0.1	0.0
						Max.	33.9	399	9.5	2.9	18.0	53.6	51.0	28.0
						Min.	14.7	1	5.4	0.1	0.1	0.0	0.0	0.0
						Average	21.3	26	7.7	0.9	6.4	2.7	1.2	0.4
						Nu. of Data	279	267	276	267	249	140	195	152

Table-4.4 Water Quality Test Results (Special Items)

River Basin	NO.	Sampling Points	Sample No.	Sampling Date D:M:Y	Sampling Time h:m	Fe mg/l	Cu mg/l	Mn mg/l	As mg/l	Cd mg/l	Pb mg/l	pH	Remarks
Kafue	2	Raglam Farm (St. 4-050)	2-a-2	06 06 90	16:30	-	N.D.	N.D.	-	-	N.D.	-	
	7	Stream (Waste Water)	7-a-2	20 06 90	09:30	6	23	27	tr	N.D.	1	-	
			7-a-2	20 06 90	09:30	4	43	31	tr	N.D.	2	5.6	
			7-a-2	20 06 90	09:30	5	45	31	5	N.D.	2	4.7	
			7-a-2	20 06 90	09:30	10	53	32	7	N.D.	2	4.0	
			7-a-2	20 06 90	09:30	8	47	32	10	N.D.	4	4.6	
	8	Kafue R (Chililabombwe Rd. Bridge)	8-a-5	20 06 90	11:00	tr	0.3	0.2	N.D.	N.D.	tr	-	
			8-a-5	20 06 90	11:00	0.3	1.0	0.4	N.D.	N.D.	tr	5.3	
			8-a-5	20 06 90	11:00	0.4	1.0	0.6	tr	N.D.	tr	3.5	
	17	Kafue R (near Kafironda)	17-a-4	20 06 90	13:10	tr	tr	N.D.	N.D.	N.D.	N.D.	-	
	21	Kafue R (Comm. Center Br)	21-a-2	06 06 90	13:30	tr	N.D.	N.D.	N.D.	N.D.	N.D.	-	
			21-a-4	18 06 90	17:10	tr	tr	N.D.	N.D.	N.D.	N.D.	-	

[Note] tr:Trace (very small amount), N.D.:Not detected

4.3 Consideration on Test Results

(1) Water Quality in Kafue River

< Main Pollutant Source >

There are large-scale stopes and deposit yards of copper ore. Plants, business offices and allied offices of the refinery, are widely distributed throughout the Copperbelt Province and the upper reaches of the Kafue River, and they make up towns such as Ndola, Kitwe, Chingola, Chililabombwe, Mufulira and Luanshya. These business establishments and towns feed industrial waste water and municipal sewage water into the Kafue River through waterways and small rivers.

The waste water produced by the mining work, the main pollutant source, contains a lot of inorganic matter. The tributary river, feeding the waste water near the Chililabombwe Bridge of the Kafue River, is considerably polluted by waste water from Chingola. This is shown in the test results of the water in the dry and rainy seasons sampled at Point-7. Besides a large quantity of copper and manganese, iron and toxic substances such as arsenic and lead can also be detected in the water sample at Point-7. In the water sampled at Point 8, Chililambwe Bridge, the same substances as detected at Point-7 are also detected. Point-8 is located at the downstream of Point-7.

The test results show that river water in rainy season becomes high in turbidity and slightly alkaline. This is because the rain water flushes the suspended solids and mining lime deposits into the rivers.

< Pollution and Self-purification >

Judging from the test results of samples collected at the middle and lower reaches of the Kafue River, the pollution caused at the upper Kafue River never affects the middle and lower stream of Kafue River.

In general, mining waste water contains a large quantity of suspended matter and metallic components, this is because an acidification of waste water will increase the quantity of the dissolved metallic components. The test results show that the water-soluble metallic components are hydrated to hydroxides which become insoluble metal salts and precipitate onto the river bed along with other suspended matter. This occurs because the acidic waste water is artificially neutralized with limestone and the water of Kafue River shows neutral or slightly alkaline. Besides, according to the test results of electric conductivity and chloride concentration, good water from the tributary rivers feeds into the Kafue River resulting in a dilution of the river water which allows the water quality of the Kafue River to improve.

< Organic Pollution >

To examine organic pollution, the dissolved oxygen (DO) and its change were measured instead of measuring such organic water pollution indexes as Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). It can be inferred from test results that the extent of the organic pollution in the upper reaches of the Kafue River is not a great problem, although the dissolved oxygen measured at some tributaries (Point-19 and 32) in Kitwe and Ndola municipalities shows low values, and the water of these points is emitting an offensive odor.

The year-round water temperature of the tributary rivers feeding the Kafue River is comparatively high resulting in the increased density of water plants. There are some cases in which the carbon dioxide assimilation of water plants allows the dissolved oxygen concentration and the pH value to increase. Especially at the Ndola Dam, there is active overgrowth of plants and algae in the stagnated water. Judging from these, the eutrophication of the river water is remarkable.

< Countermeasure and Monitoring >

At present , the main stream of the Kafue River can purify itself. However, the metallic components in the waste water will deposit for many years at the bottom of river. Ultimately these deposits might become a source of pollution. If the river water is used for drinking water, it is necessary to take measures to enforce waste water treatment such as neutralization, precipitation and separation.

It will also be necessary to monitor the quality of the river water to reduce the pollutant loads before they are fed into the river since the mining waste water contains many kinds of materials restricted by the water quality standard as shown in Table-4.5.

Table-4.5 Water Quality Standard (Unit: mg/lit)

Standard	Fe	Cu	Mn	As	Cd	Pb
Environmental Quality Standard (Japan; 1970)	-	-	-	0.05	0.01	0.1
Effluent Standard (Japan; 1970)	10	3	10	0.5	0.1	1.0
Water Quality Standard for Drinking Water (Japan; 1970)	0.3	1.0	0.3	0.05	0.01	0.1
Water Quality Guideline for Drinking Water (Zambia; 1986)						
- Permissible Limit -	1.0	1.5	-	0.05	0.1	0.05
- Desirable Limit -	0.3	1.0	-	0.01	0.005	0.01

(2) Water Quality in Other Rivers

Some tributaries around Lusaka (point 53 and 54) are affected by the municipal waste water of Lusaka, which contributes to the increase of organic pollution and causes the eutrophication in the dead-water area to become increasingly conspicuous.

The water in the main stream of Luangwa River and Zambezi River, some tributaries of which are only slightly affected by the municipal waste water from Lusaka, seems to be of good quality judging from the results of this investigation.

(3) Seasonal Variation of Water Quality

As a general tendency that the tests results revealed , the water quality in rainy season shows higher turbidity and slightly lower electric conductivity than those in dry season. The rain water brings a lot of suspended solids to the rivers. The decrease of electric conductivity is caused by dilution due to rain water. Judging from the higher water temperature and lower dissolved oxygen, it is presumed that the organic materials increase in rainy season. Fig.-4.2 shows the seasonal variation of water quality at the main points along the main stream of the Kafue River. At all points the values of turbidity in rainy season are higher than those in dry season. This tendency is appeared at almost all test points.

The direct pollutant loads from the process waste water of the mining activities are generally constant through the year unless the activities change. However, in rainy season the indirect pollutant loads from mining stopes, deposits, yards etc. are brought to rivers with rain water. The higher turbidity in rainy season is testified by this fact.

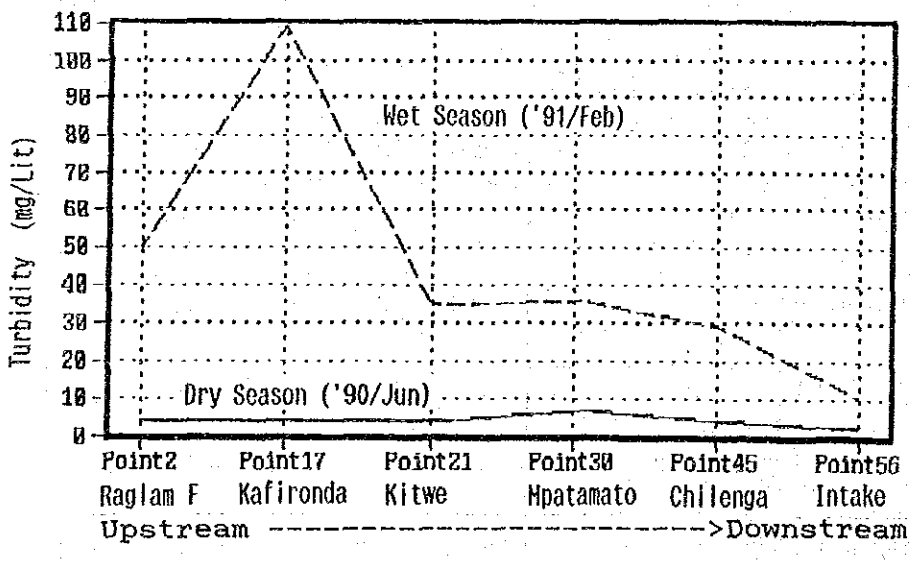


Fig.-4.2 Variation of Turbidity along Kafue River

5 HYDROLOGIC ANALYSIS

5.1 Hydrologic Database

5.1.1 Composition of Database System

All the hydrologic observation data dealt with in the Study is filed and analyzed with use of the computer database systems. In the Study, 12 computer systems were developed as shown in Table-5.1. See Fig.-5.1. These systems run using Lotus 123 software.

Table-5.1 Hydrologic Database System

No.	Application	Input to System	Output from System
DB-01	Compilation of Flow Meas.Data	Measurement Data by Measurement	Discharge Mean Discharge
DB-02	Filing of Flow Meas. Data	Measurement Data by Station	List of Flow Measurement Data
DB-03	Rating Curve (Type-1)	C/Sec., W/S/Slope Manning Roughness	Discharge Rating Curve
DB-04	Rating Curve (Type-2)	Measured Discharge and Water Level	Discharge Rating Curve
DB-05	Daily R/W/L and Discharge	Daily R/W/L and Rating Curve	Table of R/W/Level and Discharge
DB-06	Hourly R/W/L and Discharge	Hourly R/W/Level and Rating Curve	Table of R/W/Level and Discharge
DB-07	Discharge Correlation	Discharge of Two Stations	Correlation Curve
DB-08	Flow Regime of Station	Daily Discharge in One Year	Table of Flow Regime
DB-09	River Flow Analysis	Daily, Monthly or Annual Discharge	Table of River Flow
DB-10	Reservoir Water Balance	W/L, Outflow Evp, H-A-V Curve	Table of Reservoir Water Balance
DB-11	Daily Well Water Level	Daily Well Water Level	Table of Daily Well Water Level
DB-12	Correlation btw Well/W/L & River/W/Level	Well Water Level River Water Level	Correlation btw Well/W/Level and River/W/Level

[NOTE] W/W/L : Well Water level, R/W/L : River Water Level
C/Sec : Cross Section, W/S/Slope : Water Surface Slope
H-A-V Curve : Water Level - Reservoir Area - Storage Volume Curve

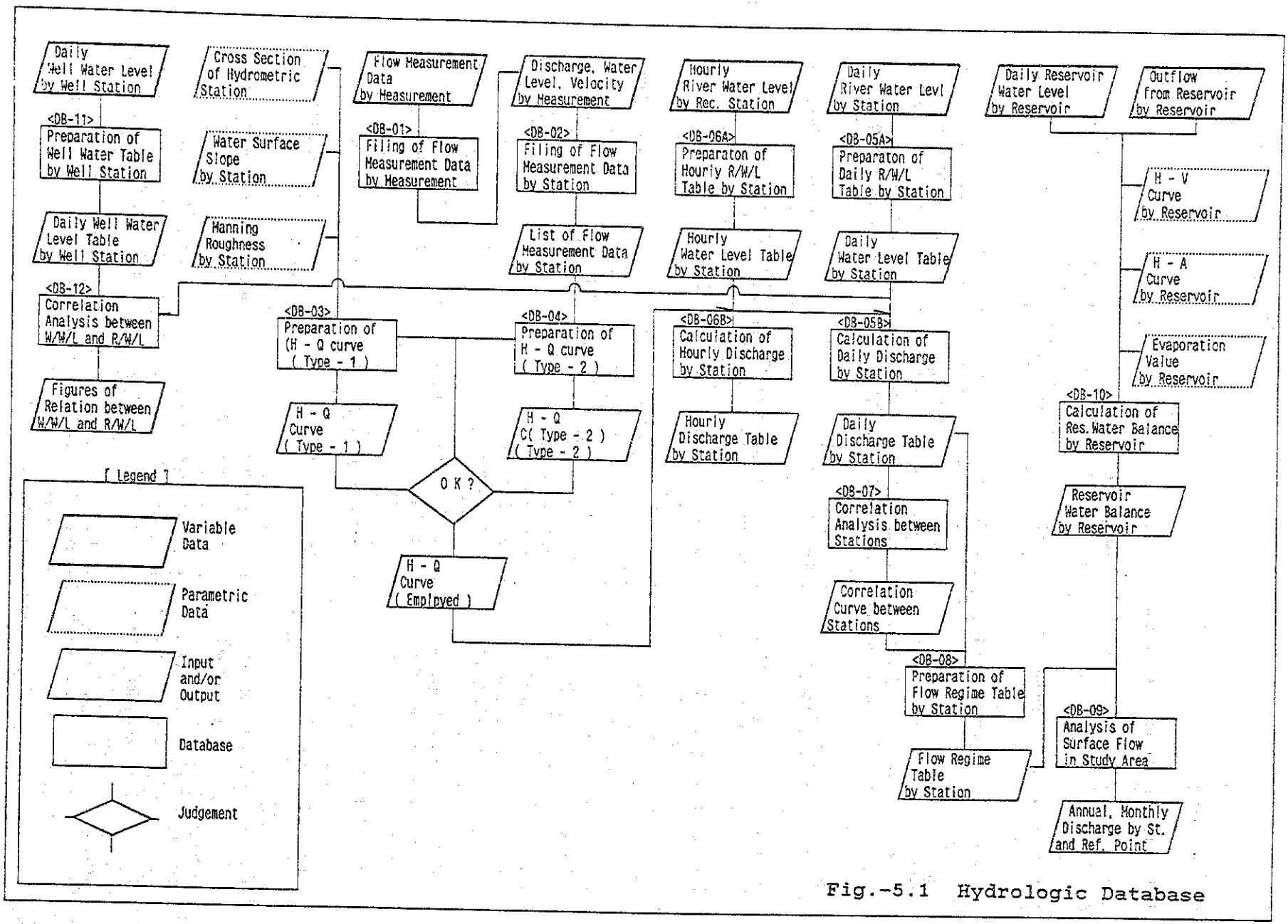


Fig.-5.1 Hydrologic Database

5.1.2 Description of Database

(1) Flow Measurement Data

The flow measurement data is treated and filed with the following database systems.

< DB-01: Flow Measurement Data by Measurement >

DB-01 is a system to compile and tabulate the flow measurement data of each measurement, giving mean velocity and discharge at the measured water level. Refer to Table-5.2 and Fig.-5.2.

< DB-02: Flow Measurement Data by Station >

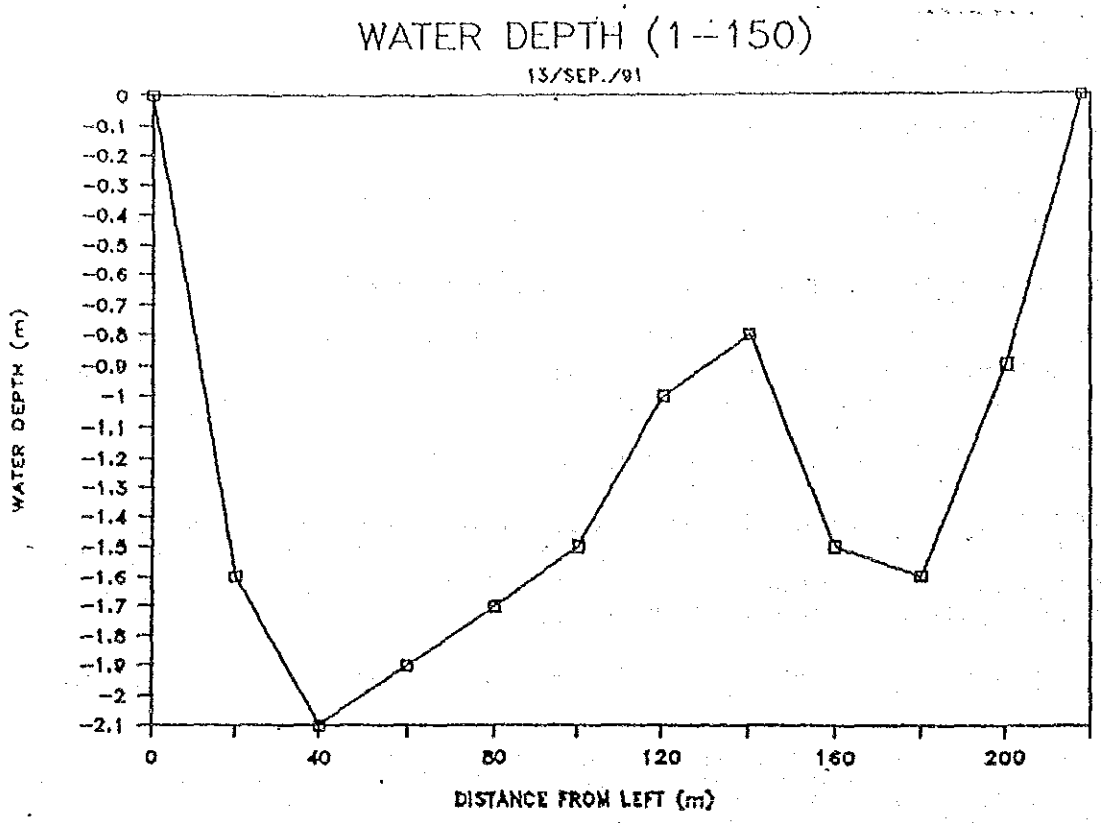
DB-02 is a system to file the flow measurement data of each station. This system gives the table showing 1) water level 2) Discharge 3) Discharge Area and 4) Mean Velocity in feet and metric system. Refer to Table-5.3.

Table-5.2 DB-01: Flow Measurement Data by Measurement

FLOW MEASUREMENT ST. : 1-150 ZAMBEZI PUMP HOUSE 13/SEP./91

ITEMS	NO-L	NO-1	NO-2	NO-3	NO-4	NO-5	NO-6	NO-7	NO-8	NO-9	NO-10	NO-R
WATER DEPTH (m)	0.00	1.60	2.10	1.90	1.70	1.50	1.00	0.80	1.50	1.60	0.90	0.00
SE/WIDTH (m)	0.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	18.00
TOTAL SE/WIDTH(m)	0.00	20.00	40.00	60.00	80.00	100.00	120.00	140.00	160.00	180.00	200.00	218.00
VELOCITY.2-1(f/s)	0.00	0.60	1.20	1.10	1.00	0.90	0.70	0.60	0.40	0.10	0.00	0.00
VELOCITY.2-2(f/s)	0.00	0.60	1.20	1.10	1.00	0.90	0.70	0.60	0.40	0.10	0.00	0.00
MEAN VEL.2 (f/s)	0.00	0.60	1.20	1.10	1.00	0.90	0.70	0.60	0.40	0.10	0.00	0.00
VELOCITY.8-1(f/s)	0.00	0.20	0.90	0.60	0.70	0.60	0.50	0.40	0.05	0.10	0.10	0.00
VELOCITY.8-2(f/s)	0.00	0.20	0.90	0.80	0.70	0.60	0.50	0.40	0.05	0.10	0.05	0.00
MEAN VEL.8 (f/s)	0.00	0.20	0.90	0.70	0.70	0.60	0.50	0.40	0.05	0.10	0.08	0.00
MEAN VEL (f/s)	0.000	0.400	1.050	0.900	0.850	0.750	0.600	0.500	0.225	0.100	0.038	0.000
MEAN VEL (m/s)	0.000	0.122	0.320	0.274	0.259	0.229	0.183	0.152	0.069	0.030	0.011	0.000
L/MEAN DEPTH (m)	0.000	0.800	1.975	1.950	1.750	1.550	1.125	0.850	1.325	1.575	1.075	0.000
L/MEAN WIDTH (m)	0.00	20.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	-
L/SEC. AREA (m2)	0.00	16.00	19.75	19.50	17.50	15.50	11.25	8.50	13.25	15.75	10.75	-
R/MEAN DEPTH (m)	0.000	1.725	2.050	1.850	1.650	1.375	0.950	0.975	1.525	1.425	0.450	-
R/MEAN WIDTH (m)	0.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	18.00	-
R/SEC. AREA (m2)	0.00	17.25	20.50	18.50	16.50	13.75	9.50	9.75	15.25	14.25	8.10	-
S/AREA (m2)	0.00	33.25	40.25	38.00	34.00	29.25	20.75	18.25	28.50	30.00	18.85	-
TOTAL AREA (m2)	0.0	33.3	73.5	111.5	145.5	174.8	195.5	213.8	242.3	272.3	291.1	-
S/DISCHARGE(m3/s)	0.00	4.05	12.88	10.42	8.81	6.69	3.79	2.78	1.95	0.91	0.22	-
TOTAL DIS. (m3/s)	0.00	4.05	16.94	27.36	36.17	42.85	46.65	49.43	51.39	52.30	52.52	-

WATER LEVEL (f) : 2.02 WATER LEVEL (m) : 0.62
TOTAL DISCHARGE : 52.30 MEAN VELOCITY(m/s) : 0.19



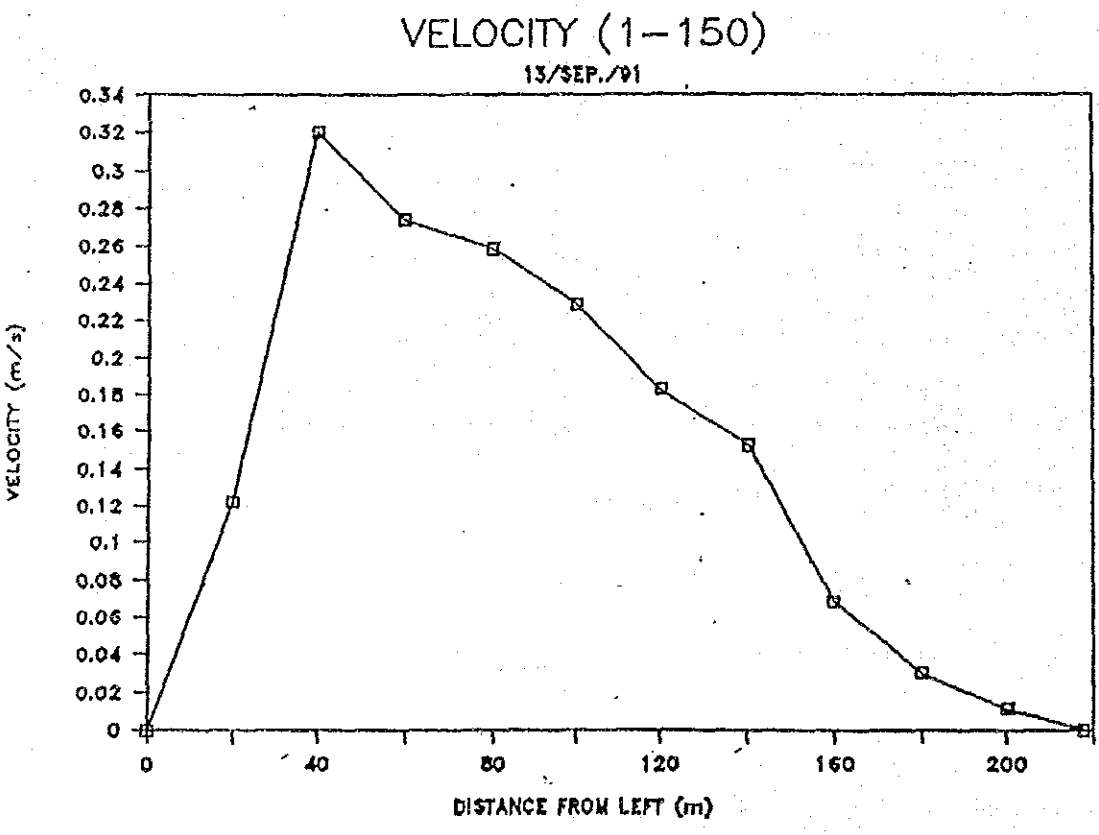


Fig-5.2 DB-01: Flow Measurement Data by Measurement

Table-5.3 DB-02: Flow Measurement Data by Station

LIST OF FLOW MEASUREMENT ST.: 1-950 WATOPA PONTOON

NO.	DATE	-----[Feet - Second]----- H (f)	Q (f3/s)	A (f2)	V (f/s)	+++++[Meter - Second]++++ H (m)	Q (m3/s)	A (m2)	V (m/s)
1	26-May-58	6.50	2970	3407	0.87	1.98	84	317	0.27
2	08-Aug-58	5.90	2358	3288	0.72	1.80	67	305	0.22
3	13-Sep-58	5.52	2047	3141	0.65	1.68	58	292	0.20
4	08-Nov-58	6.00	2604	3344	0.76	1.83	74	311	0.23
5	22-Nov-58	6.57	2801	3093	0.91	2.00	79	287	0.28
6	03-Jan-59	9.45	8034	4686	1.71	2.88	227	435	0.52
7	08-Jan-59	10.38	10434	5067	2.06	3.16	295	471	0.63
8	11-Feb-59	12.02	13929	5850	2.38	3.66	394	543	0.73
9	19-Feb-59	12.98	15840	6310	2.51	3.96	449	586	0.77
10	27-Feb-59	14.14	18191	6796	2.68	4.31	515	631	0.82
11	24-Mar-59	14.25	18544	6700	2.77	4.34	525	622	0.84
12	26-Mar-59	13.63	16923	6430	3.83	4.15	479	597	1.17
13	27-Mar-59	13.35	16413	6312	2.60	4.07	465	586	0.79
14	11-Apr-59	10.73	10374	5060	2.05	3.27	294	470	0.62
15	16-Apr-59	10.19	9303	4860	1.91	3.11	263	452	0.58
16	18-Apr-59	9.90	8716	4745	1.84	3.02	247	441	0.56
17	14-May-59	7.63	4720	3875	1.22	2.33	134	360	0.37
18	30-May-59	6.85	3368	3574	0.94	2.09	95	332	0.29
19	19-Jun-59	6.38	2920	3490	0.84	1.94	83	324	0.26
20	30-Jun-59	6.27	2840	3420	0.83	1.91	80	318	0.25
21	10-Jul-59	6.43	2705	3390	0.80	1.96	77	315	0.24
22	22-Jul-59	6.02	2425	3350	0.72	1.83	69	311	0.22
23	25-Jul-59	6.00	2415	3295	0.73	1.83	68	306	0.22
24	29-Sep-59	5.27	1643	3061	0.54	1.61	47	284	0.16
25	15-Oct-59	5.10	1580	3014	0.53	1.55	45	280	0.16
26	17-Oct-59	5.09	1310	2965	0.44	1.55	37	275	0.13
27	20-Nov-59	5.36	1690	3075	0.55	1.63	48	286	0.17
28	28-Nov-59	5.76	2080	3320	0.65	1.76	59	308	0.20
29	20-Dec-59	6.83	3436	3655	0.94	2.08	97	340	0.29
30	22-Jan-60	8.35	5699	4148	1.37	2.55	161	385	0.42
31	27-Jan-60	8.07	5081	4095	1.24	2.46	144	380	0.38
32	16-Feb-60	9.90	8254	4818	1.71	3.02	234	448	0.52
33	24-Feb-60	11.71	12042	5631	2.14	3.57	341	523	0.65
34	29-Feb-60	12.20	13136	5854	2.24	3.72	372	544	0.68
35	09-Mar-60	14.45	18130	6810	2.77	4.40	513	633	0.84
36	18-Mar-60	16.20	22350	8175	2.74	4.94	633	759	0.84
37	31-Mar-60	18.83	26800	9560	2.80	5.74	759	888	0.85
38	22-Apr-60	10.90	10260	5426	1.89	3.32	291	504	0.58
39	29-Apr-60	9.85	8170	4723	1.73	3.00	231	439	0.53
40	12-May-60	8.86	6391	4336	1.47	2.70	181	403	0.45
41	21-May-60	8.20	5222	4073	1.28	2.50	148	378	0.39
42	02-Jul-60	6.80	3185	3588	0.89	2.07	90	333	0.27
43	15-Jul-60	6.60	2952	3482	0.85	2.01	84	323	0.26

(2) Discharge Rating Curve

Discharge rating curve is prepared with either of the following systems according to the number of measurement data.

< DB-03: Discharge Rating Curve = Type-1 >

In case that flow measurement data is few, this system DB-03 prepares discharge rating curve using the hydrometric station's parametric data : cross section, water surface slope and Manning roughness. Refer to Table-5.4 and Fig.-5.3.

Table-5.4 DB-03: Discharge Rating Curve = Type-1

4-941 KALEYA DAM SITE <<< H - A - V - Q CALCULATION >>>

n = 0.03000 i = 1/2500

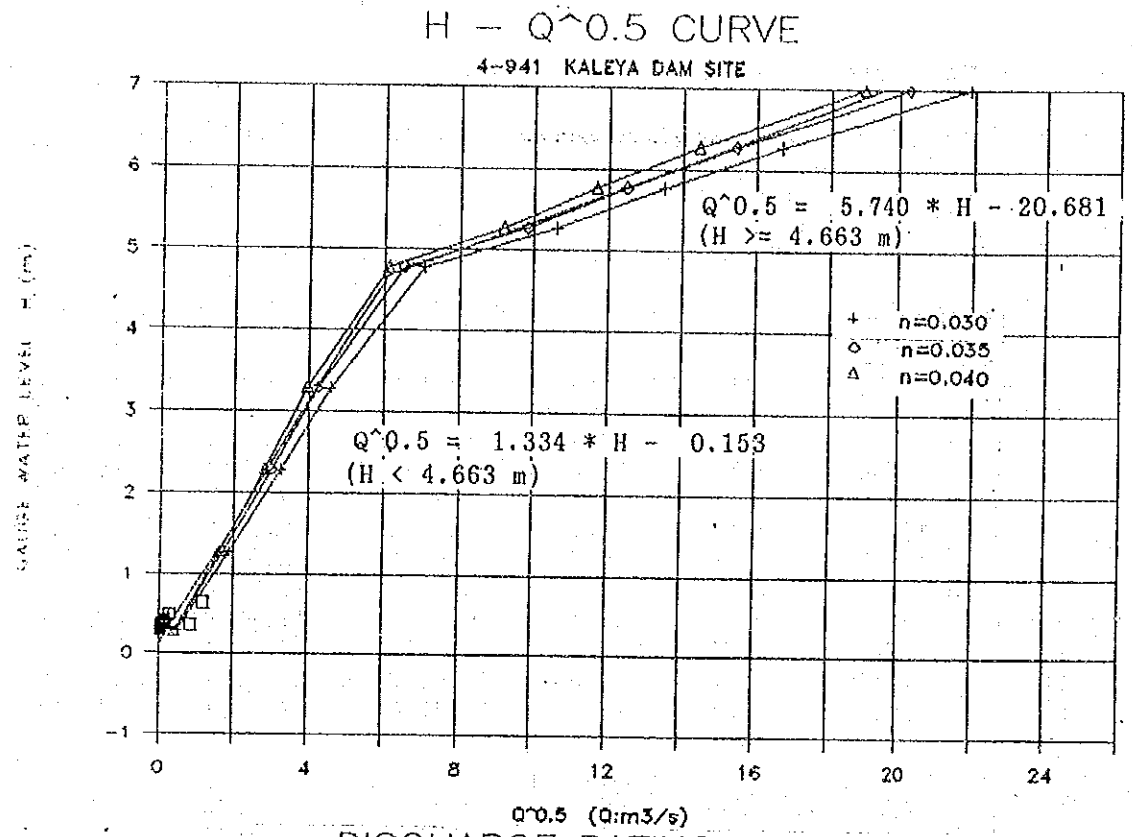
h(m)	H(m)	A(m2)	S(m)	R(m)	V(m/s)	Q(m3/s)	Q^0.5
1,243.00	0.28	0.94	4.06	0.23	0.25	0.24	0.49
1,244.00	1.28	5.76	6.85	0.84	0.59	3.42	1.85
1,245.00	2.28	13.35	10.24	1.30	0.80	10.62	3.26
1,246.00	3.28	22.06	12.94	1.70	0.95	20.99	4.58
1,247.50	4.78	91.30	123.35	0.74	0.55	49.80	7.06
1,248.00	5.28	152.14	129.26	1.18	0.74	113.07	10.63
1,248.50	5.78	215.20	149.61	1.44	0.85	182.82	13.52
1,249.00	6.28	293.57	173.36	1.69	0.95	278.05	16.67
1,249.72	7.00	430.46	199.81	2.15	1.11	478.68	21.88

n = 0.03500 i = 1/2500

h(m)	H(m)	A(m2)	S(m)	R(m)	V(m/s)	Q(m3/s)	Q^0.5
1,243.00	0.28	0.94	4.06	0.23	0.22	0.20	0.45
1,244.00	1.28	5.76	6.85	0.84	0.51	2.93	1.71
1,245.00	2.28	13.35	10.24	1.30	0.68	9.10	3.02
1,246.00	3.28	22.06	12.94	1.70	0.82	17.99	4.24
1,247.50	4.78	91.30	123.35	0.74	0.47	42.69	6.53
1,248.00	5.28	152.14	129.26	1.18	0.64	96.92	9.84
1,248.50	5.78	215.20	149.61	1.44	0.73	156.70	12.52
1,249.00	6.28	293.57	173.36	1.69	0.81	238.33	15.44
1,249.72	7.00	430.46	199.81	2.15	0.95	410.29	20.26

n = 0.04000 i = 1/2500

h(m)	H(m)	A(m2)	S(m)	R(m)	V(m/s)	Q(m3/s)	Q^0.5
1,243.00	0.28	0.94	4.06	0.23	0.19	0.18	0.42
1,244.00	1.28	5.76	6.85	0.84	0.45	2.56	1.60
1,245.00	2.28	13.35	10.24	1.30	0.60	7.97	2.82
1,246.00	3.28	22.06	12.94	1.70	0.71	15.74	3.97
1,247.50	4.78	91.30	123.35	0.74	0.41	37.35	6.11
1,248.00	5.28	152.14	129.26	1.18	0.56	84.80	9.21
1,248.50	5.78	215.20	149.61	1.44	0.64	137.11	11.71
1,249.00	6.28	293.57	173.36	1.69	0.71	208.54	14.44
1,249.72	7.00	430.46	199.81	2.15	0.83	359.01	18.95



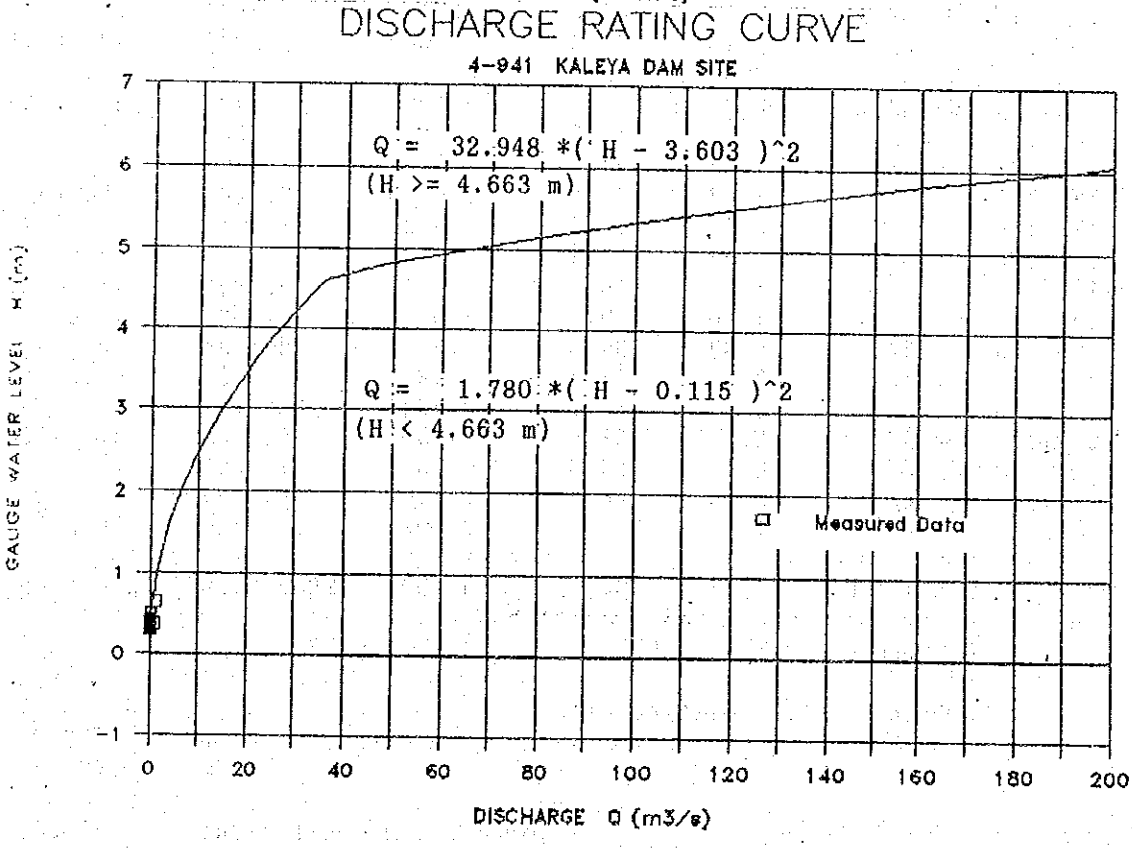


Fig-5.3 DB-03: Discharge Rating Curve = Type-1

< DB-04: Discharge Rating Curve = Type-2 >

In case that many flow measurement data is available, this system prepares discharge rating curve using the data filed in DB-04. Refer to Table-5.5 and Fig.-5.4.

Table-5.5 DB-04: Discharge Rating Curve = Type-2

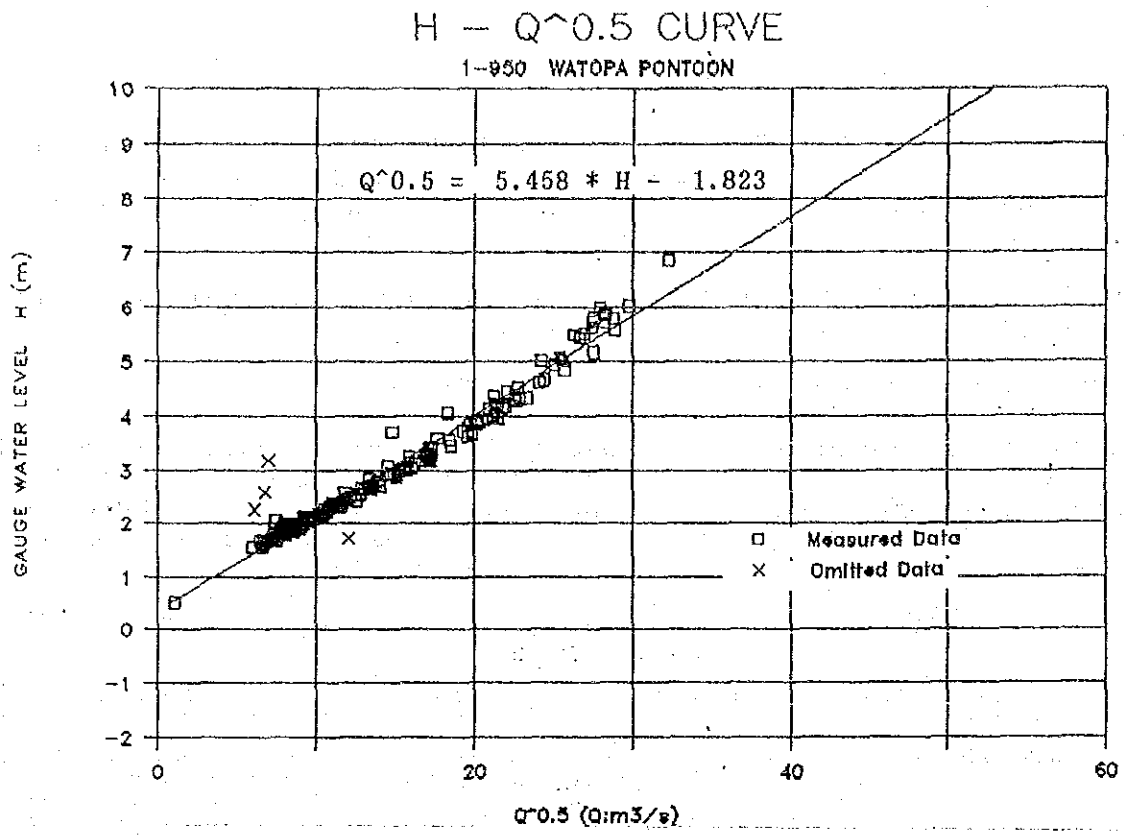
DISCHARGE RATING CURVE STATION: 1-950 WATOPA PONTOON

NO.		DATE	H(m)	Q(m3/s)	H^2.0	Q^0.5	H*Q^0.5
1	1	58/ 5/26	1.98	84.1	3.9252	9.1707	18.1689
2	2	8/ 8	1.80	66.8	3.2340	8.1714	14.6947
3	3	9/13	1.68	58.0	2.8308	7.6134	12.8096
4	4	11/ 8	1.83	73.7	3.3445	8.5870	15.7040
5	5	11/22	2.00	79.3	4.0102	8.9059	17.8344
6	6	59/ 1/ 3	2.88	227.5	8.2965	15.0830	43.4445
7	7	1/ 8	3.16	295.5	10.0098	17.1889	54.3826
8	8	2/11	3.66	394.4	13.4227	19.8601	72.7615
9	9	2/19	3.96	448.5	15.6523	21.1787	83.7895
10	10	2/27	4.31	515.1	18.5750	22.6961	97.8172
167	171	4/23	3.96	466.1	15.7006	21.5886	85.5426
168	172	86/ 8/ 8	2.18	107.0	4.7494	10.3445	22.5440
169	173	9/ 8	1.95	78.0	3.8053	8.8325	17.2297
170	174	89/10/ 6	0.51	1.3	0.2622	1.1396	0.5835
171	175	90/ 2/ 9	3.03	257.3	9.1809	16.0406	48.6029
172	176	3/ 8	3.26	251.3	10.6276	15.8531	51.6810
173	177	5/ 8	3.03	257.3	9.1809	16.0406	48.6029
174	178	6/26	2.13	87.0	4.5369	9.3247	19.8616
175	179	7/29	2.01	65.6	4.0401	8.1019	16.2847
176	180	8/22	1.92	55.3	3.6864	7.4351	14.2753
177	181	9/26	1.71	46.0	2.9241	6.7853	11.6028
178	182	10/25	1.70	49.9	2.8900	7.0626	12.0064
179	183	12/ 6	1.88	66.9	3.5344	8.1786	15.3758
180	184	91/ 1/12	3.08	211.7	9.4864	14.5509	44.8169
181	185	2/ 4	4.29	514.1	18.4041	22.6740	97.2714
OMIT157		79/11/12	2.27	37.9	5.1564	6.1553	13.9773
OMIT158		80/ 5/23	3.18	50.0	10.1064	7.0696	22.4747
OMIT169		6/ 7	2.59	46.4	6.7122	6.8084	17.6393
OMIT166		4/ 9	1.73	145.0	2.9973	12.0420	20.8479
T O T A L			548.97	46401	1895.2297	2666.2666	9343.3469

DISCHARGE - RATING CURVE : Q = a * (H + b)^2

(where, OMIT : Omitted data)

a' =	5.458147
b' =	-1.823601
a =	29.791368
b =	-0.261824
Correlation Coefficient	0.981



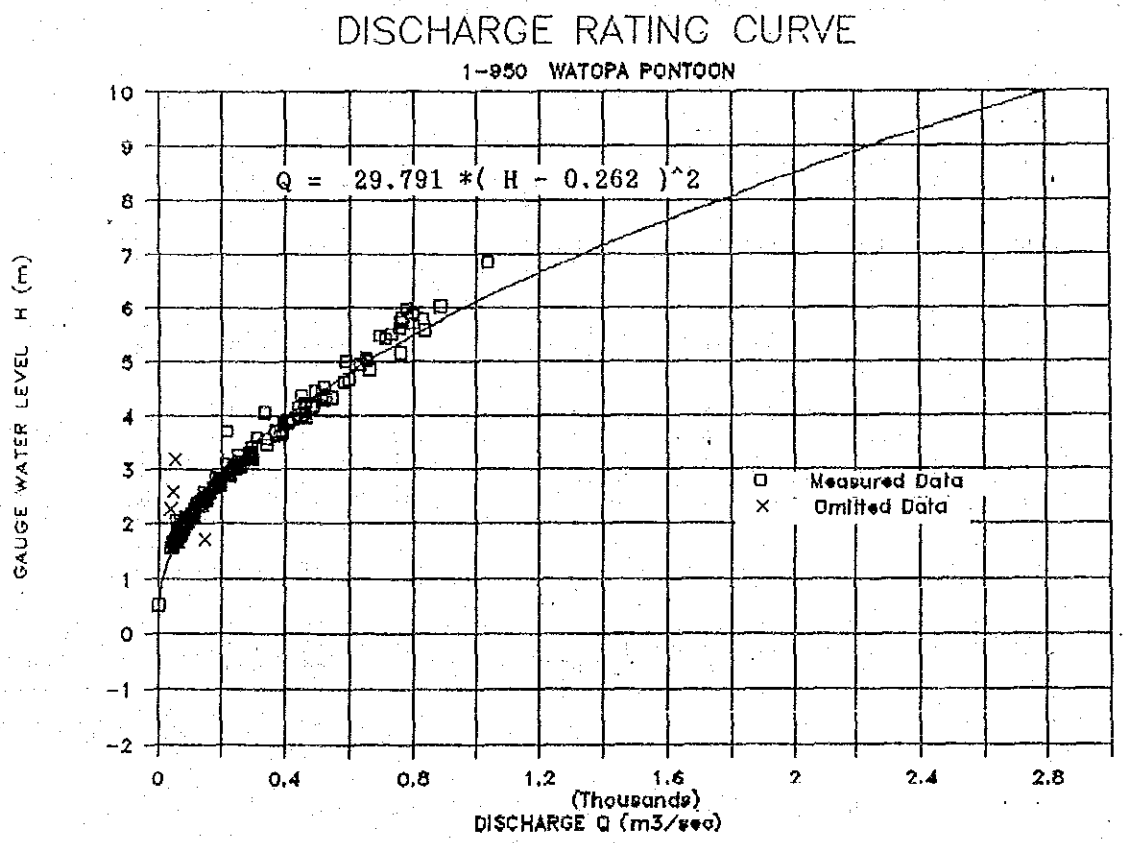


Fig.-5.4 DB-04: Discharge Rating Curve = Type-2