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NATIONAL CAPITAL DISTRICT COMMISSION
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THE STUDY ON THE PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN IN PAPUA NEW GUINEA

FINAL REPORT

APPENDIX

MARCH 1994

TOKYO ENGINEERING CONSULTANTS
IN ASSOCIATION WITH
PACIFIC CONSULTANTS INTERNATIONAL

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PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

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PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

POTENTIAL SURFACE WATER RESOURCES IN LALOKI, GORDIE AND BROWN RIVER BASINS

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1. Introduction

This report is prepared to present the results obtained through a series of studies on the *potential surface water resources in the Laloki, the Brown and the Goldie Rivers located* north of the NCD area with the aim of realizing the efficient water supply to the entire NCD area.

The surface water resources of the Laloki River are judged adequate for providing water both for water supply and electric power generation at present, though the volume expected to be utilized is limited. A minimum drought discharge of eight (8) m^3/s to nine (9) m^3/s is expected, and the discharge that will be utilized by the Electric Commission (ELCOM) is estimated at about 8 m^3/s. The water supply to the NCD area is diverted from the penstock to the Rouna 1 headpond at present with a discharge of about 1.2 m^3/s.

Considering ELCOM's facilities installed and those scheduled for installation, the increased demand of water to be supplied to the NCD area, which is estimated at about 4.0 m^3/s, is considered to be diverted from the Laloki River. The key point in the discussion is not the discharge off-take but the location of the diversion site. Therefore, although abundant volume of water may be available in the Brown and the Goldie River Basins, it is not necessary to consider the option of utilizing these resources, other than those in the Laloki River Basin, considering the cost necessary for conveying the water and the principal needs of water supply.

2. River Basins

2.1 Laloki River Basin

The Laloki River, flowing north of Port Moresby, has been utilized for power generation and water supply of the National Capital District including Port Moresby. The basin consists of controlled, and some uncontrolled sub-basins; namely:

- Sirinumu Dam Sub-basin,
- Eilogo Creek Sub-basin,
- Eworogo Creek Sub-basin,

- Laloki River Sub-basin 1 (Sirinumu Dam - Eilogo Creek), and
- Laloki River Sub-basin 2 (Eilogo Creek - Rouna 2 head pond).

The runoff of the Sirinumu Dam Sub-basin is regulated by a dam whose reservoir capacity is 354 million m^3. The dam is operated by the Electricity Commission (ELCOM), and the responsibility for operation of the dam rests with the Water Resources Board under the Water Resources Act.

The catchment areas measured on the 1:100,000 series maps are as follows:

- Sirinumu Dam: 156 km^2
- Eilogo Creek: 31 km^2
- Eworogo Creek: 77 km^2
- Laloki River at Sogeri: 311 km^2
- Laloki River at Rouna 2 head pond: 312 km^2

Much of the vegetation in the catchment area of Sirinumu Dam is dry eucalyptus forest with sparse cover. This type of forest is found along the southern side of the reservoir, between the reservoir and the top of the Astolabe Range. Along the eastern and northern sides, the forest cover is denser and wetter, and is closer to the rain forest in character.

Downstream of Sirinumu Dam, are dry sparse eucalyptus forests with some stands of banksias on both sides of the Laloki River down to the vicinity of the confluence of Eilogo Creek. Downstream of Eilogo Creek as far as Rouna 2 head pond, this type of forest is confined mainly to the southern side of the river.

In contrast with the upper Laloki catchment, the forest cover in the Eworogo and Eilogo Creek catchment is denser rain forest type vegetation. In the upper parts of the catchment area vegetation is very dense, with fern trees visible. Large areas of the Eworogo Creek catchment have been cleared for cattle grazing. Formerly, much of the cleared area consisted of rubber estates and remnants of the rubber plantations still remain. As a result of the catchment, Eworogo Creek carries a substantial sediment load and appears to be the main contributor of sediment to the Laloki River.

2.2 Brown River Basin

The Brown River, one of the tributaries of the Laloki River, flows north of the Laloki River basin westward. The catchment area is located between the Goldie and the Vanapa river basins, and bounded by Owen Stanley Range (Kokoda trail) at the northeastern end. The catchment area of the river is 1,400 km^2 at the Karema Village (Hiritano Highway Bridge). The river basin consists mainly of the following three (3) sub-basins.

- Naoro River Basin: 536 km^2
- Oveia River Basin: 252 km^2
- Rest of the Brown River Basin: 612 km^2

The Oveia and the Naoro Rivers meet the Brown River near Roguoia Village. The Naoro River Basin is further subdivided into Babuiagi - Fagume and GU River Basins, and the Oveia River Basin is divided into the Roguoia Creek and Oveia River Basins at their upstream reaches.

The area is covered by the dense tropical forests, but this forest vegetation becomes sparse and dry in the downstream portion. No river water extraction is found along the river.

2.3 Goldie River Basin

The Goldie River is also one of the tributaries of the Laloki River, and the river basin extends eastward, between the Brown and the Laloki River Basins. The catchment area is 525 km^2 at the confluence of the Laloki River, downstream of the existing Bomana Pumping Station, which is presently used for supplying community water to the NCD area.

The Goldie River has some tributaries, namely

- Ebealue Creek, and
- Ua Ule - Eolia Creek.

The vegetation along the river is found to be almost similar to that along the Brown River with the dense tropical forests in the upstream area, and rather sparse vegetation in the downstream flood lands. The river flow is presently utilized only for water supply of the army barracks with the pumping station located on the right bank about four (4) km upstream of the confluence of the Laloki River.

3. Available Data and Information

3.1 General

Generally speaking, hydrometric stations, such as discharge gauging and rainfall stations are established more densely in the Laloki River Basin, since various developments have been made along the Laloki River so far. There are many discharge gauging and rainfall stations in this basin, with which observations commenced in 1950s. Therefore, long term daily data is also available for hydrological studies.

In addition to these observed data, several hydraulic studies were carried out by various organizations for exploiting and utilizing the surface water resources of the Laloki River Basin

On the other hand, few stations have been operating in the Brown and Goldie River Basins. In the early 1980s, several stations were established upstream of the Brown River Basin by the Bureau of Water Resources, but these are considered to be inadequate for accurate calibration of the runoff models.

The stations that have collected data are listed in Table - 3.1, and the available data, period, and location of each station are given in Fig. - 3.1 to Fig. - 3.3, respectively.

3.2 Available Data of Each River Basin

The available rainfall and discharge data in and around each river basin are discussed below.

(1) Laloki River Basin

There are 16 rainfall and seven (7) discharge gauging stations in the basin. Some of them have operated and daily data collected from 1940s or 1950s to date. Therefore, long term daily rainfall data is available though data for the seventies is not available at some stations.

Based on the available data, various hydraulic studies were carried out for exploiting the surface water resources of the Laloki River Basin. The studies include the following:

- "Operational Hydrology Study for the Laloki River System" prepared for Bureau of Water Resources in June 1989,

- "Port Moresby Water Supply, Report on Upgrading Raw Water Supply & Treatment Plant" prepared for National Capital District Interim Commission in May 1987,

- "Rouna 4 Hydroelectric Scheme" prepared by Papua New Guinea Electricity Commission in 1978,

- "Sirinumu Dam: Design Review and Surveillance Manual" prepared by Department of Housing and Construction for Papua New Guinea Electricity Commission in 1981,

- "Further Regulation of Laloki River for Power Generation Purposes" prepared by Commonwealth Department of Works for Papua New Guinea Electricity Commission in April 1968, and

- "Future Development of Power Generation for Port Moresby" prepared by Commonwealth Department of Works for Papua New Guinea Electricity Commission in November 1969.

Among the above listed studies, "Operational Hydrology Study for the Laloki River System" is a report on the hydrological study conducted most recently, by modeling the runoff of the basin in detail.

(2) Brown River Basin

Long term rainfall data is available at the Brown River Forestry and the Kokoda stations operated by the National Weather Service (NWS). The data consists of daily and monthly rainfall recorded since the 1950s. The Brown River Forestry station is located at the downstream end of the basin and the Kokoda station north of the basin. No long term data is available for the basin. The BWR recently established eight (8) rainfall stations upstream of the basin, and the daily rainfall data since 1983 or 1984 are available at such stations. However, the periods of data collection are short (5 to 10 years) and data is meager.

For discharge data, there are four (4) gauging stations in the basin. The Karema Gauging station located at the downstream end of the basin provides the longest records among the stations, and daily discharge data from 1955 is available. However, the station was once closed in 1972 and re-opened in 1981. The other stations are:

- Roguoia Station located at the junction of the Naoro and the Oveia Rivers,
- Madilogo Station on the Naoro River,
- Bogaiana Station on the Naoro River, and
- Roguoia Station on the Oveia River.

These stations were opened in 1980 or 1981, and provide daily data for about 10 years although there is some data missing.

(3) Goldie River Basin

There are no discharge gauging or rainfall stations at present in this basin. However, there are two (2) old discharge gauging stations at Uberi in the Goldie River and on the Ebealue Creek. The daily data available in these stations is from 1962 to 1972 for the Uberi Station and from 1963 to 1968 for the Ebealue Station.

4. Rainfall and Runoff

4.1 Rainfall

Average annual rainfalls for stations located in the basins are summarized below.

Station	Annual Rainfall (mm)	Station	Annual Rainfall (mm)
1. Laloki River Basin		Bogaiana	2,399.1
Rouna 1/3	1,812.1	Kagi	3,445.9
Laloki DAL	1,223.4	Manumu	1,877.6
Itikinumu Estate	3,194.8	Boridi	2,422.3
Karakatana	1,955.8	Manari	2,637.9
		Upper Naoro	2,545.7
2. Brown River Basin		Karema	1,859.4
Roguoia	1,972.2	Brown River Forestry	1,982.7
Madilogo	2,936.1	Kokoda Yoda	4,190.3

As shown in the table above , the rainfall varies from station to station, which is considered to be due to altitude. The Kokoda Yoda station, which indicates the most highest amount of rainfall, is located outside the basin, and the high rainfall indicates that the climatic condition beyond the Owen Stanley Range is different from those of the respective basins.

Based on the above annual rainfall, isohyet maps of the basins are roughly prepared as shown in Fig. - 4.1. The annual rainfall of the Laloki River Basin is more than 2,000 mm, and exceeds 3,000 mm in the upstream part of the Eworogo River, and that of the Brown River Basin also varies widely from 2,000 mm in the low altitude area to more than 3,000 mm in the hilly area along the Owen Stanley Range. Though there is no rainfall station in the Goldie River Basin, the rainfall distribution in the basin seems to have characteristics similar to the others.

Monthly rainfall data of the stations located in basins are tabulated in Table - 4.1 and Table - 4.2, and their variations are also illustrated in Fig. - 4.2 to Fig. - 4.3. The period form December to May is considered to be a wetter period. The period from June to September forms the core part of the dry season, and about 30 % of the annual rainfall occurs during this period, as stated below.

Station	Rainfall During Wet Period		Station	Rainfall During Wet Period	
	(mm)	(%)		(mm)	(%)
1. Laloki River Basin			Bogaiana	822.5	34
Rouna 1/3	485.7	27	Kagi	1,095.9	32
Laloki DAL	302.7	25	Manumu	682.0	36
Itikinumu Estate	1,261.6	39	Boridi	786.5	32
Karakatana	634.7	32	Manari	927.1	35
			Upper Naoro	894.2	35
2. Brown River Basin			Karema	491.7	26
Roguoia	559.7	28	Brown River Forestry	1,815.3	43
Madilogo	994.3	34	Kokoda Yoda	622.0	31

However, during the dry period, rather heavy rainfalls sometimes occur, suggesting variation in rainfall not only in quantity, but also in duration as seen in the tables of monthly rainfall. High variability of monthly rainfall is considered to be a significant feature of the basins.

Fig. - 4.4 shows the 5-year running mean of the annual rainfall recorded in some stations where the long term rainfall data is available. The calculated running means vary widely with fluctuation. The mean for Itikinumu Estate varies within a constant range of 2,900 mm to 3,500 mm, and the means of the Laloki DAL and the Rouna 1/3 stations, both located at the middle and downstream reaches of the Laloki River seem to vary synchronously. As far as the mean of the Laloki DAL station is concerned, its recent trend indicates that the rainfall amount is decreasing year by year, while no decrease of rainfall is indicated in the mean of the Itikinumu Estate station, located upstream of the Laloki River Basin.

4.2 Discharge

4.2.1 Laloki River

To estimate the available surface water resources of the Laloki River Basin, "Operational Hydrology Study for the Laloki River System, June 1989" prepared for Bureau of Water Resources, was referred as it is the most reliable source of information, because the study was conducted most recently, (three (3) years ago), and the rainfall-runoff model of the river system was established in the course of the study, including detailed evaluation of all available records, as mentioned below.

"Operational Hydrology Study for the Laloki River System" was carried out to develop a computer model for simulating the operation of the Laloki River System (LAMPS: Laloki Moitaka Power Simulation). LAMPS is expected to be used for short term budgeting and long term planning for maximizing the reliability of operation of the system and minimizing necessary costs. To enable accurate simulation, 30 models of stream flows each over 30 years were generated with the calibrated rainfall-runoff model called MONASH Model. The calibration of the model was performed based on the recorded historical rainfall and stream flow data which had been well evaluated and examined beforehand. Reconstitution of the river flow was also carried out to facilitate calibration of the model.

As a result, the stream flow generated by the calibrated model showed a good agreement with the historical records, as shown in Table - 4.3 and Table - 4.4, and the 30 models of generated flow are statistically compatible to the natural flows which occur as natural phenomena. The principal feature of the MONASH Model and the calibrated parameters of the model are presented in Fig. - 4.5.

In this study, the stream flows described above are fully utilized for estimating the available surface water resources of the Laloki River. The generated stream flow actually consists of:

- daily mean discharge of the inflow to the Sirinumu Dam (m^3/s),
- daily mean discharge of the uncontrolled basins (m^3/s), and
- daily rainfall in the Sirinumu Dam reservoir area (mm/day).

The sum discharge of these values is the daily mean discharge of the Laloki River without dam operation effects. To consider the dam operation effects in the study, 6.5 m^3/s of discharge is added to the sum discharge considering the following items:

- The full supply level of the Sirinumu dam is RL537.67 m according to the stage-storage data of the Bureau of Water Resources.

- The minimum operating level of the dam is RL515.19 m, which is the top of the screen bottom plate on the intake tower.

- The operating volume of the reservoir is then calculated to be approximately 350 million m^3, based on the stage-storage curve shown in Fig. - 4.6.

- However, the recorded reservoir level is decreasing to a level of about RL529.0 m, for some reason, and the actual operating volume of dam is calculated as approximately 100 million m^3.

- Therefore, 6.5 m^3/s of discharge is added, obtained by dividing the operating volume of 100 million m^3 by number of days for six (6) months from June to November.

The minimum discharge during the dry season form June to November is calculated for each year throughout the generated period of over 30 years, and statistical calculations performed for the calculated minimum discharge to obtain the probable drought discharge for 2, 5, 10 and 20 years return period for each model. The probable drought discharges are calculated using the Iwai, Pearson III and Gumbel methods as shown below.

(Unit: m^3/s)

Method	Return Period			
	20 year	10 year	5 year	2 year
Iwai	*8.5*	*8.7*	*9.0*	*9.6*
Pearson III	*8.5*	*8.7*	*9.0*	*9.6*
Gumbel	6.5	7.4	8.4	9.8

Considering that the Gumbel Method provides conservative values, the values derived by the Iwai or Pearson III Methods are recommended. The calculated probable discharge of each model is presented in Table - 4.5.

4.2.2 Brown River

There are four (4) gauging stations in the Brown River Basin; Karema, Bogaiana, Roguoia Junction and Madilogo stations. The monthly mean discharges recorded in these stations are presented in Table - 4.6, and their averages are summarized below.

(Unit: m^3/s)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Karema	109.5	131.4	151.0	135.8	88.6	56.8	43.5	*38.8*	42.5	52.6	56.4	78.1
Bogaiana	9.8	10.8	13.6	14.2	9.4	6.5	5.0	*4.8*	4.9	5.7	6.4	8.0
Roguoia JC	61.7	87.3	89.5	89.6	59.0	43.1	33.9	*29.9*	30.8	36.7	38.7	55.9
Madilogo	18.8	21.2	30.1	25.1	18.8	11.8	8.3	*7.5*	7.8	11.3	11.7	15.2

The period from June to November is considered a dry period according to the above table, and the months of June, July and August form the driest period.

The daily mean discharges recorded at the stations vary widely from year to year as shown in Fig. - 4.7. The range of variation in the wet period is wider than in the dry period in all stations. Fig. - 4.8 illustrates the correlations of recorded daily mean discharges between the Karema Gauging Station and the other three (3) stations located upstream of the basin. As seen below, good correlation is obtained.

Description	Correlation Factor Calculated
Karema vs. Roguoia Gauging Stations	0.95
Karema vs. Madilogo Gauging Stations	0.90
Karema vs. Bogaiana Gauging Stations	0.93

This indicates that the monthly rainfall patterns in the basin are almost similar.

The monthly minimum discharges of the gauging stations in the basin are tabulated in Table - 4.7. To calculate the probable drought discharges for the Brown River, the lowest discharges among the monthly minimum discharges from June to November are considered. The Karema Gauging Station is taken for the calculation because the station has the longest recording period and is located at the downstream end of the basin. The lowest discharges are plotted on a probability paper as shown in Fig. - 4.9, and the probable drought discharges of 2, 5, 10 and 20 year return period are calculated using Iwai, Pearson III and Gumbel Methods. The results of calculation are given below.

(Unit: m^3/s)

Method	Return Period			
	20 year	10 year	5 year	2 year
Iwai	17.8	19.7	22.4	28.6
Pearson III	19.0	20.2	22.3	27.8
Gumbel	11.7	17.0	22.5	30.8

Fig. - 4.10 shows the flow duration curve of the Brown River at Karema, provided by the Bureau of Water Resources. As shown in the figure, 90 % flow exceedence value is 31 m^3/s, almost equivalent to the probable discharge of 2 year return period derived from the monthly minimum discharges.

4.2.3 Goldie River

There are two (2) gauging stations in the Goldie River Basin; Uberi and Ebealue Gauging Stations located upstream of the Goldie River and in the Ebealue River, one of the tributaries of the Goldie River. The monthly discharges of these stations are tabulated in Table - 4.8, and their averages are summarized below.

(Unit: m^3/s)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Uberi	8.2	9.7	9.7	7.5	8.2	5.4	*5.1*	5.8	7.4	6.1	5.3	6.3
Ebealue	1.0	1.1	2.7	0.8	0.8	0.4	*0.3*	*0.3*	0.4	0.5	0.8	0.5

There is no rainfall station in this basin and the available gauging stations are located in the tributary and in the quite upstream parts of the basin. The recorded period of the discharge is rather short. A statistical method is not suitable for calibrating the rainfall-runoff model nor for estimating probable discharges. Therefore, the drought discharge of the Goldie River is estimated based on the specific discharge derived from the probable drought discharges calculated for the Brown River, since the river characteristics and the conditions of basin such as vegetation, rainfall patterns, etc. are similar to those of the Brown River. The calculations are summarized in the following table.

Return Period (year)	Probable Discharge for the Brown River (m^3/s)	Specific Discharge ($l/s/km^2$)	Probable Discharge for the Goldie River (m^3/s)
2	27.8	0.0000199	10.4
5	22.3	0.0000159	8.4
10	20.2	0.0000144	7.6
20	19.0	0.0000136	7.1

The monthly minimum discharges and their variations are given in Table -4.9 and Fig. -4.11, respectively, for reference.

5. Potential Surface Water and Diversion Sites

5.1 Potential Surface Water Resources

The calculated probable drought discharges of the Laloki, the Brown and the Goldie Rivers are summarized in the following table.

River	Probable Drought Discharge (m^3/s)			
	2 year	5 year	10 year	20 year
Laloki River	9.6	9.0	8.7	8.5
Brown River	27.8	22.3	20.2	19.0
Goldie River	10.4	8.4	7.6	7.1

As shown in the table, the calculated probable draught discharges of the Laloki River vary in the range of 8.5 m^3/s to 9.6 m^3/s, and the normal discharge is about 10.0 m^3/s, which satisfies the requirements of both water supply to the NCD area, and electric power generation at present.

The future requirement in 2012 is estimated at about 4.0 m^3/s based on the expected population growth, while the present requirement is about 1.20 m^3/s, which is diverted from one of the penstocks to Rouna 1 power station. In case the increment of discharge is diverted from the same point as is done now, the power generation will be affected by this additional diversion, and the additional power can be handled by Moitaka Power Station to some extent, which has the spare capacity to cope with the additional loads caused by this change. However, if the additional water is diverted downstream of the existing tailrace of the Rouna 4 Power Station, the electric power generation will not be affected.

The surface water resources of the other two (2) rivers are adequate. It is not necessary to utilize the flow of these rivers, because the flow of the Laloki River is considered adequate as discussed above.

5.2 Alternative Diversion Sites

The alternative sites where the additionally required water is diverted are considered as follows:

Alternative Sites	Description
• Upstream of the penstock to the Rouna 1/3 Power Station:	The electric power generation will be affected to some extent, and the Moitaka Power Station, which has a sufficient capacity to generate the additionally required power, will have to be utilized.
• Downstream of the Rouna 4 tailrace:	Costly to construct the necessary intake and conveying facilities downstream of the Rouna 4 tailrace, because the topography around the site is steep, consisting of gorges.
• Bomana Pumping Station Site:	It is necessary to improve the existing pumping station increasing its capacity or to provide a new pumping station near the existing one.

Table - 3.1 List of Discharge and Rainfall Stations

		Grid Reference
I.	DISCHARGE GAUGING STATION	
I.1.	LALOKI RIVER SYSTEM	
	• Dam Site No.2 (604370)	488520
	• Sirinumu (604500)	485550
	• Eilogo Plantation (604600)	527554
	• Arubada (604960)	483555
	• Sogeri (605580)	458583
	• Artificial Station (605600)	-
	• Sogeri, Pre-dam (605700)	442581
	• Sogeri, Post-dam (605710)	439582
	• Bomana Pumping Station (606350)	284618
I.2.	GOLDIE RIVER SYSTEM	
	• Uberi (606450)	546652
	• Ebealue (606650)	366691
I.3.	BROWN RIVER SYSTEM	
	• Karema (607300)	256829
	• Rouoia JC (607270)	595922
	• Madilogo (607250)	607825
	• Bogaiana (607210)	738733

		Grid Reference	Altitude
II.	RAINFALL STATION		
II.1.	LALOKI RIVER SYSTEM		
	• Igomuti Village (604100)	556450	600 m
	• Omarinumu (604200)	520438	720 m
	• Karakatana (604300)	504527	520 m
	• Ruruluba (605230)	581591	500 m
	• Rouna 1/3 (55011)*	Latitude: 09 25 South Longitude: 147 21 East	158 m
	• Laloki DAL (55082)*	Latitude: - Longitude: -	- m
II.2.	GOLDIE RIVER SYSTEM		
	N/A		
II.3.	BROWN RIVER SYSTEM		
	• Roguoia (55096R)	595922	330 m
	• Madilogo (55097R)	602826	665 m
	• Bogiana (55098R)	738732	780 m
	• Kagi (55099R)	741904	1,600 m
	• Manumu (55100R)	632972	590 m
	• Boridi (55101R)	698961	1,200 m
	• Manari (55102R)	683835	780 m
	• Upper Naoro (55103R)	847847	2,210 m
	• Karema (55117R)	256829	
	• Brown River Forestry (55024)*	Latitude: 09 16 South Longitude: 147 05 East	18 m

Note: *: Stations operated by National of Weather Service (NWS)

Table - 4.1 Monthly Rainfalls Observed in the Brown River Basin (1/5)

(Roguola Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1983	*	*	*	*	*	*	*	*	*	*	*	*
1984	196.0	*	*	*	*	96.0	*	*	*	*	128.0	414.0
1985	338.0	58.0	*	*	*	*	39.0	21.0	306.0	158.0	287.0	321.0
1986	278.0	307.0	414.0	332.0	29.0	45.0	10.0	88.0	86.0	46.0	114.0	159.0
1987	319.0	172.0	258.0	142.0	59.0	24.0	34.0	5.0	165.0	52.0	143.0	441.0
1988	*	*	*	*	*	*	*	*	*	*	*	*
1989	*	*	*	*	*	*	*	*	*	*	*	*
1990	*	*	*	*	*	*	*	*	*	*	*	*
1991	*	*	*	*	*	*	*	*	*	*	*	*
1992	*	*	*	*	*	*	*	*	*	*	*	*
Ave.	282.8	179.0	336.0	237.0	44.0	55.0	27.7	38.0	185.7	85.3	168.0	333.8
								Average Annual Rainfall (mm):				1,972.2

(Madilogo Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1983	*	*	*	*	*	*	*	*	*	*	*	*
1984	*	*	*	*	*	75.0	25.0	69.0	*	*	*	*
1985	481.0	341.0	420.0	389.0	119.0	139.0	59.0	68.0	492.0	380.0	361.0	364.0
1986	305.0	380.0	493.0	485.0	112.0	103.0	8.0	78.0	*	*	*	*
1987	*	*	*	234.0	31.0	33.0	18.0	2.0	172.0	59.0	148.0	287.0
1988	448.0	*	*	*	37.0	40.0	49.0	85.0	148.0	364.0	312.0	260.0
1989	274.0	*	*	*	*	109.0	58.0	76.0	*	*	*	*
1990	*	*	*	*	*	*	*	*	*	*	*	*
1991	*	*	*	*	*	*	*	*	*	*	*	*
1992	*	*	*	*	*	*	*	*	*	*	*	*
Ave.	377.0	360.5	456.5	369.3	74.8	83.2	36.2	63.0	270.7	267.7	273.7	303.7
								Average Annual Rainfall (mm):				2,936.1

(Bogaiana Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1983	*	*	*	*	*	*	*	*	*	*	*	*
1984	*	*	*	*	*	47.0	19.0	*	*	*	*	*
1985	*	*	*	423.0	256.0	246.0	134.0	172.0	490.0	337.0	317.0	338.0
1986	326.0	357.0	368.0	481.0	220.0	144.0	33.0	79.0	127.0	118.0	31.0	136.0
1987	370.0	70.0	130.0	273.0	110.0	51.0	21.0	2.0	268.0	107.0	159.0	196.0
1988	223.0	56.0	479.0	133.0	138.0	0.0	0.0	*	*	*	*	*
1989	*	*	*	*	*	*	*	*	*	*	*	*
1990	*	*	348.0	347.0	326.0	137.0	141.0	85.0	221.0	317.0	109.0	267.0
1991	348.0	359.0	134.0	329.0	83.0	30.0	97.0	218.0	5.0	10.0	155.0	197.0
1992	228.0	232.0	400.0	375.0	*	*	*	*	*	*	*	*
Ave.	299.0	214.8	309.8	337.3	188.8	93.6	63.6	111.2	222.2	177.8	154.2	226.8
								Average Annual Rainfall (mm):				2,399.1

Table - 4.1 Monthly Rainfalls Observed in the Brown River Basin (2/5)

(Kagi Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1983	*	*	*	*	*	*	*	*	*	*	*	*
1984	*	*	*	*	*	131.0	27.0	72.0	354.0	201.0	274.0	655.0
1985	663.0	351.0	427.0	254.0	197.0	239.0	102.0	69.0	276.0	274.0	451.0	333.0
1986	408.0	468.0	443.0	628.0	102.0	204.0	57.0	116.0	*	*	*	*
1987	502.0	315.0	513.0	224.0	68.0	16.0	92.0	*	*	*	*	*
1988	*	*	*	*	*	0.0	137.0	116.0	132.0	*	*	*
1989	*	*	*	*	*	130.0	56.0	167.0	182.0	*	*	*
1990	*	*	*	*	*	211.0	172.0	163.0	414.0	*	*	*
1991	*	*	*	*	129.0	82.0	131.0	166.0	7.0	0.0	*	*
Ave.	524.3	378.0	461.0	368.7	124.0	126.6	96.8	124.1	227.5	158.3	362.5	494.0
								Average Annual Rainfall (mm):				3,445.9

(Manumu Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1983	*	*	*	*	*	*	*	*	*	*	*	*
1984	126.0	359.0	*	*	*	135.0	28.0	68.0	43.0	*	*	*
1985	255.0	171.0	316.0	182.0	71.0	114.0	39.0	26.0	309.0	140.0	271.0	203.0
1986	295.0	227.0	*	*	*	*	43.0	71.0	67.0	67.0	93.0	184.0
1987	253.0	126.0	267.0	97.0	93.0	44.0	16.0	1.0	154.0	67.0	115.0	299.0
1988	361.0	235.0	269.0	294.0	47.0	96.0	56.0	43.0	79.0	283.0	348.0	224.0
1989	370.0	*	*	*	*	102.0	86.0	50.0	186.0	173.0	304.0	*
1990	*	*	160.0	20.0	4.0	12.0	*	*	*	*	*	*
1991	243.0	296.0	134.0	190.0	0.0	0.0	113.0	0.0	13.0	327.0	195.0	388.0
1992	269.0	*	*	*	*	*	*	*	*	*	*	*
Ave.	271.5	235.7	229.2	156.6	43.0	71.9	54.4	37.0	121.6	176.2	221.0	259.6
								Average Annual Rainfall (mm):				1,877.6

(Boridi Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1983	*	*	*	*	*	*	*	*	*	*	*	*
1984	*	*	*	*	*	56.0	30.0	48.0	156.0	206.0	186.0	598.0
1985	663.0	168.0	299.0	121.0	2.0	181.0	33.0	29.0	312.0	159.0	293.0	348.0
1986	360.0	301.0	365.0	584.0	148.0	181.0	38.0	108.0	160.0	70.0	113.0	166.0
1987	137.0	152.0	*	*	*	26.0	67.0	6.0	0.0	0.0	3.0	354.0
1988	406.0	326.0	309.0	285.0	92.0	128.0	63.0	51.0	98.0	480.0	312.0	231.0
1989	*	*	*	*	*	113.0	51.0	72.0	130.0	277.0	277.0	25.0
1990	*	*	170.0	340.0	124.0	163.0	144.0	231.0	336.0	210.0	155.0	225.0
1991	450.0	301.0	113.0	262.0	103.0	58.0	88.0	158.0	51.0	6.0	179.0	354.0
1992	273.0	388.0	485.0	268.0	*	*	*	*	*	*	*	*
Ave.	381.5	272.7	290.2	310.0	93.8	113.3	64.3	87.9	155.4	176.0	189.8	287.6
								Average Annual Rainfall (mm):				2,422.3

Table - 4.1 Monthly Rainfalls Observed in the Brown River Basin (3/5)

(Manari Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1983	*	*	*	*	*	*	*	*	*	*	*	*
1984	351.0	305.0	*	*	*	178.0	12.0	120.0	246.0	189.0	183.0	498.0
1985	593.0	316.0	422.0	362.0	147.0	128.0	51.0	123.0	439.0	191.0	392.0	299.0
1986	349.0	309.0	413.0	377.0	159.0	114.0	47.0	80.0	120.0	189.0	85.0	207.0
1987	494.0	235.0	351.0	241.0	71.0	59.0	35.0	10.0	206.0	141.0	137.0	298.0
1988	179.0	240.0	289.0	197.0	206.0	120.0	149.0	138.0	182.0	304.0	228.0	203.0
1989	*	*	*	*	*	*	*	*	*	234.0	223.0	*
1990	*	*	292.0	344.0	296.0	189.0	168.0	87.0	256.0	209.0	38.0	251.0
1991	256.0	345.0	84.0	242.0	91.0	74.0	81.0	*	*	*	*	203.0
1992	156.0	296.0	507.0	340.0	*	*	*	*	*	*	*	*
Ave.	339.7	292.3	336.9	300.4	161.7	123.1	77.6	93.0	241.5	208.1	183.7	279.9
								Average Annual Rainfall (mm):				2,637.9

(Upper Naoro Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1983	*	*	*	*	*	*	*	*	*	*	*	*
1984	290.0	273.0	397.0	337.0	176.0	206.0	*	*	*	*	206.0	340.0
1985	*	*	*	249.0	198.0	263.0	134.0	88.0	207.0	183.0	303.0	134.0
1986	454.0	395.0	424.0	*	*	*	14.0	68.0	115.0	102.0	80.0	182.0
1987	509.0	512.0	375.0	238.0	62.0	*	*	*	179.0	65.0	158.0	248.0
1988	484.0	373.0	319.0	213.0	103.0	176.0	62.0	73.0	98.0	473.0	*	*
1989	*	*	*	*	*	106.0	63.0	119.0	204.0	234.0	287.0	408.0
1990	627.0	239.0	540.0	246.0	3.0	91.0	137.0	139.0	351.0	226.0	77.0	208.0
1991	426.0	106.0	6.0	45.0	78.0	17.0	4.0	57.0	*	*	*	135.0
1992	224.0	*	*	*	*	*	*	*	*	*	*	*
Ave.	430.6	316.3	343.5	221.3	103.3	143.2	69.0	90.7	192.3	213.8	185.2	236.4
								Average Annual Rainfall (mm):				2,545.7

(Karema Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1961	197.0	541.0	94.0	233.0	139.0	14.0	74.0	59.0	199.0	154.0	140.0	222.0
1962	504.0	210.0	26.0	338.0	141.0	54.0	31.0	72.0	146.0	73.0	71.0	192.0
1963	469.0	28.0	392.0	136.0	84.0	23.0	27.0	106.0	141.0	65.0	53.0	249.0
1964	202.0	79.0	279.0	47.0	123.0	25.0	1.0	42.0	150.0	345.0	52.0	91.0
1965	91.0	132.0	426.0	229.0	174.0	12.0	0.0	0.0	34.0	78.0	7.0	270.0
1966	249.0	352.0	135.0	82.0	47.0	33.0	7.0	7.0	141.0	187.0	139.0	357.0
1967	484.0	248.0	619.0	174.0	*	56.0	22.0	3.0	85.0	125.0	58.0	313.0
1968	262.0	237.0	177.0	108.0	136.0	16.0	37.0	7.0	67.0	67.0	60.0	49.0
1969	170.0	335.0	165.0	341.0	123.0	113.0	12.0	20.0	36.0	35.0	209.0	210.0
1970	171.0	445.0	552.0	72.0	123.0	3.0	82.0	195.0	210.0	434.0	203.0	*
1971	420.0	207.0	212.0	269.0	351.0	108.0	76.0	70.0	*	260.0	219.0	8.0
1972	174.0	188.0	573.0	*	*	1.0	8.0	0.0	17.0	23.0	58.0	31.0
1973	359.0	157.0	380.0	330.0	192.0	159.0	78.0	31.0	5.0	*	*	*
Ave.	288.6	243.0	310.0	196.6	148.5	47.5	35.0	47.1	102.6	153.8	105.8	181.1
								Average Annual Rainfall (mm):				1,859.4

Table - 4.1 Monthly Rainfalls Observed in the Brown River Basin (4/5)

(Kokoda Yoda (Mamba Estate) Station, NWS)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1949	*	*	*	*	*	*	*	*	*	*	535.0	643.0
1950	681.0	631.0	474.0	422.0	443.0	230.0	315.0	266.0	545.0	341.0	464.0	455.0
1951	443.0	446.0	224.0	172.0	141.0	105.0	184.0	163.0	215.0	375.0	633.0	807.0
1952	489.0	812.0	798.0	195.0	242.0	370.0	215.0	224.0	535.0	438.0	386.0	314.0
1953	487.0	437.0	467.0	773.0	162.0	196.0	332.0	313.0	432.0	240.0	496.0	729.0
1954	452.0	871.0	341.0	540.0	364.0	102.0	115.0	259.0	250.0	561.0	420.0	647.0
1955	306.0	526.0	105.0	407.0	309.0	116.0	202.0	185.0	193.0	216.0	523.0	426.0
1956	359.0	292.0	431.0	395.0	113.0	59.0	90.0	224.0	289.0	286.0	323.0	*
1957	215.0	187.0	791.0	554.0	329.0	165.0	308.0	262.0	426.0	460.0	425.0	589.0
1958	429.0	591.0	593.0	423.0	193.0	176.0	118.0	265.0	325.0	420.0	323.0	603.0
1959	359.0	341.0	481.0	597.0	305.0	395.0	291.0	77.0	345.0	242.0	595.0	188.0
1960	798.0	560.0	322.0	448.0	186.0	345.0	104.0	328.0	170.0	515.0	399.0	485.0
1961	626.0	438.0	351.0	307.0	528.0	321.0	259.0	456.0	154.0	492.0	388.0	304.0
1962	219.0	320.0	390.0	347.0	320.0	116.0	299.0	286.0	326.0	554.0	243.0	398.0
1963	163.0	257.0	486.0	220.0	247.0	274.0	196.0	364.0	259.0	527.0	346.0	611.0
1964	498.0	360.0	319.0	455.0	431.0	41.0	257.0	379.0	316.0	360.0	564.0	238.0
1965	473.0	417.0	622.0	180.0	405.0	181.0	20.0	65.0	314.0	300.0	126.0	655.0
1966	516.0	495.0	392.0	306.0	502.0	222.0	88.0	226.0	333.0	678.0	578.0	348.0
1967	544.0	525.0	143.0	240.0	373.0	172.0	153.0	167.0	364.0	593.0	338.0	644.0
1968	576.0	210.0	416.0	217.0	247.0	155.0	390.0	179.0	438.0	357.0	448.0	599.0
1969	353.0	484.0	537.0	350.0	222.0	243.0	219.0	209.0	285.0	479.0	393.0	733.0
1970	293.0	396.0	690.0	403.0	331.0	154.0	282.0	221.0	156.0	652.0	536.0	450.0
1971	614.0	398.0	334.0	439.0	344.0	310.0	269.0	104.0	276.0	318.0	279.0	310.0
1972	*	263.0	247.0	315.0	169.0	111.0	85.0	36.0	143.0	149.0	608.0	286.0
1973	754.0	*	*	*	*	*	*	*	*	*	*	*
1974	409.0	480.0	296.0	246.0	307.0	174.0	347.0	172.0	273.0	600.0	504.0	329.0
1975	327.0	608.0	704.0	628.0	456.0	237.0	167.0	274.0	373.0	219.0	465.0	516.0
1976	204.0	215.0	314.0	208.0	275.0	176.0	68.0	60.0	272.0	280.0	369.0	446.0
1977	263.0	539.0	230.0	260.0	363.0	108.0	268.0	282.0	627.0	669.0	525.0	240.0
1978	303.0	184.0	453.0	248.0	*	235.0	215.0	128.0	177.0	369.0	398.0	520.0
1979	74.0	413.0	533.0	280.0	372.0	184.0	184.0	117.0	170.0	392.0	545.0	453.0
1980	508.0	122.0	224.0	532.0	204.0	121.0	146.0	242.0	166.0	372.0	589.0	339.0
1981	300.0	63.0	70.0	372.0	259.0	355.0	270.0	117.0	273.0	456.0	427.0	415.0
1982	423.0	321.0	517.0	309.0	249.0	209.0	146.0	272.0	130.0	149.0	101.0	*
1983	365.0	570.0	549.0	391.0	450.0	242.0	84.0	340.0	369.0	437.0	573.0	415.0
1984	383.0	354.0	206.0	283.0	597.0	393.0	135.0	358.0	244.0	*	*	214.0
1985	385.0	327.0	411.0	*	*	*	*	*	*	*	*	*
1986	445.0	462.0	521.0	648.0	216.0	337.0	191.0	177.0	307.0	249.0	376.0	282.0
1987	*	*	*	*	*	*	*	*	*	*	*	*
1988	406.6	266.4	617.6	390.8	394.2	225.8	*	*	*	*	*	*
1989	551.4	466.8	*	*	*	*	*	*	*	499.0	*	*
1990	248.2	207.4	176.0	454.0	331.6	297.8	326.4	286.0	749.8	560.4	343.2	333.6
1991	391.8	244.6	102.4	374.2	116.4	188.4	747.8	470.6	90.2	595.4	401.8	659.4
Ave.	415.9	402.5	407.1	377.1	310.7	211.6	218.5	231.2	305.7	416.2	432.1	461.8

Average Annual Rainfall (mm): 4,190.3

Table - 4.1 Monthly Rainfalls Observed in the Brown River Basin (5/5)

(Brown River Forestry Station, NWS)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1968	*	*	*	*	*	*	*	*	*	*	48.0	203.0
1969	171.0	294.0	164.0	246.0	37.0	201.0	8.0	16.0	124.0	104.0	168.0	*
1970	*90.0*	*345.0*	*433.0*	*53.0*	*95.0*	*0.0*	*68.0*	*174.0*	*155.0*	*381.0*	*142.0*	*253.0*
1971	291.0	179.0	159.0	180.0	319.0	133.0	120.0	66.0	211.0	237.0	225.0	157.0
1972	216.0	156.0	496.0	117.0	155.0	0.0	5.0	0.0	9.0	13.0	53.0	*
1973	301.0	146.0	349.0	316.0	136.0	112.0	61.0	*	33.0	217.0	446.0	423.0
1974	357.0	296.0	196.0	274.0	146.0	68.0	47.0	11.0	178.0	142.0	90.0	174.0
1975	102.0	269.0	334.0	281.0	220.0	90.0	40.0	89.0	98.0	98.0	291.0	275.0
1976	439.0	121.0	215.0	213.0	323.0	112.0	47.0	6.0	2.0	205.0	209.0	*
1977	225.0	293.0	106.0	293.0	161.0	116.0	91.0	82.0	75.0	132.0	72.0	108.0
1978	198.0	218.0	205.0	108.0	169.0	15.0	23.0	59.0	29.0	54.0	244.0	*
1979	*	*	377.0	185.0	226.0	*	*	*	*	*	*	*
1980	*	*	*	*	*	*	*	*	*	*	*	*
Ave.	239.0	231.7	275.8	206.0	180.6	84.7	51.0	55.9	91.4	158.3	180.7	227.6
								Average Annual Rainfall (mm).				1,982.7

Table - 4.2 Monthly Rainfall Observed in Laloki River Basin (1/4)

(Rouna 1/3 Station, NWS)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1957	*	*	*	*	*	*	*	162.0	109.0	82.0	37.0	279.0
1958	158.0	296.0	303.0	143.0	112.0	61.0	2.0	11.0	420.0	120.0	158.0	145.0
1959	186.0	162.0	249.0	302.0	46.0	46.0	28.0	31.0	42.0	57.0	79.0	134.0
1960	201.0	177.0	247.0	194.0	332.0	84.0	8.0	63.0	47.0	109.0	47.0	246.0
1961	207.0	363.0	235.0	82.0	229.0	23.0	76.0	67.0	73.0	77.0	167.0	203.0
1962	455.0	352.0	318.0	184.0	77.0	42.0	15.0	53.0	170.0	102.0	115.0	193.0
1963	388.0	285.0	345.0	217.0	90.0	180.0	84.0	85.0	151.0	52.0	62.0	227.0
1964	263.0	207.0	331.0	141.0	121.0	11.0	93.0	77.0	243.0	110.0	207.0	131.0
1965	140.0	216.0	355.0	176.0	142.0	5.0	0.0	0.0	11.0	90.0	1.0	287.0
1966	270.0	417.0	320.0	92.0	19.0	108.0	26.0	59.0	181.0	125.0	57.0	122.0
1967	536.0	336.0	560.0	95.0	166.0	61.0	48.0	91.0	55.0	91.0	63.0	166.0
1968	221.0	421.0	201.0	107.0	153.0	9.0	46.0	129.0	76.0	69.0	14.0	156.0
1969	270.0	427.0	162.0	304.0	20.0	34.0	6.0	38.0	57.0	43.0	75.0	234.0
1970	209.0	450.0	275.0	111.0	76.0	57.0	94.0	50.0	263.0	340.0	184.0	385.0
1971	236.0	240.0	215.0	177.0	235.0	131.0	107.0	48.0	141.0	135.0	86.0	129.0
1972	*	311.0	339.0	177.0	211.0	10.0	0.0	0.0	20.0	45.0	105.0	43.0
1973	240.0	*	*	*	*	*	*	*	*	*	*	*
1974	247.0	107.0	173.0	249.0	134.0	25.0	60.0	27.0	179.0	853.0	291.0	335.0
1975	617.0	546.0	581.0	141.0	292.0	414.0	48.0	124.0	112.0	197.0	178.0	112.0
1976	385.0	258.0	217.0	258.0	132.0	161.0	10.0	45.0	0.0	109.0	163.0	281.0
1977	161.0	282.0	67.0	282.0	184.0	73.0	*	*	100.0	*	19.0	168.0
1978	476.0	327.0	180.0	65.0	146.0	64.0	61.0	31.0	103.0	2.0	259.0	101.0
1979	304.2	143.0	386.0	150.0	281.0	33.0	67.0	0.0	78.0	67.0	69.0	139.0
1980	322.0	144.0	228.0	16.2	13.0	94.2	2.8	29.4	0.0	8.4	80.4	175.0
1981	543.8	89.8	198.0	194.2	67.4	52.0	70.2	56.6	55.8	141.6	123.4	*
1982	242.2	167.4	268.8	*	96.4	*	*	115.2	0.0	1.2	70.8	56.4
1983	*	214.4	223.0	108.6	100.4	48.8	*	35.6	*	*	118.2	*
1984	*	*	*	*	*	*	*	178.0	*	*	*	*
1985	313.4	328.0	501.6	*	*	*	*	*	*	*	*	*
1986	*	*	443.2	361.2	*	*	*	*	1.4	56.4	24.0	92.4
1987	341.0	373.2	78.0	41.8	17.4	2.4	12.8	*	18.4	26.4	43.4	81.6
1988	125.8	102.4	256.4	104.2	150.0	138.6	58.0	50.0	25.6	128.2	109.8	175.8
1989	126.2	82.0	370.2	195.0	76.0	0.0	69.4	0.0	0.0	0.0	0.0	0.0
1990	462.2	*	*	*	*	*	*	*	*	*	*	*
1991	*	*	*	*	*	*	*	*	*	*	*	*
Ave.	298.2	269.8	287.5	166.7	132.8	72.9	43.7	59.1	94.2	115.6	100.2	171.3

Average Annual Rainfall (mm): 1,812.1

Table - 4.2 Monthly Rainfall Observed in Laloki River Basin (2/4)

(Laloki DAL Station, NWS)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1949	48.6	267.0	100.4	203.2	2.0	117.0	54.4	11.8	27.4	34.8	80.2	277.8
1950	134.0	402.4	107.2	169.6	139.2	45.0	81.6	37.6	4.4	23.4	48.8	190.6
1951	141.6	166.0	347.2	74.0	23.4	11.8	0.0	32.4	44.0	1.6	233.4	34.8
1952	347.4	167.4	184.4	67.6	109.2	169.4	15.2	56.6	11.2	39.0	234.0	346.4
1953	186.8	131.4	119.6	152.4	37.8	30.0	2.6	98.8	27.8	5.6	146.8	176.6
1954	97.0	157.6	90.6	186.6	44.0	46.8	17.8	22.8	6.4	9.2	48.0	124.2
1955	125.2	307.4	114.8	82.4	61.2	6.6	0.0	0.0	48.2	20.4	149.0	60.2
1956	74.8	199.2	138.0	311.4	50.8	72.2	7.0	24.2	99.8	73.2	159.4	151.4
1957	160.2	361.2	347.0	273.0	33.4	0.0	5.2	102.6	78.6	29.2	24.0	236.8
1958	139.4	139.8	105.0	74.0	23.4	77.0	0.0	44.0	258.2	12.8	20.6	134.2
1959	150.6	119.0	172.0	193.0	26.4	10.8	23.4	5.2	16.8	17.2	13.2	198.4
1960	169.4	137.0	183.4	98.4	134.4	44.4	13.0	11.0	25.2	44.8	23.0	296.2
1961	103.0	377.0	117.4	164.6	131.0	13.6	37.4	24.2	41.8	44.2	117.4	215.0
1962	255.4	158.2	191.8	142.6	40.0	10.2	3.6	38.4	78.8	17.0	60.6	115.2
1963	424.0	146.6	343.2	142.2	20.6	195.4	45.2	4.8	82.6	39.6	13.4	85.2
1964	165.6	95.6	431.4	21.4	83.6	8.6	13.6	4.8	36.8	52.8	363.0	123.2
1965	131.8	198.6	226.8	47.8	36.4	0.0	0.0	0.0	0.0	41.0	0.0	248.0
1966	87.2	229.2	329.4	55.6	20.8	61.8	10.4	41.6	61.0	56.6	42.2	356.6
1967	330.2	290.8	453.4	68.6	48.4	62.2	35.4	65.8	61.8	72.0	1.0	80.6
1968	197.0	247.6	127.6	60.0	113.8	4.6	14.8	75.8	33.4	97.6	0.6	120.8
1969	105.8	220.0	144.0	213.2	7.6	30.8	1.8	13.6	14.8	8.4	92.2	128.0
1970	171.6	280.4	242.8	93.6	65.8	12.2	49.8	89.4	134.6	168.0	324.0	124.6
1971	254.4	191.4	178.6	169.0	104.6	200.4	6.6	30.6	24.6	109.8	102.4	122.0
1972	120.0	302.6	407.4	90.4	117.4	0.0	1.0	0.0	2.6	1.4	4.6	1.0
1973	165.4	97.0	263.0	107.2	105.2	126.0	0.0	21.6	44.8	6.6	358.2	169.2
1974	208.0	326.2	75.0	162.8	59.2	21.0	48.4	7.2	142.0	19.2	48.4	103.2
1975	134.4	185.2	279.6	130.8	210.2	204.8	35.2	36.2	11.4	149.6	134.6	267.4
1976	361.0	118.2	184.2	145.4	128.0	94.2	3.6	35.4	0.0	199.0	181.4	253.2
1977	213.0	154.8	104.4	305.4	101.6	31.8	73.4	37.6	79.6	48.6	28.0	87.6
1978	139.2	176.0	112.0	73.0	46.2	8.6	87.2	38.4	43.2	11.0	260.8	0.0
1979	158.4	119.8	253.0	93.4	33.6	0.0	0.0	0.0	0.0	0.0	0.0	97.6
1980	208.0	107.6	125.0	9.4	2.8	2.0	0.0	23.4	0.0	0.0	25.8	191.0
1981	331.0	39.8	153.2	195.0	8.8	160.0	67.8	23.4	10.2	123.0	124.8	225.0
1982	201.0	84.8	264.0	66.8	74.2	2.8	3.8	93.2	0.0	1.0	7.2	5.4
1983	32.4	223.8	145.4	77.4	92.6	17.8	27.6	5.6	34.6	82.6	46.8	226.4
1984	*	*	*	*	*	*	*	*	*	*	*	*
1985	*	*	*	*	*	*	*	*	*	*	*	*
1986	*	*	*	*	*	79.4	9.0	8.6	8.8	38.8	0.0	84.4
1987	319.0	114.8	185.8	44.4	31.4	0.0	14.8	*	19.0	5.6	6.2	192.8
1988	151.2	82.0	321.8	102.2	29.2	109.6	21.8	6.0	25.6	43.6	128.4	168.2
1989	107.0	74.4	411.8	173.2	68.0	20.2	101.6	110.8	86.8	201.0	139.0	106.2
1990	334.4	167.2	293.6	163.2	0.0	150.4	21.4	39.6	30.4	44.0	0.0	0.0
1991	159.0	124.0	54.4	120.8	0.0	0.0	14.0	136.2	0.0	39.4	104.8	0.0
Ave.	183.6	187.2	210.7	128.1	61.7	55.1	23.6	36.5	42.9	49.6	95.0	149.4

Average Annual Rainfall (mm): 1,223.4

Table - 4.2 Monthly Rainfall Observed in Laloki River Basin (3/4)

(Itikinumu Estate Station, NWS) (1/2)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1926	294.0	76.0	713.0	321.0	57.0	177.0	66.0	195.0	407.0	327.0	389.0	321.0
1927	333.0	130.0	475.0	271.0	307.0	170.0	384.0	107.0	67.0	236.0	294.0	178.0
1928	141.0	201.0	447.0	249.0	138.0	221.0	15.0	239.0	258.0	382.0	263.0	353.0
1929	155.0	253.0	465.0	335.0	70.0	198.0	68.0	96.0	175.0	418.0	104.0	574.0
1930	112.0	321.0	421.0	395.0	317.0	133.0	0.0	182.0	*	406.0	56.0	221.0
1931	552.0	47.0	516.0	500.0	179.0	10.0	146.0	153.0	272.0	94.0	232.0	333.0
1932	209.0	116.0	400.0	197.0	111.0	91.0	65.0	80.0	259.0	103.0	462.0	438.0
1933	305.0	296.0	347.0	428.0	193.0	272.0	256.0	131.0	260.0	333.0	823.0	588.0
1934	583.0	362.0	383.0	415.0	233.0	284.0	209.0	129.0	122.0	248.0	386.0	319.0
1935	323.0	352.0	331.0	530.0	71.0	154.0	81.0	102.0	205.0	343.0	450.0	190.0
1936	744.0	107.0	327.0	591.0	261.0	317.0	341,0	299.0	416.0	217.0	206.0	298.0
1937	195.0	314.0	300.0	270.0	162.0	16.0	81.0	114.0	185.0	355.0	337.0	252.0
1938	485.0	252.0	269.0	403.0	476.0	209.0	150.0	130.0	284.0	365.0	275.0	382.0
1939	299.0	295.0	214.0	324.0	249.0	201.0	244.0	164.0	169.0	259.0	370.0	266.0
1940	485.0	347.0	250.0	211.0	563.0	71.0	44.0	15.0	14.0	3.0	388.0	228.0
1941	405.0	226.0	558.0	96.0	41.0	2.0	10.0	0.0	265.0	108.0	263.0	341.0
1942	260.0	51.0	523.0	417.0	376.0	51.0	54.0	212.0	102.0	136.0	501.0	506.0
1943	466.0	399.0	525.0	574.0	322.0	163.0	265.0	451.0	194.0	417.0	702.0	320.0
1944	42.0	274.0	308.0	403.0	370.0	357.0	99.0	171.0	147.0	131.0	176.0	287.0
1945	615.0	469.0	367.0	286.0	177.0	55.0	93.0	115.0	315.0	200.0	301.0	333.0
1946	317.0	140.0	353.0	371.0	252.0	40.0	130.0	105.0	3.0	246.0	230.0	422.0
1947	139.0	381.0	365.0	673.0	491.0	106.0	40.0	331.0	538.0	374.0	161.0	370.0
1948	73.0	272.0	289.0	395.0	153.0	107.0	64.0	275.0	16.0	333.0	460.0	341.0
1949	87.0	393.0	175.0	413.0	175.0	442.0	197.0	140.0	257.0	481.0	263.0	554.0
1950	291.0	517.0	132.0	444.0	419.0	358.0	168.0	401.0	157.0	361.0	212.0	199.0
1951	230.0	226.0	460.0	191.0	132.0	142.0	22.0	240.0	145.0	130.0	395.0	214.0
1952	715.0	459.0	545.0	277.0	241.0	409.0	56.0	302.0	307.0	255.0	560.0	204.0
1953	434.0	152.0	342.0	307.0	251.0	59.0	15.0	303.0	146.0	331.0	458.0	298.0
1954	534.0	220.0	229.0	424.0	418.0	128.0	54.0	51.0	168.0	370.0	220.0	439.0
1955	399.0	513.0	141.0	477.0	340.0	144.0	214.0	48.0	152.0	137.0	395.0	174.0
1956	227.0	177.0	322.0	374.0	527.0	256.0	107.0	170.0	233.0	502.0	278.0	298.0
1957	178.0	343.0	260.0	640.0	59.0	0.0	47.0	189.0	150.0	192.0	110.0	653.0
1958	150.0	231.0	256.0	143.0	352.0	98.0	20.0	64.0	572.0	304.0	175.0	393.0
1959	124.0	174.0	344.0	414.0	165.0	52.0	80.0	14.0	146.0	225.0	297.0	206.0
1960	239.0	273.0	419.0	259.0	589.0	247.0	25.0	64.0	130.0	304.0	262.0	276.0
1961	208.0	626.0	151.0	271.0	490.0	220.0	259.0	342.0	238.0	287.0	451.0	372.0
1962	629.0	322.0	362.0	422.0	295.0	178.0	53.0	180.0	572.0	315.0	287.0	268.0
1963	448.0	329.0	390.0	230.0	268.0	196.0	172.0	239.0	318.0	85.0	137.0	317.0
1964	279.0	190.0	261.0	461.0	416.0	147.0	141.0	236.0	324.0	495.0	517.0	111.0
1965	321.0	201.0	274.0	180.0	177.0	19.0	8.0	15.0	57.0	215.0	12.0	330.0
1966	229.0	318.0	531.0	233.0	245.0	106.0	44.0	192.0	292.0	306.0	294.0	467.0
1967	380.0	468.0	458.0	255.0	228.0	281.0	178.0	305.0	304.0	206.0	231.0	222.0
1968	227.0	301.0	384.0	*	243.0	65.0	97.0	246.0	147.0	244.0	143.0	549.0
1969	429.0	332.0	272.0	379.0	134.0	239.0	51.0	44.0	147.0	266.0	270.0	345.0
1970	365.0	389.0	312.0	292.0	225.0	163.0	267.0	293.0	554.0	473.0	647.0	371.0
1971	449.0	381.0	277.0	444.0	434.0	564.0	88.0	105.0	471.0	448.0	184.0	119.0
1972	171.0	410.0	447.0	439.0	317.0	58.0	99.0	5.0	41.0	*	292.0	75.0
1973	405.0	170.0	536.0	368.0	225.0	162.0	83.0	168.0	332.0	305.0	502.0	369.0
1974	508.0	482.0	292.0	419.0	259.0	238.0	149.0	59.0	223.0	158.0	183.0	136.0

Table - 4.2 Monthly Rainfall Observed in Laloki River Basin (4/4)

(Itikinumu Estate Station, NWS) (2/2)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1975	94.0	278.0	362.0	449.0	528.0	305.0	146.0	152.0	364.0	126.0	393.0	388.0
1976	519.0	177.0	310.0	480.0	247.0	409.0	15.0	68.0	47.0	442.0	269.0	293.0
1977	162.0	320.0	186.0	550.0	404.0	47.0	333.0	179.0	263.0	205.0	146.0	220.0
1978	262.0	245.0	*	299.0	296.0	82.0	81.0	79.0	187.0	58.0	497.0	497.0
1979	174.0	134.0	587.0	249.0	638.0	608.0	179.0	36.0	46.0	309.0	167.0	414.0
1980	416.0	259.0	156.0	318.0	145.0	118.0	95.0	39.0	18.0	89.0	235.0	316.0
1981	619.0	76.0	384.0	309.0	167.0	244.0	393.0	306.0	129.0	348.0	239.0	226.0
1982	354.0	268.0	341.0	140.0	164.0	20.0	7.0	127.0	13.0	53.0	57.0	151.0
1983	63.0	191.0	300.0	448.0	410.0	95.0	69.0	133.0	180.0	219.0	568.0	509.0
1984	432.0	391.0	290.0	337.0	433.0	185.0	80.0	332.0	278.0	234.0	105.0	409.0
1985	325.0	300.0	270.0	657.0	220.0	195.0	145.0	84.0	630.0	241.0	363.0	426.0
1986	*	*	*	*	*	*	*	*	*	*	*	*
1987	652.4	46.0	137.0	274.6	75.0	68.2	58.4	*	240.8	122.6	342.6	289.4
1988	426.0	158.8	622.6	264.2	278.0	330.2	166.2	54.0	*	*	*	*
Ave.	333.7	276.2	355.1	363.7	277.4	178.7	118.8	160.7	227.5	264.6	311.2	327.2
Average Annual Rainfall (mm):												3,194.8

(Karakatana Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1958	*	*	*	*	*	*	*	*	*	94.0	109.0	120.0
1959	88.0	141.0	137.0	311.0	72.0	18.0	*	*	19.0	133.0	127.0	155.0
1960	175.0	108.0	250.0	238.0	362.0	181.0	11.0	72.0	67.0	106.0	*	223.0
1961	211.0	319.0	129.0	380.0	345.0	109.0	189.0	186.0	141.0	244.0	199.0	203.0
1962	354.0	317.0	323.0	278.0	168.0	40.0	61.0	77.0	397.0	135.0	118.0	147.0
1963	214.0	207.0	278.0	185.0	71.0	183.0	175.0	121.0	163.0	50.0	54.0	233.0
1964	144.0	144.0	219.0	225.0	*	13.0	105.0	105.0	175.0	109.0	249.0	130.0
1965	114.0	221.0	211.0	124.0	135.0	3.0	0.0	0.0	20.0	106.0	4.0	239.0
1966	134.0	82.0	239.0	80.0	94.0	38.0	13.0	136.0	108.0	82.0	176.0	134.0
1967	467.0	221.0	385.0	61.0	138.0	144.0	82.0	105.0	*	174.0	93.0	89.0
1968	188.0	314.0	222.0	83.0	172.0	36.0	139.0	153.0	56.0	131.0	12.0	278.0
1969	316.0	280.0	127.0	330.0	*	13.0	4.0	13.0	61.0	120.0	112.0	165.0
1970	127.0	382.0	234.0	184.0	193.0	51.0	145.0	20.0	252.0	*	*	*
1971	739.0	502.0	469.0	346.0	521.0	228.0	*	62.0	278.0	225.0	101.0	126.0
1972	168.0	216.0	318.0	263.0	214.0	8.0	53.0	0.0	52.0	48.0	144.0	38.0
1973	260.0	131.0	369.0	354.0	103.0	254.0	19.0	*	*	221.0	261.0	238.0
1974	233.0	350.0	95.0	308.0	119.0	153.0	54.0	59.0	178.0	161.0	157.0	61.0
1975	208.0	247.0	241.0	160.0	357.0	151.0	104.0	101.0	*	*	*	*
1976	343.0	68.0	108.0	*	*	*	*	*	0.0	172.0	*	*
1977	*	*	*	*	182.0	6.0	13.0	13.0	*	*	*	*
Ave	249.1	236.1	241.9	230.0	202.9	90.5	72.9	76.4	131.1	135.9	127.7	161.2
Average Annual Rainfall (mm):												1,955.8

Table 4.3 Monthly Statistics Of Generated Streamflows

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A. INFLOWS TO SIRINUMU RESERVOIR													
Maximum Daily	Hist	98	141	57	85	76	74	90	19	159	69	23	58
Mean													
Discharge (m^3/s)	Gen	176	202	116	185	155	181	105	53	103	85	118	143
Highest		382	310	187	366	415	396	159	104	157	157	201	326
Lowest		99	139	79	90	74	73	50	25	63	47	58	61
Mean Daily	Hist	6.73	8.31	6.81	10.39	8.96	4.37	4.10	2.41	6.78	4.67	3.37	5.03
Discharge (m^3/s)	Gen	7.89	9.64	9.32	8.99	7.96	5.39	3.68	2.82	4.16	4.67	4.28	5.30
Highest		9.64	10.99	10.83	10.35	9.57	6.85	4.43	3.44	4.83	6.20	5.27	6.44
Lowest		6.37	8.11	7.71	7.77	6.14	4.36	2.96	2.42	3.40	3.46	3.37	4.32
Standard	Hist	6.33	5.77	3.01	3.10	6.27	3.24	3.81	1.50	6.28	3.80	1.81	2.40
Deviation	Gen	4.50	5.15	3.59	4.21	3.90	3.14	2.14	1.37	2.68	2.64	2.57	3.12
B. FLOWS FROM UNCONTROLLED CATCHMENT TO ROUNA 2 HEAD POND													
Maximum Daily	Hist	51	81	66	95	66	27	26	25	43	28	35	62
Mean													
Discharge (m^3/s)	Gen	106	85	86	87	98	69	25	40	54	36	55	62
Highest		341	125	127	162	244	124	41	166	99	65	138	99
Lowest		56	60	57	48	51	25	16	17	32	24	28	31
Mean Daily	Hist	7.76	9.94	10.54	11.47	11.24	5.83	4.45	3.88	7.07	7.23	7.25	7.15
Discharge (m^3/s)	Gen	8.93	10.60	12.22	11.85	9.66	6.24	3.38	3.22	4.73	5.55	6.02	7.35
Highest		9.72	11.55	13.48	13.38	10.33	7.08	3.81	3.91	5.39	6.73	7.07	8.00
Lowest		8.18	9.51	10.99	10.91	8.72	5.50	3.00	2.65	3.88	4.48	5.11	6.62
Standard	Hist	4.93	4.55	3.02	4.38	4.32	2.12	1.95	1.85	4.48	3.50	4.31	2.49
Deviation	Gen	2.85	3.24	3.56	3.83	3.23	2.33	1.22	1.66	2.49	2.38	2.45	2.67

Table 4.4 Overall Statistics Of Generated Streamflows

A. Inflows to Sirinumu Reservoir				
				Reconstituted
	1893	Gen	1897	1893
Mean Daily Flow (m^3/s)	6.52	6.15	5.05	6.70
Standard Deviation (m^3/s)	10.47	10.26	9.66	12.18
Skew Coefficient	6.96	8.51	4.90	12.13
Lag-one Auto Correlation Coefficient	0.685	0.569	0.503	0.200
B. Flows from uncontrolled catchment to Rouna 2 head pond				
	Hist	Gen	Gen	Elcom Data
	1889	unadj	adj	1988
Mean Daily Flow (m^3/s)	7.71	7.46	7.46	8.66
Standard Deviation (m^3/s)	7.04	4.67	6.80	7.38
Skew Coefficient	3.48	2.53	4.40	3.86
Lag-one Auto Correlation Coefficient	0.727	0.748	0.672	0.652

Table 4.5 Summary of the Calculated Probable Drought Discharge in the Laloki River

(Unit: m3/s)

Replicate No.	Iwai Method				Pearson III Method				Gumbel Method			
	20	10	5	2	20	10	5	2	20	10	5	2
1	8.4	8.6	8.9	9.6	8.4	8.6	9.0	9.6	6.2	7.2	8.2	9.8
2	8.6	8.8	9.0	9.6	8.5	8.7	9.1	9.6	6.6	7.5	8.4	9.8
3	8.7	9.0	9.2	9.8	8.7	8.9	9.3	9.9	6.7	7.6	8.6	10.1
4	8.7	9.0	9.2	9.8	8.7	8.9	9.3	9.9	6.7	7.6	8.6	10.1
5	8.6	8.8	9.1	9.5	8.6	8.8	9.1	9.6	6.9	7.7	8.5	9.7
6	8.4	8.6	8.9	9.5	8.4	8.6	8.9	9.5	6.4	7.3	8.3	9.7
7	8.5	8.7	9.0	9.5	8.5	8.7	9.0	9.5	6.8	7.6	8.4	9.7
8	8.5	8.7	8.9	9.4	8.5	8.7	8.9	9.4	6.7	7.5	8.4	9.6
9	8.7	8.9	9.2	9.8	8.7	8.9	9.2	9.8	6.6	7.6	8.5	10.0
10	8.5	8.7	9.0	9.5	8.5	8.7	9.0	9.5	6.7	7.5	8.4	9.7
11	8.4	8.6	8.9	9.6	8.4	8.6	9.0	9.6	6.2	7.2	8.2	9.8
12	8.4	8.6	9.0	9.6	8.3	8.6	9.0	9.7	6.0	7.1	8.2	9.9
13	8.4	8.7	8.9	9.4	8.5	8.6	8.9	9.4	6.6	7.5	8.3	9.6
14	8.4	8.6	8.9	9.5	8.4	8.6	8.9	9.5	6.5	7.4	8.3	9.7
15	8.4	8.6	8.9	9.5	8.3	8.6	8.9	9.5	6.2	7.2	8.2	9.8
16	8.5	8.7	9.0	9.5	8.5	8.7	9.0	9.6	6.7	7.5	8.4	9.7
17	8.4	8.6	8.9	9.4	8.3	8.6	8.9	9.4	6.6	7.4	8.3	9.6
18	8.4	8.6	8.9	9.5	8.5	8.6	8.9	9.5	6.3	7.3	8.3	9.8
19	8.4	8.6	8.9	9.5	8.4	8.6	8.9	9.5	6.3	7.2	8.3	9.8
20	8.6	8.8	9.1	9.7	8.6	8.8	9.1	9.8	6.3	7.4	8.4	10.0
21	8.4	8.6	8.9	9.6	8.4	8.6	9.0	9.6	6.2	7.2	8.2	9.8
22	8.6	8.8	9.0	9.6	8.5	8.7	9.1	9.6	6.6	7.5	8.4	9.8
23	8.7	9.0	9.2	9.8	8.7	8.9	9.3	9.9	6.7	7.6	8.6	10.1
24	8.4	8.6	8.9	9.4	8.4	8.6	8.9	9.5	6.5	7.4	8.3	9.7
25	8.6	8.8	9.1	9.5	8.6	8.8	9.1	9.6	6.9	7.7	8.5	9.7
26	8.4	8.6	8.9	9.5	8.4	8.6	8.9	9.5	6.4	7.3	8.3	9.7
27	8.5	8.7	9.0	9.5	8.5	8.7	9.0	9.5	6.8	7.6	8.4	9.7
28	8.5	8.7	8.9	9.4	8.5	8.7	8.9	9.4	6.7	7.5	8.4	9.6
29	8.7	8.9	9.2	9.8	8.7	8.9	9.2	9.8	6.6	7.6	8.5	10.0
30	8.5	8.7	9.0	9.5	8.5	8.7	9.0	9.5	6.7	7.5	8.4	9.7
Average	**8.5**	**8.7**	**9.0**	**9.6**	**8.5**	**8.7**	**9.0**	**9.6**	**6.5**	**7.4**	**8.4**	**9.8**

Table - 4.6 Monthly Mean Discharge of the Brown River Basin (1/2)

(Karema Gauging Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1955	122.20	133.90	110.90	*	*	*	29.88	23.42	23.90	23.52	38.34	50.69
1956	59.03	96.79	90.85	110.00	67.74	32.81	23.29	23.16	37.50	39.14	56.30	68.44
1957	55.74	116.50	151.90	177.10	104.20	53.29	43.31	48.61	49.70	*	72.41	121.50
1958	137.50	171.80	183.80	145.80	88.38	68.19	*	*	*	*	77.76	104.20
1959	116.00	121.60	136.20	235.50	70.65	*	*	*	31.84	28.29	33.85	60.06
1960	105.30	166.30	131.20	*	*	*	*	41.92	43.07	54.87	57.55	*
1961	121.70	148.70	114.10	85.08	143.90	81.31	69.23	51.04	43.32	74.57	65.44	91.25
1962	123.90	133.80	160.70	156.60	136.20	65.18	48.26	49.89	75.39	64.85	64.87	76.70
1963	109.80	111.80	158.50	111.70	65.08	53.41	44.78	53.89	66.72	53.10	46.77	70.30
1964	139.20	155.40	141.30	109.30	73.78	50.06	42.16	35.97	41.75	49.24	74.26	46.55
1965	84.18	126.40	198.20	132.90	69.86	43.44	32.30	26.76	26.33	24.82	19.85	50.86
1966	120.70	192.70	189.50	71.42	58.96	39.07	28.77	24.32	28.62	57.88	60.84	69.66
1967	177.50	218.40	188.90	108.30	*	54.71	44.95	41.36	37.18	78.23	61.10	71.33
1968	95.53	109.00	108.90	96.53	77.17	50.37	34.66	40.93	*	44.64	32.10	72.28
1969	106.70	175.40	166.00	184.70	101.20	66.20	*	*	43.51	44.07	49.94	91.61
1970	87.75	124.80	152.40	116.30	68.19	41.33	37.08	39.40	49.85	100.80	105.50	*
1971	141.40	135.60	120.40	139.10	121.10	90.91	65.09	36.69	*	56.27	45.05	67.44
1972	63.91	93.25	183.80	158.30	137.30	68.04	43.90	27.41	22.08	23.61	28.13	37.17
1981	*	*	*	*	60.69	49.37	*	*	*	46.65	43.46	101.50
1982	99.94	53.73	237.40	122.20	86.64	60.42	49.15	46.90	40.39	37.21	35.32	44.83
1983	51.39	108.90	168.10	133.90	98.75	62.17	44.24	39.63	37.80	53.03	84.22	165.30
1984	106.80	161.40	195.60	124.10	95.78	57.57	46.51	37.15	40.77	44.23	38.49	117.90
1985	176.50	124.20	146.90	121.80	86.34	66.66	62.66	46.27	80.43	83.09	105.40	109.70
1986	140.60	131.40	171.60	243.00	*	*	35.54	31.87	31.32	*	26.31	29.33
1987	84.40	79.50	115.20	106.90	55.20	40.00	35.90	31.90	34.20	33.20	37.50	*
1988	*	123.70	125.30	109.10	71.40	61.00	47.00	40.10	44.10	94.50	67.60	89.30
1989	101.00	*	153.40	158.50	99.80	61.40	49.20	47.00	51.00	*	*	81.60
1990	168.60	140.20	117.50	*	*	*	*	*	*	*	*	*
1991	*	*	*	*	*	46.70	42.60	45.00	40.10	51.90	93.10	62.30
1992	59.30	93.60	109.50	*	*	*	*	*	*	*	*	*
Ave.	109.50	131.44	151.00	135.76	88.62	56.82	43.50	38.77	42.54	52.57	56.35	78.07

(Bogaiana Gauging Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1980	*	*	*	*	*	*	*	*	*	*	*	8.46
1981	12.45	11.18	15.17	13.21	8.22	6.41	5.20	*	4.15	7.18	6.74	10.72
1982	11.72	10.42	18.72	12.53	10.75	7.89	5.86	*	3.21	2.83	2.53	3.89
1983	3.54	7.50	11.20	10.11	7.29	5.77	4.04	3.41	3.30	4.29	6.31	12.41
1984	9.68	13.16	*	*	*	*	*	4.83	4.49	4.94	4.74	11.03
1985	15.17	12.37	*	*	*	*	*	6.11	8.74	8.79	10.10	11.55
1986	12.35	12.52	14.96	23.07	11.96	7.47	5.15	*	4.37	3.51	3.43	3.80
1987	7.07	10.37	12.47	12.81	7.26	4.67	3.83	3.02	3.55	3.11	*	4.16
1988	8.59	9.51	9.12	*	*	5.66	4.78	3.91	4.40	8.64	6.75	8.89
1989	10.41	*	13.38	13.22	10.73	6.77	*	*	*	*	*	*
1990	*	*	*	*	*	7.40	6.31	7.41	8.02	8.12	7.03	6.14
1991	*	*	*	*	*	*	*	*	*	*	10.27	7.28
1992	7.07	10.43	*	*	*	*	*	*	*	*	*	*
Ave.	9.81	10.83	13.57	14.16	9.37	6.51	5.02	4.78	4.91	5.71	6.43	8.03

Table - 4.6 Monthly Mean Discharge of the Brown River Basin (2/2)

(Roguoia Junction Gauging Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1981	*	*	*	*	*	*	*	*	18.53	*	32.92	68.32
1982	*	*	*	*	*	37.29	26.56	25.09	17.50	13.22	11.87	22.16
1983	32.32	*	*	*	*	49.18	35.72	29.32	28.04	33.04	52.66	94.57
1984	71.76	81.92	102.50	84.80	69.33	48.83	36.07	29.15	29.24	38.06	39.98	*
1985	*	*	*	*	67.26	59.91	56.52	47.03	59.97	56.14	65.67	*
1986	*	*	*	134.70	65.85	44.65	*	*	*	*	*	*
1987	*	*	*	68.56	38.84	25.34	20.54	15.50	18.75	17.92	20.10	33.61
1988	67.40	73.30	61.80	66.60	44.60	36.40	27.70	23.50	23.60	46.00	43.90	60.80
1989	75.10	106.80	104.10	93.40	68.10	42.60	29.60	28.40	30.10	41.70	*	*
1990	*	*	*	*	*	43.26	38.25	41.20	51.59	47.44	42.70	*
1991	*	*	*	*	*	*	*	*	*	*	*	*
1992	*	*	*	*	*	*	*	*	*	*	*	*
Ave.	61.65	87.34	89.47	89.61	59.00	43.05	33.87	29.90	30.81	36.69	38.73	55.89

(Madilogo Gauging Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1981	*	*	*	*	*	*	*	*	7.30	13.41	13.91	24.14
1982	24.15	20.34	33.98	21.64	17.89	12.45	8.21	7.47	5.13	*	3.80	6.91
1983	5.89	14.97	22.54	23.26	16.44	11.74	7.62	5.99	5.55	8.30	12.76	24.63
1984	19.87	25.82	31.25	30.15	25.00	16.42	11.57	8.84	9.49	9.48	7.92	19.95
1985	28.11	23.02	32.60	26.47	22.54	*	*	10.50	19.95	17.71	21.11	22.14
1986	24.91	24.33	*	27.37	25.16	13.79	8.89	7.42	7.48	6.06	5.45	5.73
1987	*	*	*	21.65	12.33	7.87	6.08	4.51	6.11	5.52	5.61	8.23
1988	16.83	18.87	*	*	12.14	10.62	*	7.04	8.90	17.11	12.43	15.69
1989	*	*	*	*	*	*	*	*	*	*	*	*
1990	*	*	*	*	*	*	*	*	1.83	14.01	12.20	11.61
1991	*	*	*	*	19.20	9.90	7.51	7.83	5.93	10.48	22.01	13.15
1992	12.11	*	*	*	*	*	*	*	*	*	*	*
Ave.	18.84	21.23	30.09	25.09	18.84	11.83	8.31	7.45	7.77	11.34	11.72	15.22

Table - 4.7 Monthly Minimum Discharge of the Brown River Basin (1/2)

(Karema Gauging Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Dry Season						Dec.
						Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	
1955	88.64	90.74	64.00	*	*	*	25.49	21.11	***20.11***	21.10	21.10	36.53
1956	33.56	69.95	67.97	69.95	35.12	24.36	21.10	***21.10***	23.22	33.56	36.53	25.49
1957	36.53	73.91	96.71	113.90	61.45	37.95	32.57	32.57	32.57	*	49.28	61.45
1958	89.21	113.90	126.90	107.60	70.80	53.67	*	*	*	*	61.45	61.45
1959	69.24	81.70	89.77	111.80	51.54	*	*	*	21.81	20.67	22.94	26.34
1960	44.75	72.78	82.84	*	*	*	*	37.10	32.85	34.27	37.10	*
1961	*	80.71	75.05	58.06	84.11	60.32	47.29	42.76	***37.10***	45.60	41.63	52.11
1962	69.10	96.00	105.40	95.44	82.69	52.68	43.61	***40.50***	54.66	49.28	47.58	53.81
1963	81.28	80.43	79.01	73.63	51.83	43.33	37.95	36.53	37.08	40.78	***34.83***	41.63
1964	70.52	104.80	96.85	82.69	57.77	40.21	32.00	30.59	***26.48***	36.82	46.73	29.17
1965	41.91	67.12	99.12	75.90	51.26	36.25	28.89	22.94	21.47	19.46	***16.57***	18.69
1966	83.54	130.80	113.60	56.92	42.20	32.57	25.40	21.55	***19.77***	34.55	35.97	44.75
1967	103.60	114.10	113.30	83.26	*	45.88	36.82	32.57	***29.74***	43.90	50.13	55.22
1968	69.10	79.58	81.56	68.82	53.32	36.53	28.18	25.09	*	32.28	24.50	42.20
1969	76.10	112.30	109.10	97.42	67.20	52.08	*	*	30.30	36.19	31.69	48.03
1970	58.62	74.76	99.40	66.84	50.98	33.98	30.59	27.67	***27.10***	45.88	81.00	*
1971	101.70	92.61	71.37	100.20	84.96	74.48	44.75	29.74	*	37.67	29.45	39.36
1972	45.60	66.55	115.30	105.10	96.00	48.43	35.68	21.21	18.86	***18.24***	18.55	23.28
1981	*	*	*	*	43.04	38.25	*	*	*	26.12	27.08	44.28
1982	50.00	32.01	87.99	80.21	63.01	51.73	45.84	42.36	38.27	35.47	***33.17***	36.62
1983	39.15	56.65	99.50	79.34	69.55	52.48	38.93	35.66	***32.75***	38.14	43.92	95.18
1984	78.60	91.57	145.70	92.95	58.65	49.90	39.40	32.89	33.11	***32.57***	33.45	49.67
1985	95.84	84.98	81.65	87.13	58.77	53.51	49.53	***42.69***	50.48	56.64	75.67	74.32
1986	78.36	90.07	108.90	120.10	*	*	31.24	27.60	25.28	*	22.09	21.87
1987	23.20	61.90	88.10	67.10	44.70	36.20	34.00	30.10	29.80	***28.80***	29.90	*
1988	*	78.00	62.00	70.60	56.10	50.10	41.80	36.20	***36.20***	36.30	45.30	69.00
1989	65.40	*	113.30	110.60	66.50	51.30	41.30	40.00	40.10	*	*	62.30
1990	86.20	82.00	79.90	*	*	*	*	*	*	*	*	*
1991	*	*	*	*	51.30	42.60	39.50	40.80	36.30	***35.70***	63.10	53.10
1992	47.80	75.50	*	*	*	*	*	*	*	*	*	*

Note: The figures shown in bold and italic characters indicate annual minimum discharges.

(Bogaiana Gauging Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Dry Season						Dec.
						Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	
1980	*	*	*	*	*	*	*	*	*	*	*	2.92
1981	7.93	8.55	7.93	8.29	6.09	4.99	4.41	*	3.33	4.60	5.24	6.79
1982	9.25	8.55	13.82	10.25	8.28	6.17	*	*	2.72	2.56	2.23	2.71
1983	2.58	5.24	8.17	6.82	6.09	4.87	3.43	2.86	***2.54***	3.30	3.42	7.20
1984	7.70	9.75	*	*	*	*	*	3.91	3.59	3.54	3.94	6.48
1985	10.93	9.85	*	*	*	*	*	5.39	6.34	6.24	6.63	8.18
1986	8.63	10.21	10.55	14.42	7.40	6.23	4.45	*	3.31	2.98	2.74	2.72
1987	2.85	8.15	10.11	8.40	5.68	3.99	3.38	2.78	2.78	2.26	*	2.60
1988	4.03	7.04	6.51	*	*	4.81	4.04	***3.16***	3.52	3.27	5.08	6.82
1989	6.75	*	12.21	10.26	7.63	5.64	5.00	*	*	*	*	*
1990	*	*	*	*	*	6.24	5.21	5.73	6.97	6.19	5.04	***4.87***
1991	*	*	*	*	*	*	*	*	*	*	*	5.72
1992	5.47	*	*	*	*	*	*	*	*	*	*	*

Note: The figures shown in bold and italic characters indicate annual minimum discharges.

(Roguoia Junction Gauging Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Dry Season						Dec.
						Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	
1981	*	*	*	*	*	*	*	*	13.98	*	24.61	41.91
1982	*	*	*	*	*	28.71	23.02	18.75	14.81	10.13	***9.84***	14.58
1983	20.49	*	*	*	*	43.55	30.66	26.00	***22.98***	27.44	27.14	63.97
1984	58.26	67.56	79.12	66.98	50.54	43.82	29.16	25.13	23.78	***23.09***	34.21	*
1985	*	*	*	*	55.38	52.20	48.71	***44.29***	49.06	47.09	52.66	*
1986	*	*	*	82.54	46.64	37.31	*	*	*	*	*	*
1987	*	*	*	47.94	30.66	20.36	17.43	14.02	13.37	***13.13***	14.21	16.60
1988	37.99	59.33	45.02	47.49	35.28	29.35	23.49	20.01	17.83	***16.78***	*	*
1989	37.70	58.90	44.90	47.40	34.90	28.90	23.00	19.60	17.50	***16.50***	31.30	49.20
1990	51.50	73.60	86.20	69.90	51.90	33.10	24.60	***22.20***	24.50	30.70	42.00	*
1991	*	*	*	*	*	*	***28.21***	28.42	28.23	37.18	33.53	34.55
1992	*	*	*	*	*	*	*	*	*	*	*	*

Note: The figures shown in bold and italic characters indicate annual minimum discharges.

(Madilogo Gauging Station),

Year	Jan.	Feb.	Mar.	Apr.	May	Dry Season						Dec.
						Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	
1981	*	*	*	*	*	*	*	*	5.75	7.98	10.69	15.05
1982	19.75	15.83	26.55	17.07	12.34	9.38	7.12	5.66	4.55	*	3.03	4.39
1983	4.23	8.93	16.20	15.34	12.89	9.84	6.20	4.94	***4.09***	6.36	7.20	14.96
1984	15.18	20.29	23.82	24.09	16.79	14.25	8.78	7.33	7.35	7.09	6.32	10.32
1985	19.36	18.25	19.30	19.80	14.64	*	*	9.49	12.63	12.71	15.01	16.72
1986	17.58	19.80	*	20.52	16.08	10.85	7.56	5.99	5.47	4.86	4.07	***4.00***
1987	*	*	*	14.96	9.42	6.18	5.29	4.12	4.09	***3.72***	4.28	4.26
1988	7.97	13.69	*	*	8.91	8.17	7.77	***6.00***	6.56	6.55	9.21	*
1989	*	*	*	*	*	*	*	*	*	*	*	*
1990	*	*	*	*	*	*	*	*	*	10.85	8.21	8.67
1991	*	*	*	*	11.98	7.79	6.41	6.51	5.19	***5.12***	12.29	10.21
1992	9.53	*	*	*	*	*	*	*	*	*	*	*

Note:, The figures shown in bold and italic characters indicate annual minimum discharges.,

Table - 4.8 Monthly Mean Discharge of the Goldie River Basin

(Uberi Gauging Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1962	11.18	7.10	9.05	10.24	8.57	5.44	*	9.43	11.68	8.07	7.64	6.86
1963	9.44	11.15	11.92	5.57	6.03	5.48	5.51	9.02	9.06	4.54	3.74	8.10
1964	*	*	*	7.53	7.72	5.32	5.07	8.20	8.94	7.59	9.45	4.25
1965	6.67	6.68	7.88	4.85	8.53	2.81	1.85	2.13	2.01	2.66	1.80	7.08
1966	5.77	14.65	11.32	4.71	6.87	5.14	2.13	1.90	*	*	*	*
1967	13.31	13.67	10.64	7.74	*	6.14	8.02	8.48	6.96	7.63	3.40	4.43
1968	5.81	7.60	8.78	5.53	7.30	3.40	2.37	4.39	7.89	5.88	2.82	7.40
1969	9.96	7.56	11.53	11.93	7.86	7.31	4.00	*	*	*	6.22	9.35
1970	6.98	11.78	7.39	5.87	6.18	3.97	8.61	9.61	10.58	*	*	*
1971	*	8.41	7.57	9.12	11.19	11.16	9.79	3.60	8.40	9.40	7.49	5.81
1972	4.49	8.32	10.65	9.79	11.70	3.59	3.11	1.68	1.36	3.17	5.12	3.75
Ave.	8.18	9.69	9.67	7.53	8.20	5.43	5.05	5.84	7.43	6.12	5.30	6.34

(Ebealue Gauging Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1963	*	*	*	*	*	*	*	*	*	*	*	*
1964	0.54	0.55	*	*	0.82	0.57	0.84	0.46	0.98	0.61	2.53	0.72
1965	0.50	1.09	2.66	*	*	*	0.12	0.08	0.06	0.16	0.05	0.36
1966	0.36	1.54	*	*	0.55	0.27	0.12	*	0.13	0.52	0.40	0.44
1967	2.79	*	3.84	1.24	0.74	0.53	0.31	0.59	0.32	0.37	0.28	0.29
1968	0.69	1.43	1.58	0.37	1.06	0.38	0.15	0.20	*	0.64	*	*
Ave.	0.98	1.15	2.69	0.81	0.79	0.43	0.31	0.33	0.37	0.46	0.81	0.45

Table - 4.9 Monthly Maximum Discharge of the Goldie River Basin

(Uberi Gauging Station)

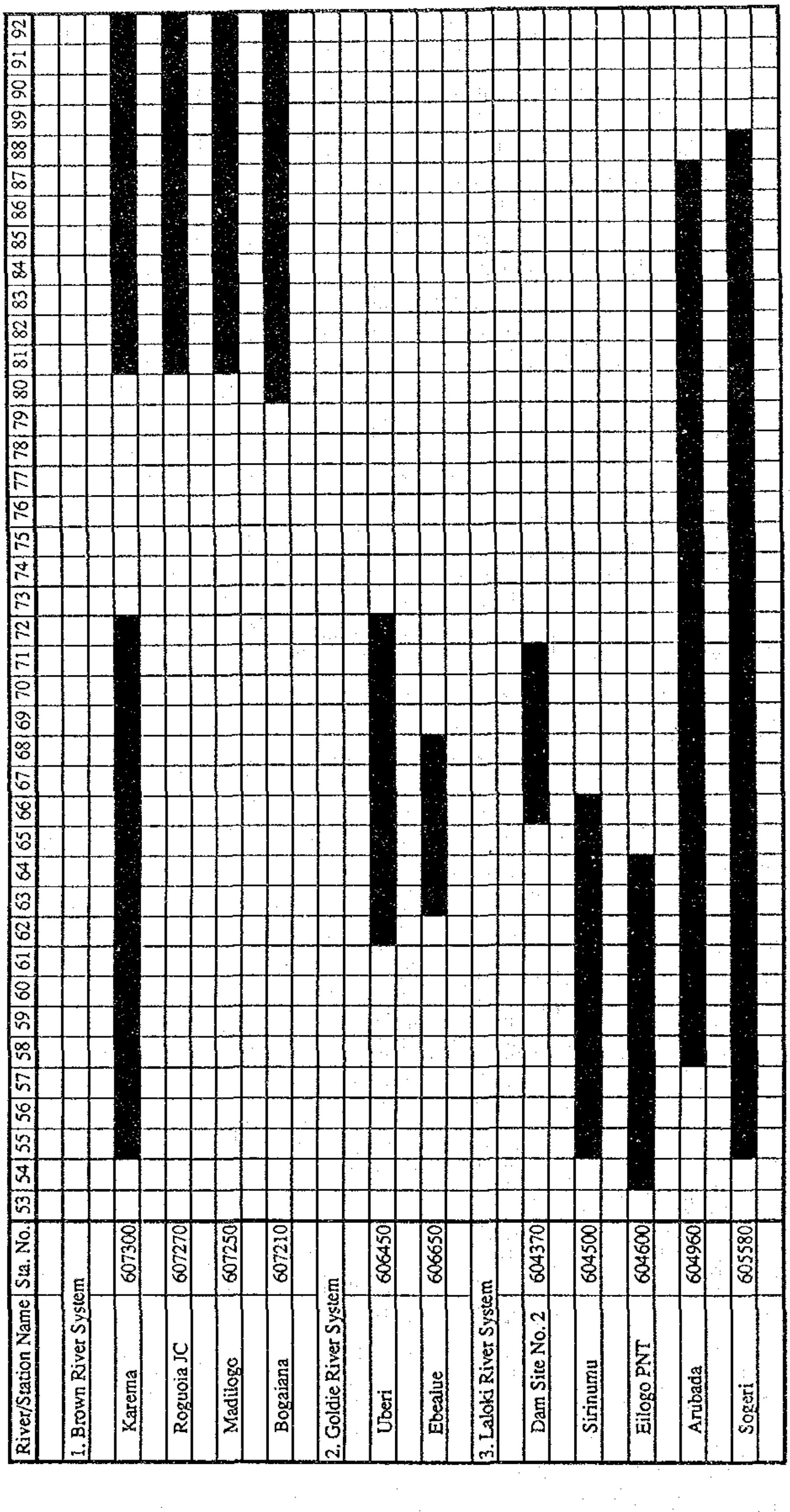
Year	Jan.	Feb.	Mar.	Apr.	May	Dry Season Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1962	4.05	3.23	5.47	5.44	4.70	3.29	*	3.29	6.83	3.82	2.69	3.29
1963	4.73	5.66	4.90	2.69	2.80	2.80	3.00	3.09	3.00	2.49	***2.01***	3.03
1964	*	*	*	3.57	4.39	3.12	***2.69***	3.48	3.94	4.11	5.27	2.58
1965	3.23	3.82	3.03	2.95	3.94	2.15	1.50	1.27	1.13	1.16	***1.13***	1.87
1966	3.03	5.10	5.15	2.97	3.12	2.69	1.61	1.42	*	*	*	*
1967	5.92	6.77	6.20	3.96	*	3.65	3.82	3.60	3.06	4.13	***2.14***	2.34
1968	3.09	2.97	3.77	3.54	3.14	2.17	1.92	***1.68***	1.99	3.09	1.80	3.48
1969	3.65	4.28	4.39	3.85	4.59	4.45	3.03	*	*	*	2.62	4.84
1970	3.09	5.61	3.68	3.48	3.71	2.70	2.58	3.40	4.36	*	*	*
1971	*	5.15	4.93	4.87	6.03	7.00	4.87	***2.46***	3.51	5.81	3.82	2.82
1972	2.89	3.48	6.20	4.64	5.47	2.59	2.08	1.33	***1.12***	1.18	1.15	2.26

Note: The figures shown in bold and italic characters indicate annual minimum discharges.

(Ebealue Gauging Station)

Year	Jan.	Feb.	Mar.	Apr.	May	Dry Season Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1963	*	*	*	*	*	*	*	*	*	*	*	*
1964	0.25	0.39	*	*	0.41	0.30	0.27	0.26	***0.21***	0.30	0.46	0.30
1965	0.29	0.39	0.47	*	*	*	0.09	0.05	***0.01***	0.03	0.02	0.01
1966	0.08	0.26	*	*	0.19	0.13	0.07	*	0.04	0.10	0.09	0.17
1967	0.95	*	1.07	0.50	0.26	0.29	0.22	0.24	0.17	0.19	***0.15***	0.14
1968	0.21	0.29	0.58	0.23	0.31	0.16	0.08	0.06	*	0.10	*	*

Note: The figures shown in bold and italic characters indicate annual minimum discharges.



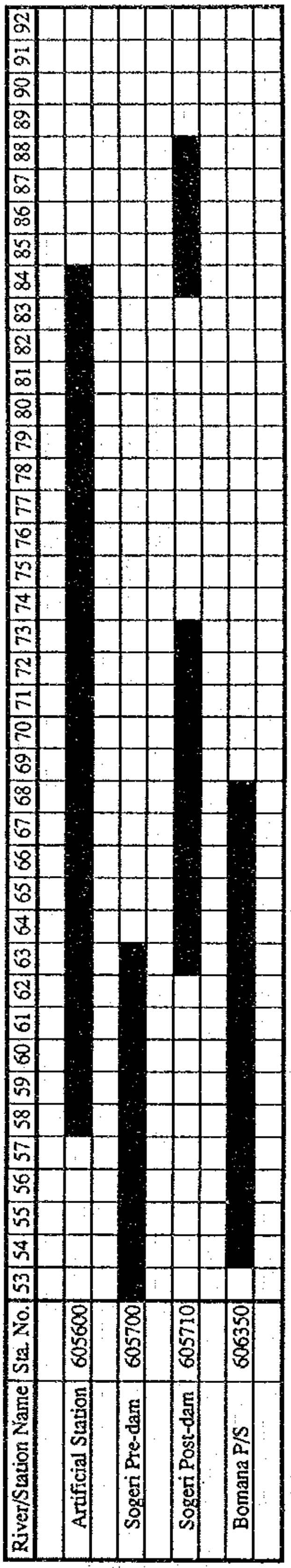
TITLE

AVAILABLE DISCHARGE DATA (1/2)

Fig. No.
3.1

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



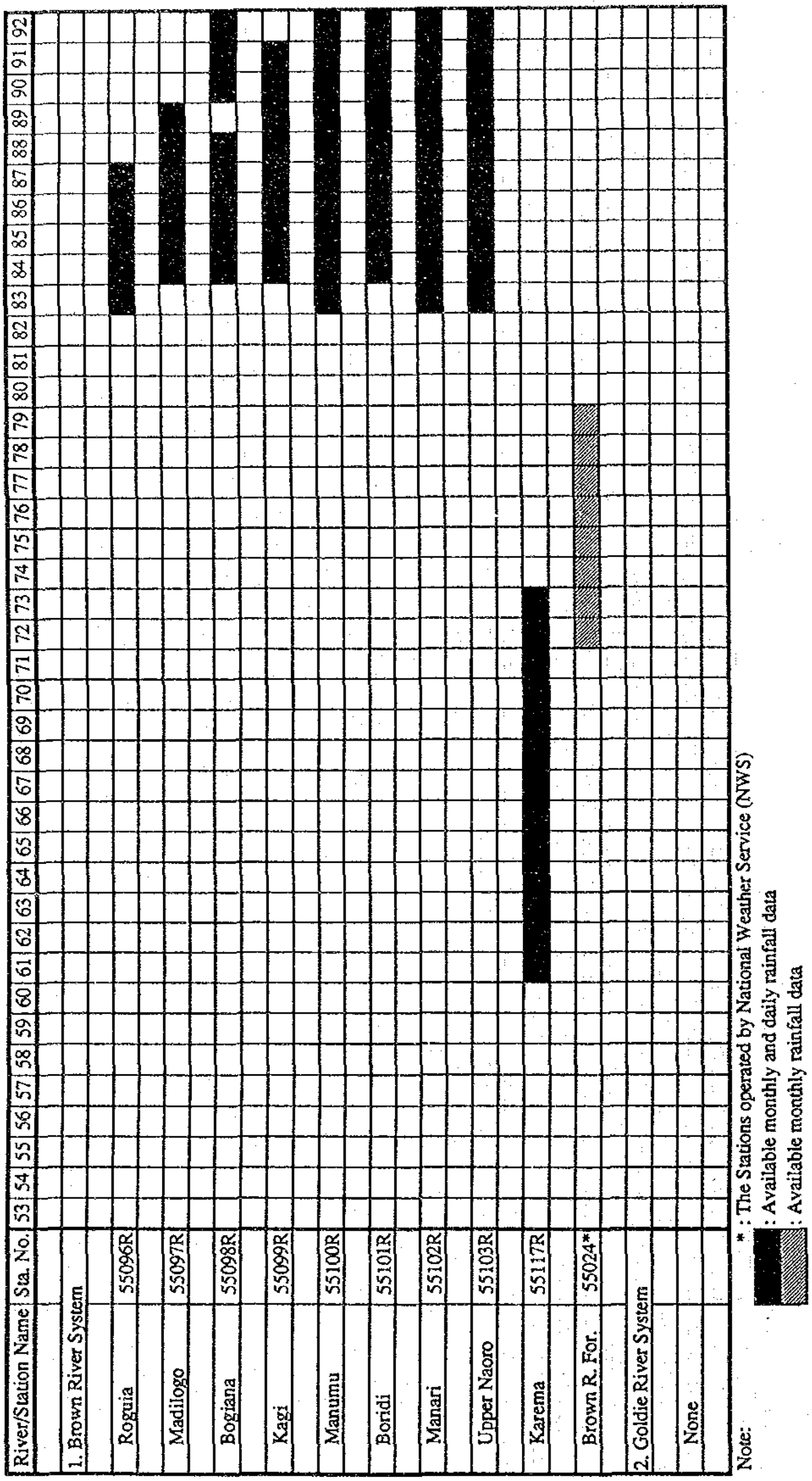
TITLE

AVAILABLE DISCHARGE DATA (2/2)

Fig. No.
3.1

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



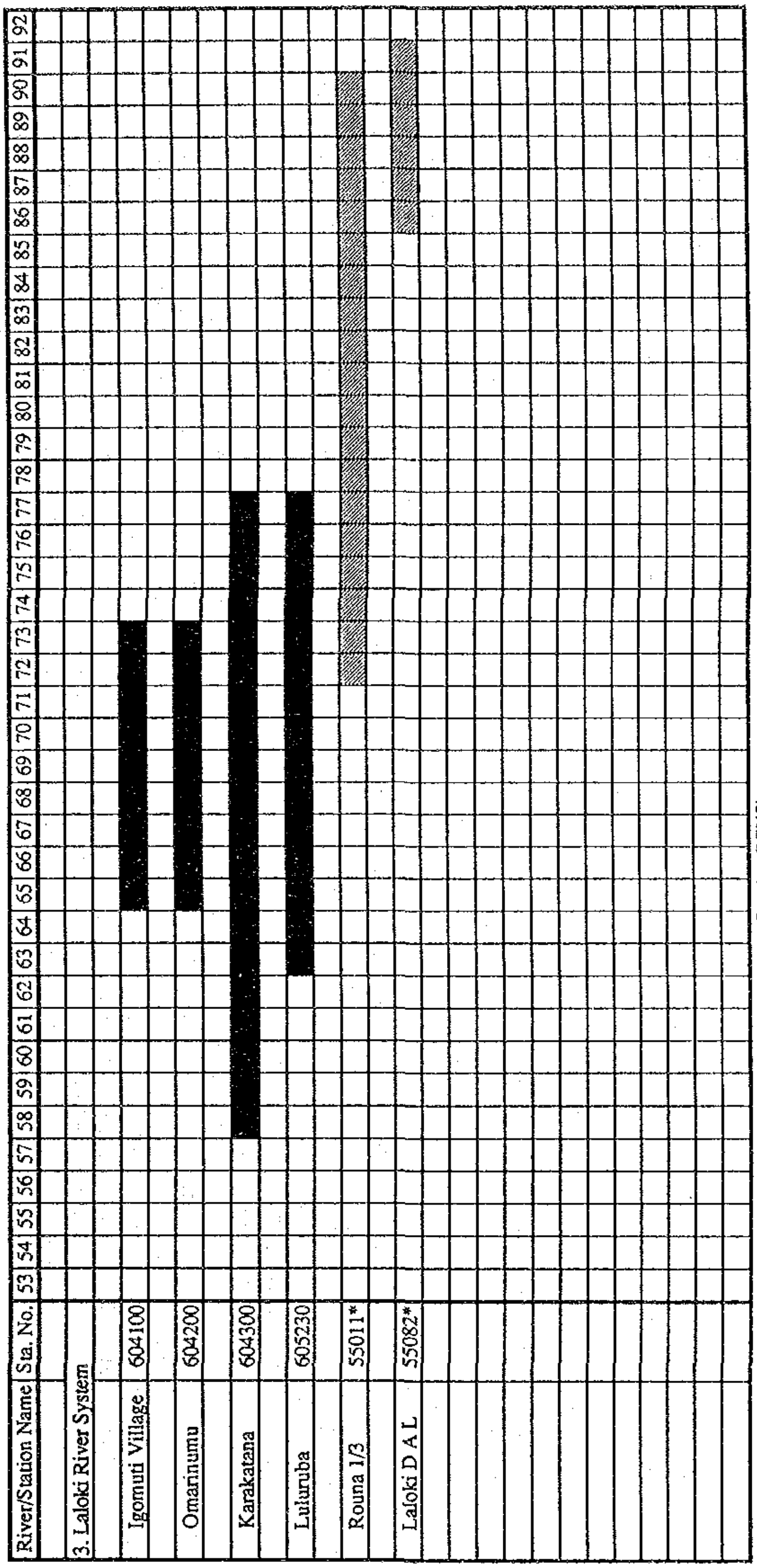
TITLE

AVAILABLE RAINFALL DATA (1/2)

Fig. No.
3.2

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



Note: * : The Stations operated by National Weather Service (NWS)

: Available monthly and daily rainfall data

: Available monthly rainfall data

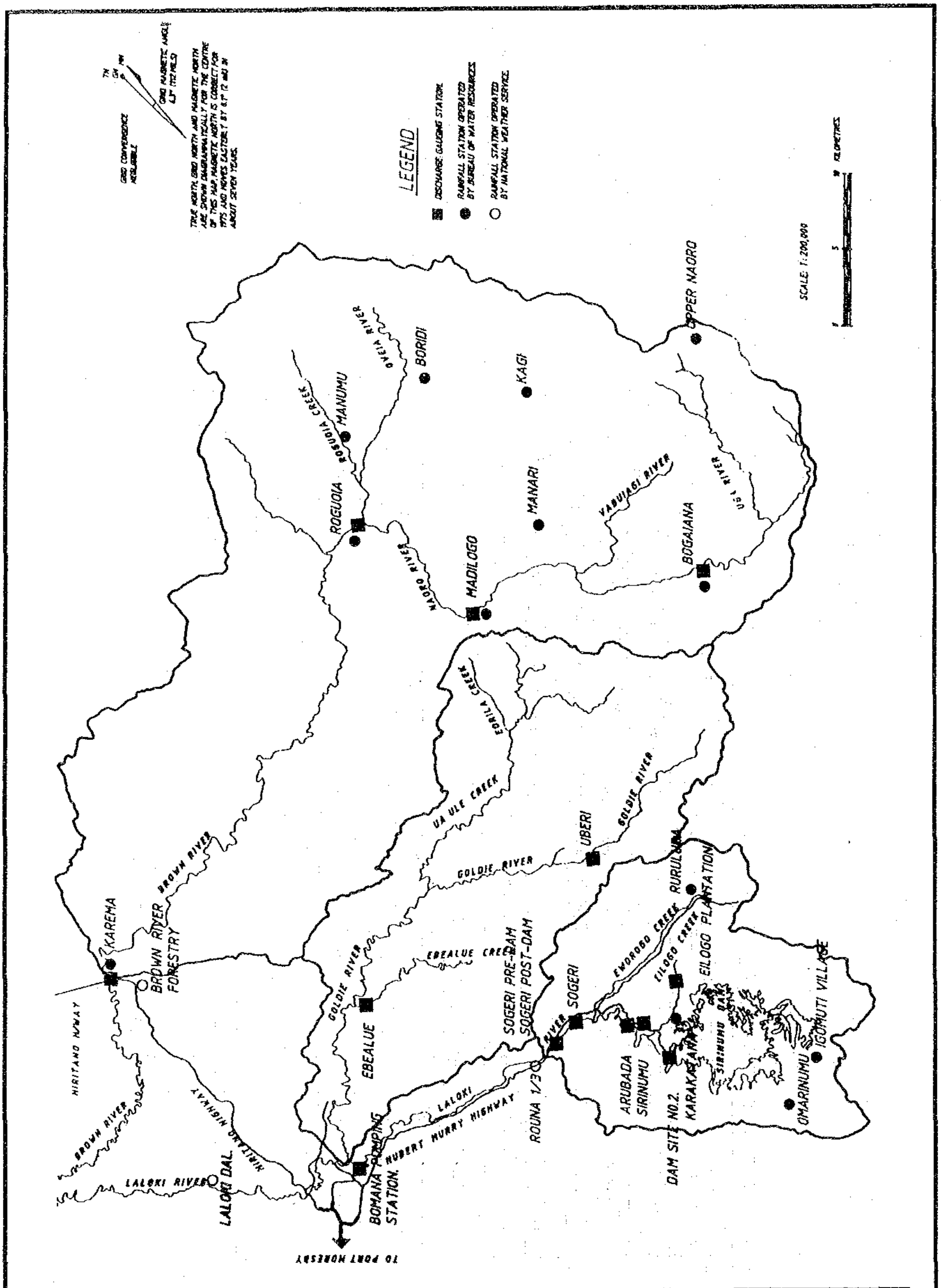
TITLE

AVAILABLE RAINFALL DATA (2/2)

Fig. No.
3.2

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



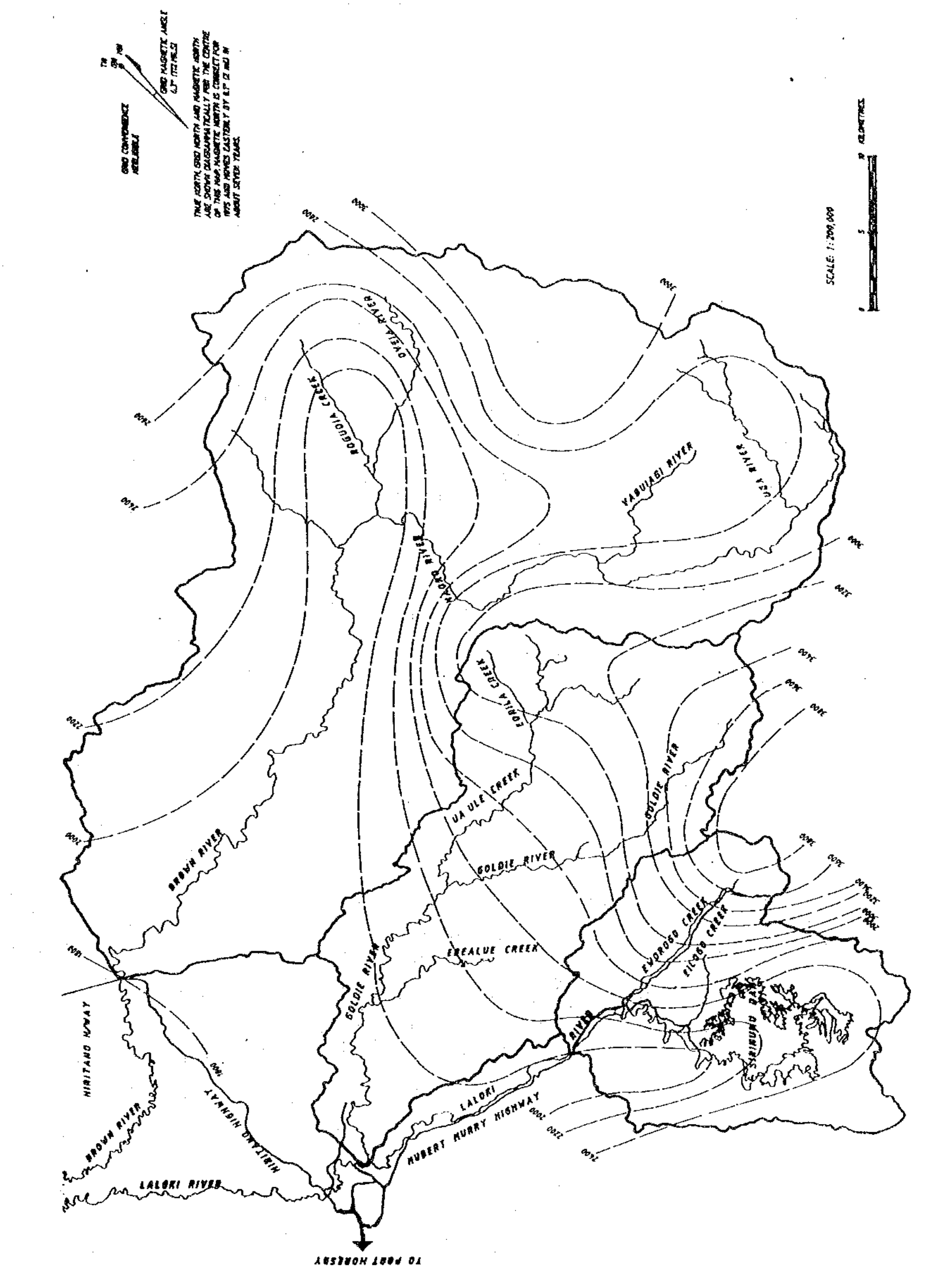
TITLE

LOCATION OF DISCHARGE GAUGING AND RAINFALL STATIONS

Fig. No. **3.3**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



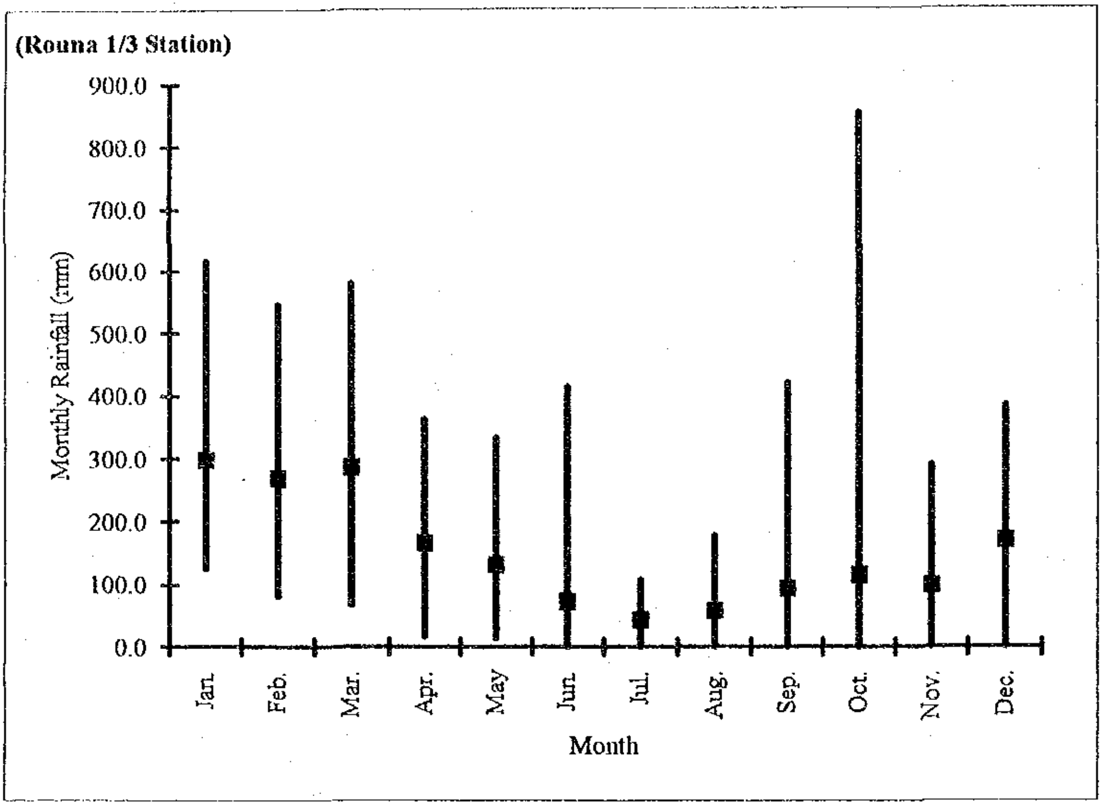
TITLE

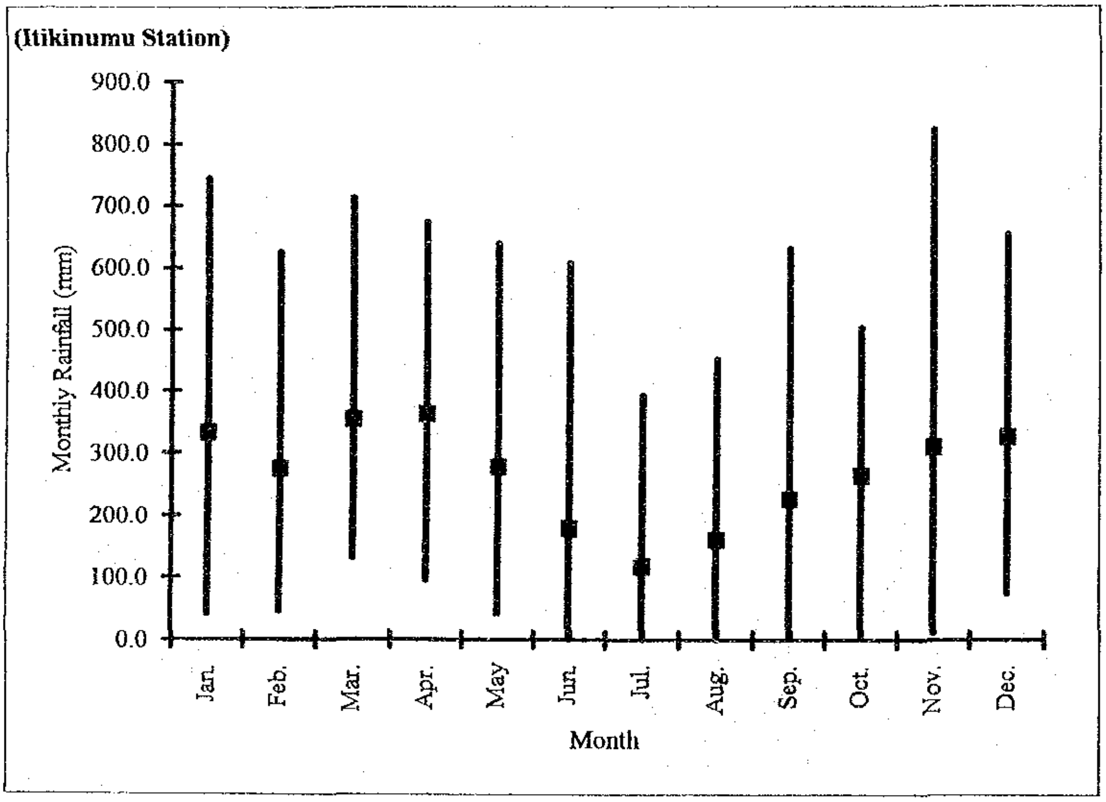
ISOHYET MAP OF THE LALOKI, GOLDIE AND BROWN RIVER BASINS

Fig. No. **4.1**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL





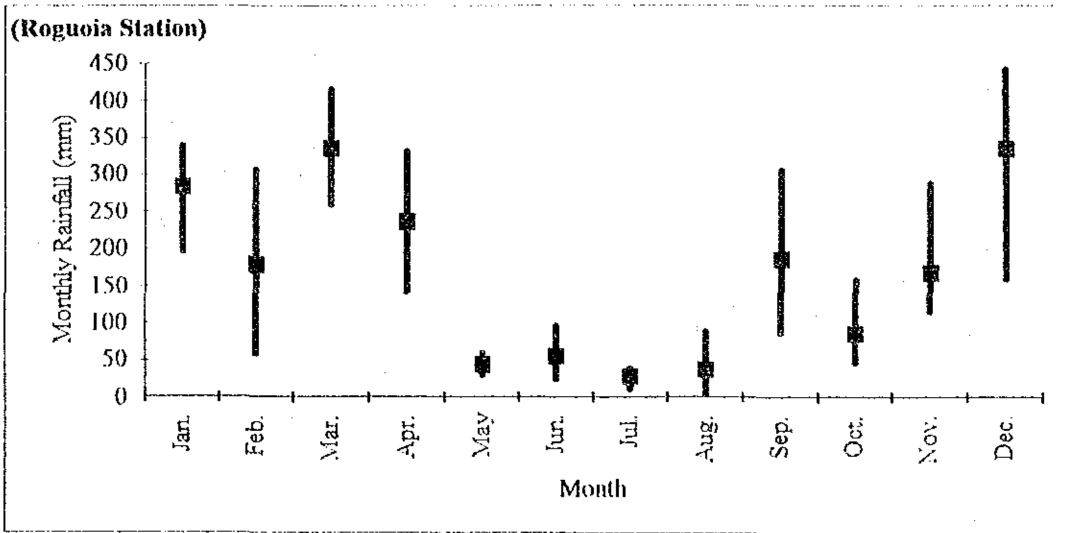
TITLE

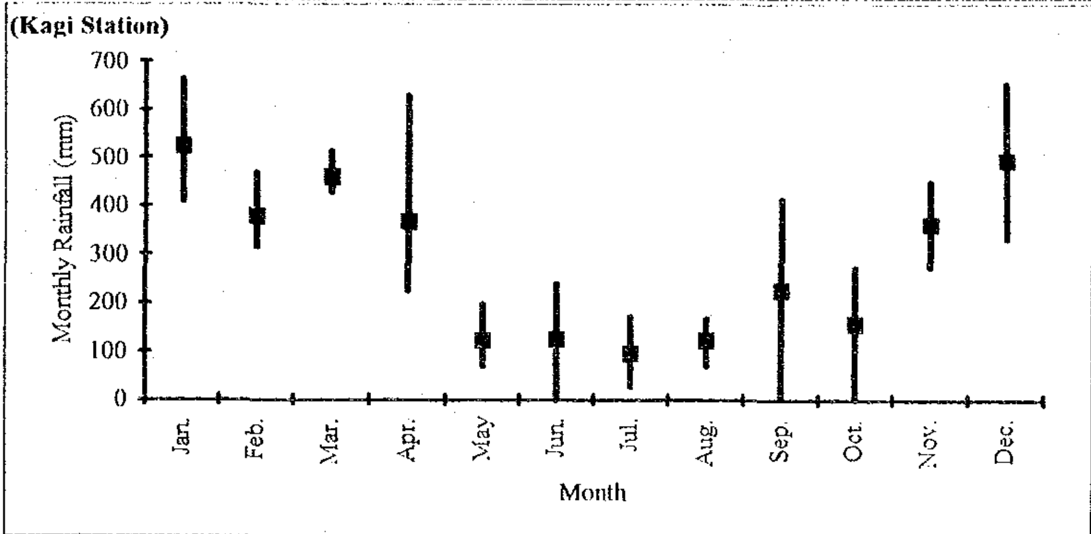
VARIATION OF MONTHLY RAINFALL IN THE LALOKI RIVER BASIN

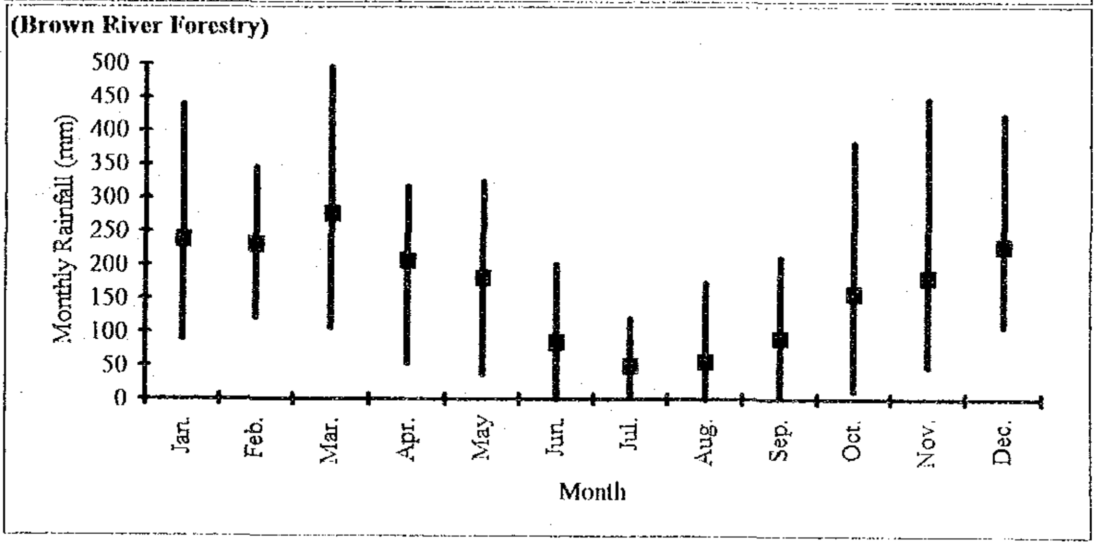
Fig. No. 4.2

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL







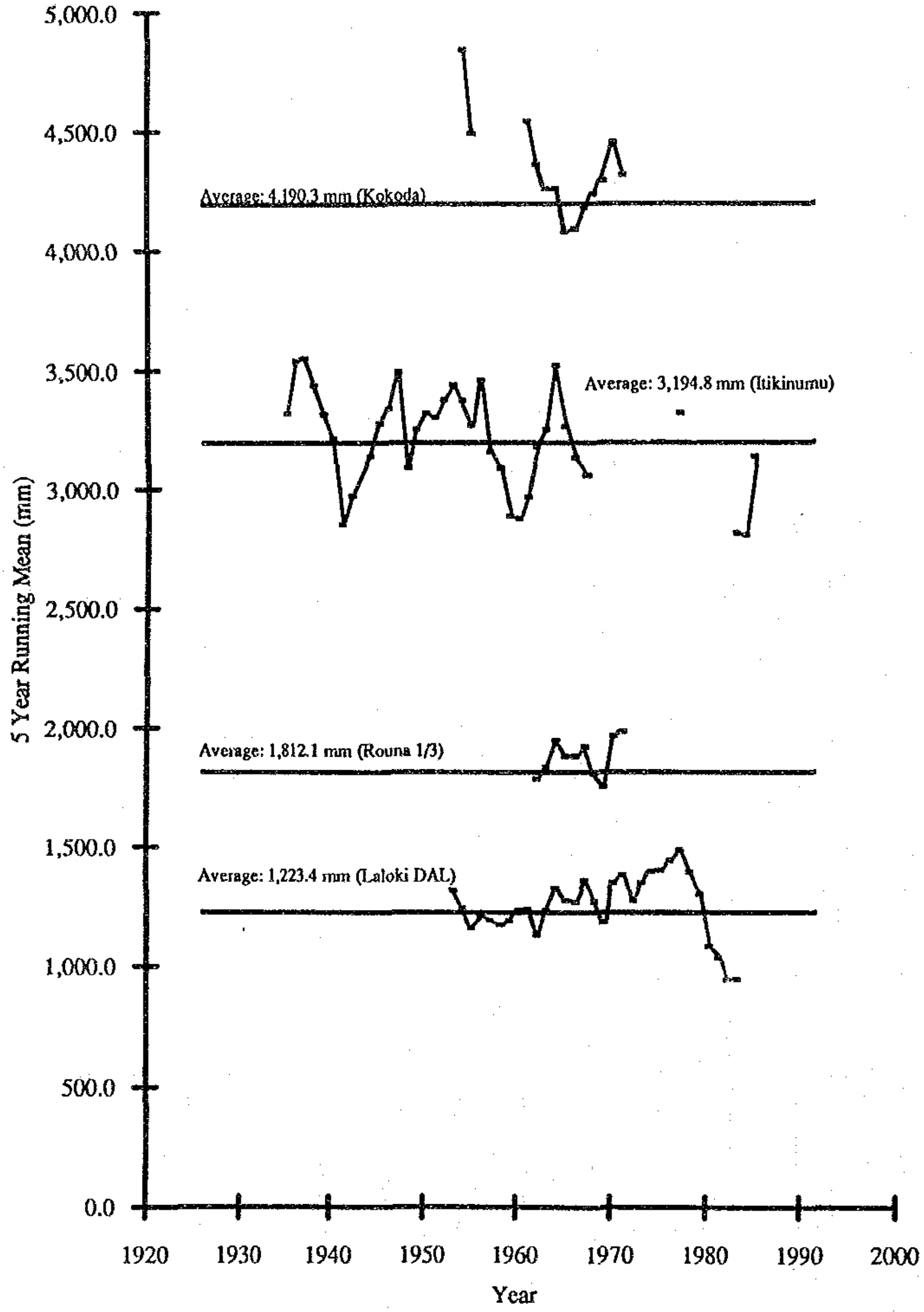
TITLE

VARIATION OF MONTHLY RAINFALL IN THE BROWN RIVER BASIN

Fig. No. **4.3**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



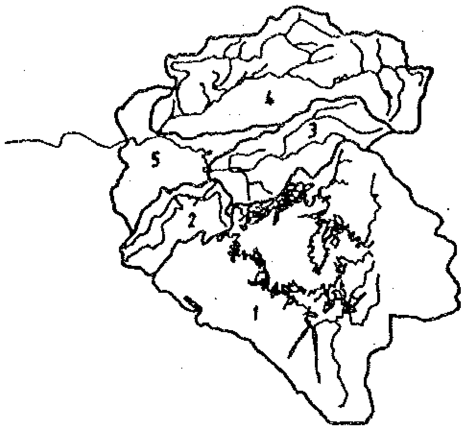
TITLE

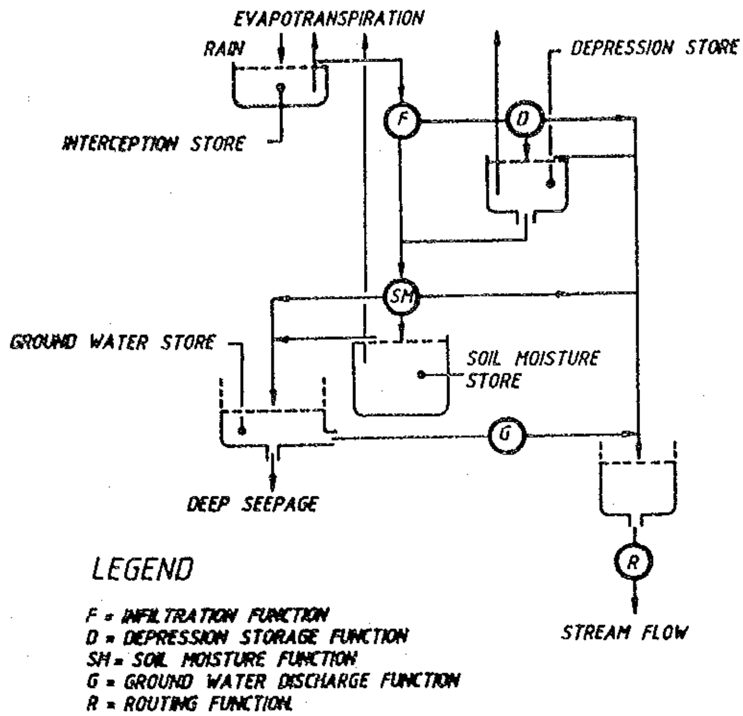
5-YEAR RUNNING MEAN OF ANNUAL RAINFALL

Fig. No.
4.4

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL





ADOPTED PARAMETER VALUES FOR MONASH MODEL

Parameter	Description	Units	Subcatchment Numbers 1	2	3	4	5
OOEFF	Maximum daily infiltration rate	mm/day	200	200	500	500	200
SMSC	Soil moisture storage capacity	mm	50	50	50	100	40
DSC	Depression storage capacity	mm	2.5	2.5	2.5	2.5	2.5
EM	Maximum evapotranspiration rate	mm/day	8	8	8	8	8
ADS	Fraction of catchment draining to depression storage		0.1	0.1	0.1	0.1	0.1
SUB	Maximum proportion of infiltrated moisture diverted to inteflow		0.4	0.4	0.3	0.5	0.4
CRAK	Maximum proportion of infiltrated moisture diverted to groundwater store						
CPDAY	Groundwater recession coefficient		0.0008	0.0008	0.0005	0.0012	0.0008
CINS	Interception storage capacity	mm	1	1	1	1	1
DM	Depression store filling exponent		1	1	1	1	1
ZDAY	Exponent in groundwater recession equation		1.5	1.5	1.5	1.5	1.5
ALEAK	Fraction of stored groundwater lost each day by deep seepage/leakage		0	0	0	0	0
SQ	Exponent in infiltration equation		2	2	2	2	2
A	Catchment area (incremental)	km2	156	20	31	77	27
C0	Routing coefficient		10	5	30	30	2

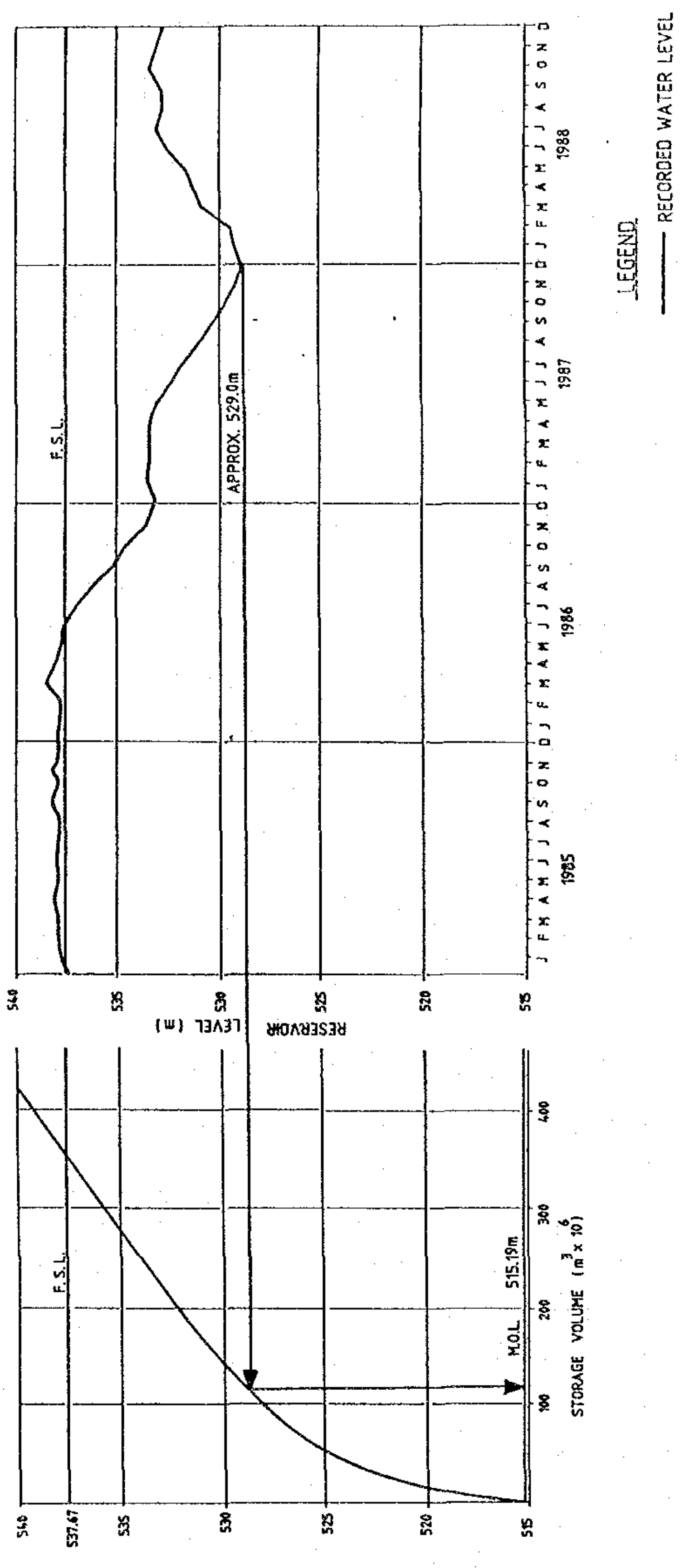
TITLE

CALIBRATED MONASH MODEL

Fig. No. **4.5**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL



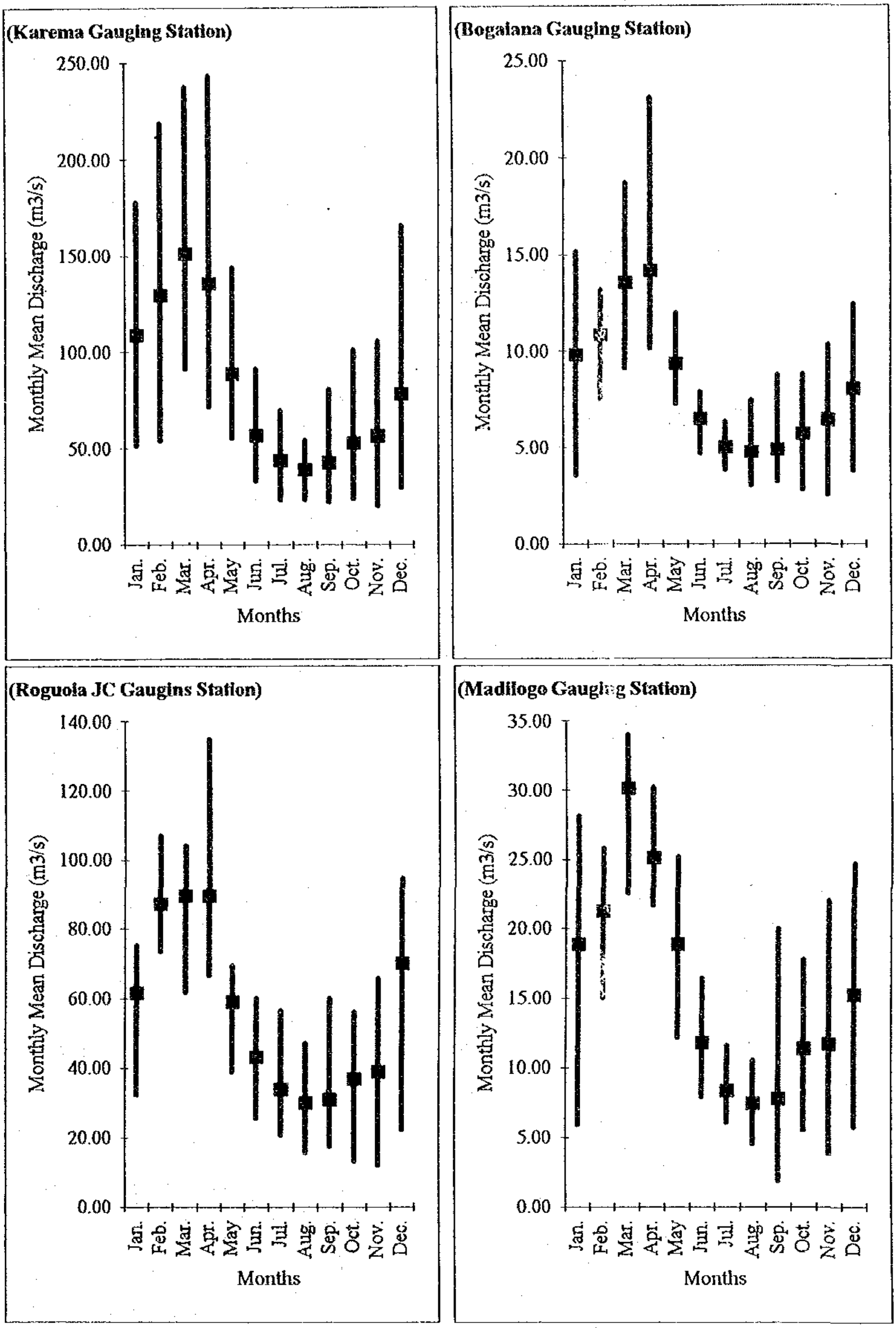
TITLE

STAGE-STORAGE CURVE AND RESERVOIR WATER LEVEL OF SIRINUMU DAM.

Fig. No.
4.6

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



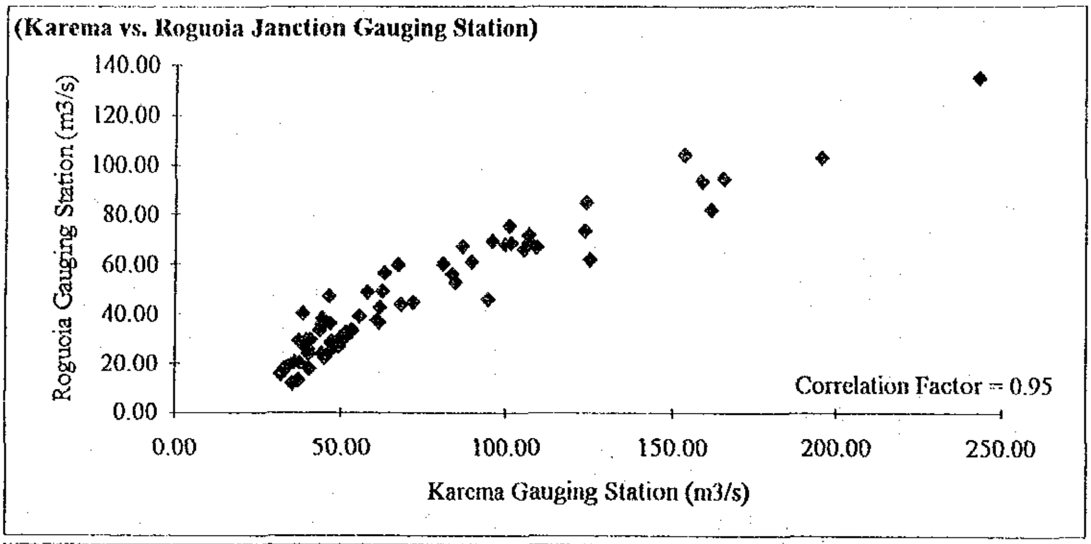
TITLE

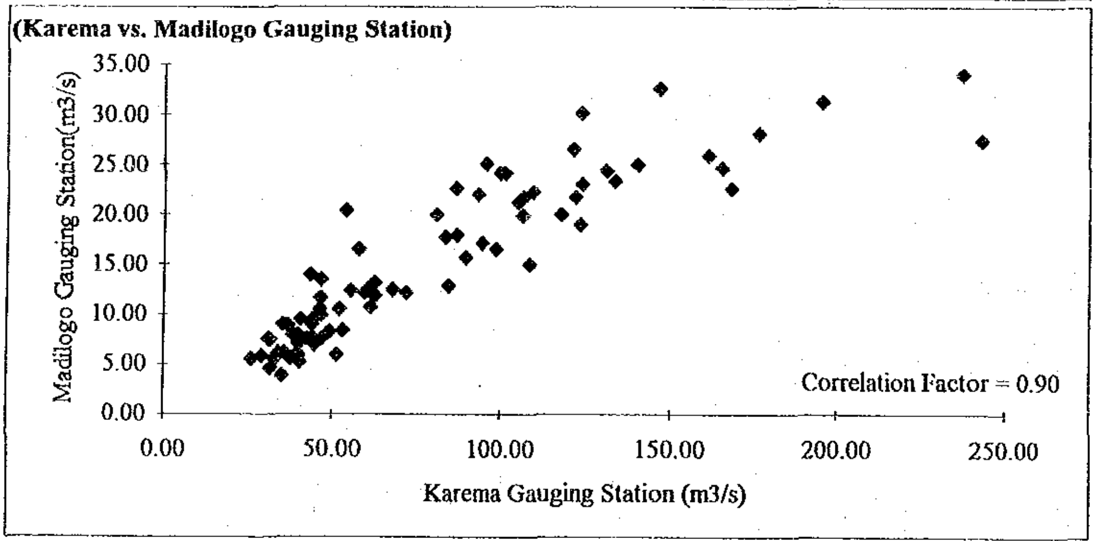
VARIATION OF MONTHLY MEAN DISCHARGES OF THE BROWN RRIVER BASIN

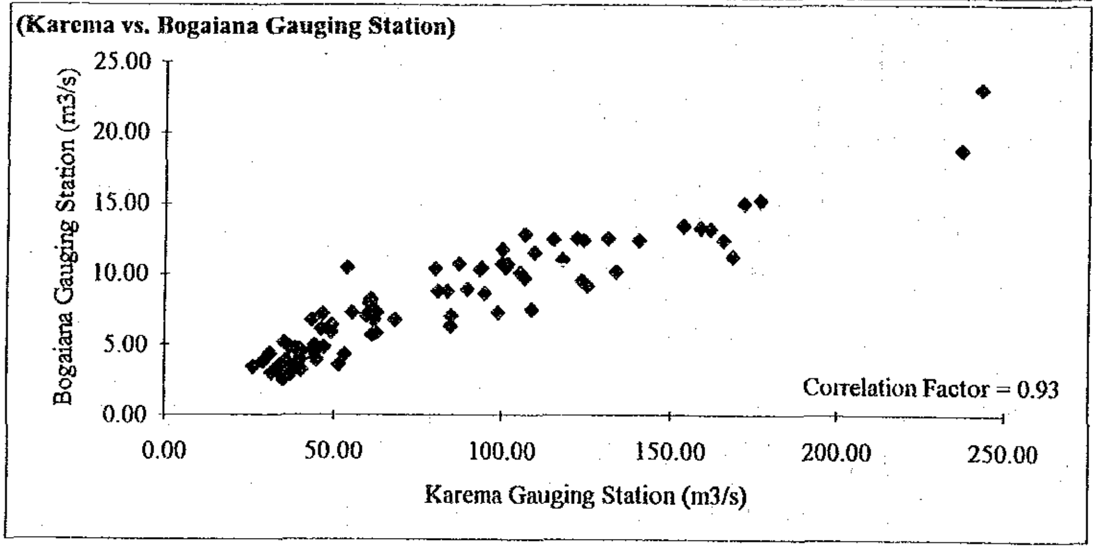
Fig. No. **4.7**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL







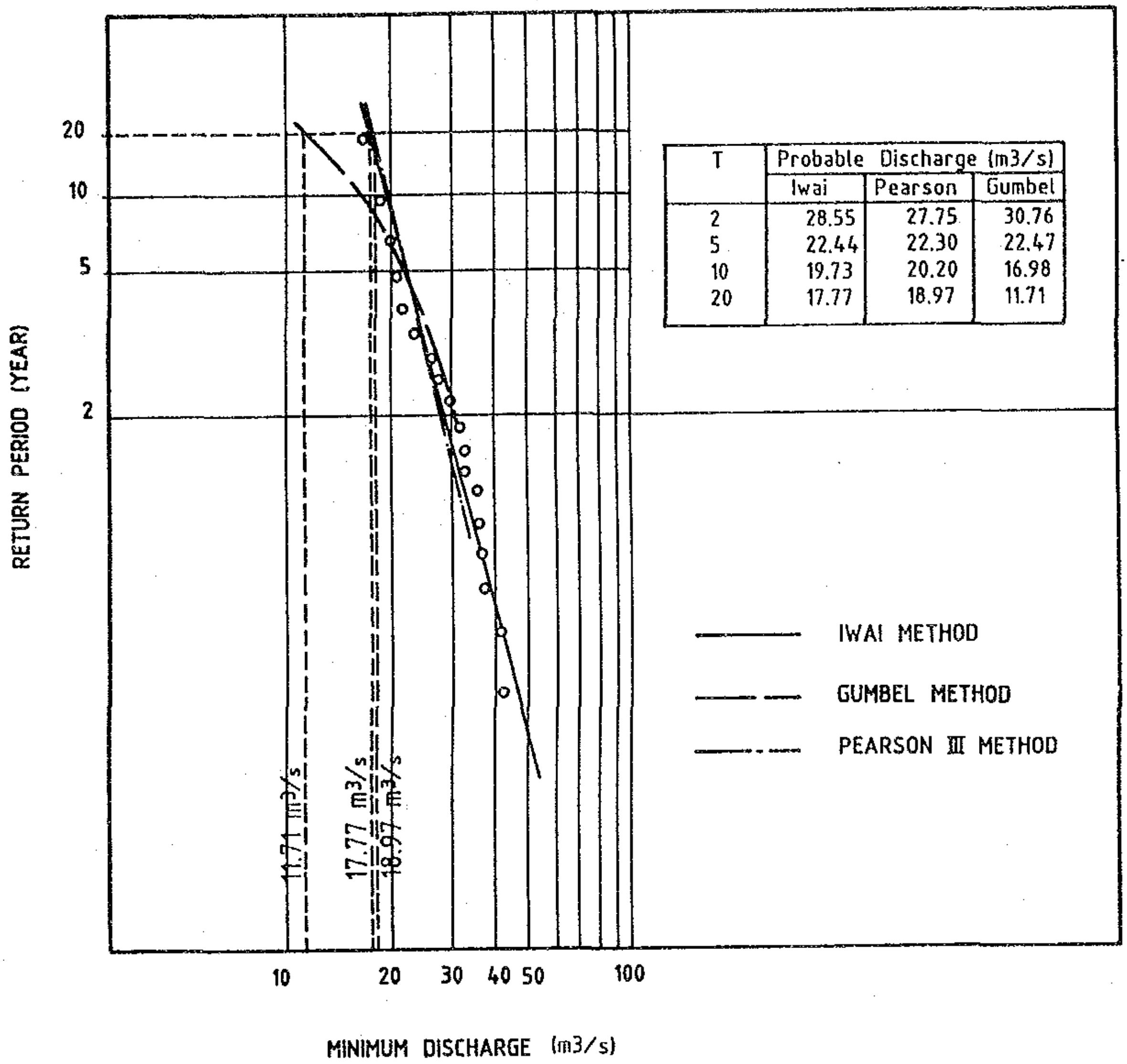
TITLE

CORRELATION OF MONTHLY MEAN DISCHARGES IN THE BROWN RIVER BASIN

Fig. No. **4.8**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



T	Probable Discharge (m3/s)		
	Iwai	Pearson	Gumbel
2	28.55	27.75	30.76
5	22.44	22.30	22.47
10	19.73	20.20	16.98
20	17.77	18.97	11.71

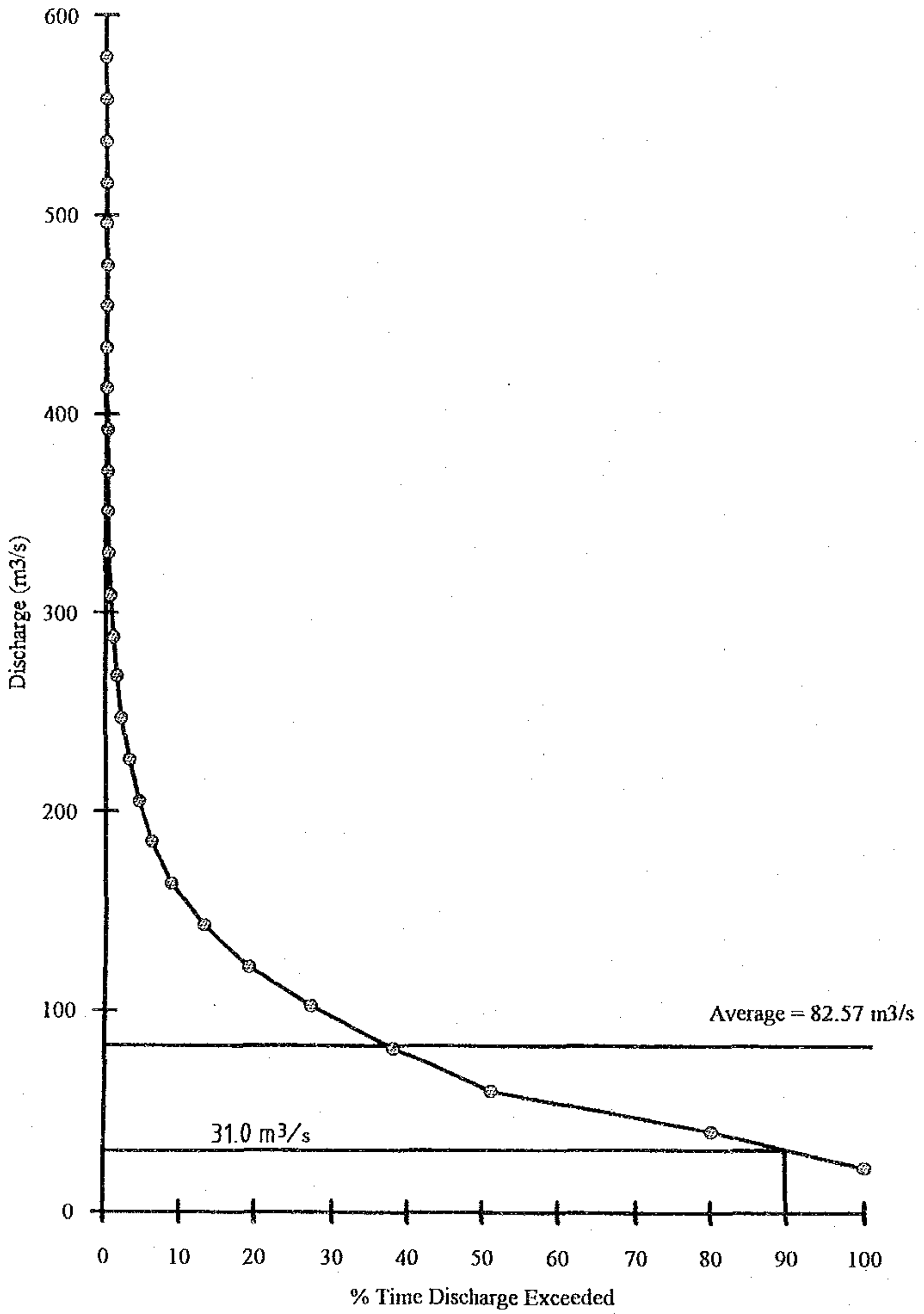
TITLE

PROBABLE DRAUGHT DISCHARGE AT KAREMA OF BROWN RIVER

Fig. No.
4.9

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



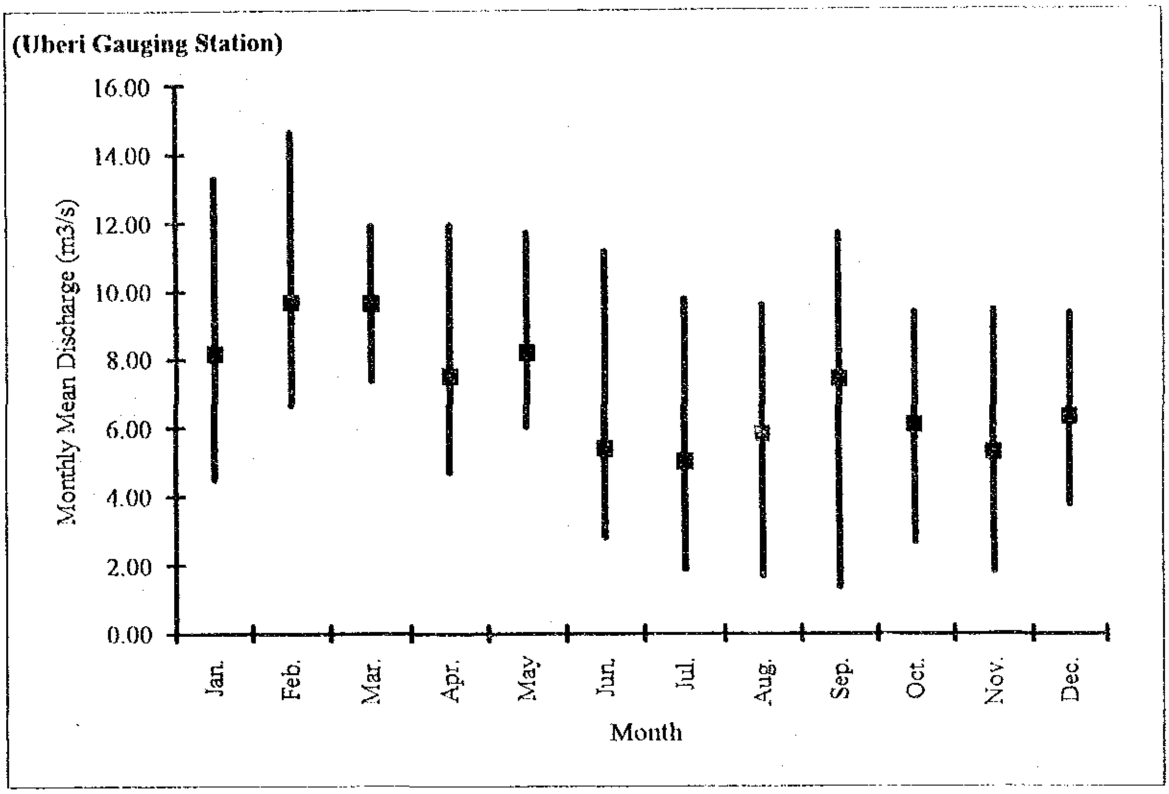
TITLE

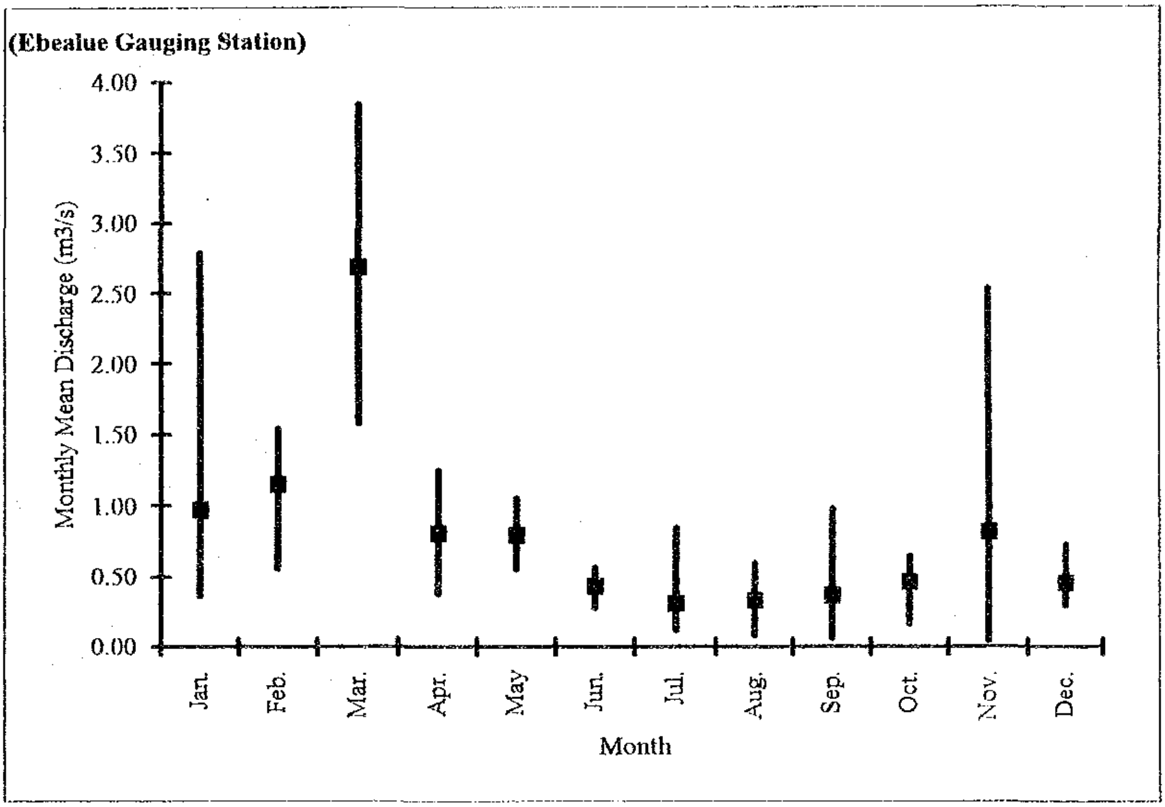
FLOW DURATION CURVE OF THE BROWN AT KAREMA

Fig. No.
4.10

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL





TITLE

Fig. No.

MONTHLY MEAN DISCHARGE OF THE GOLDIE RIVER **4.11**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

WATER QUALITY

CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX - B WATER QUALITY

1 Introduction

Water quality for this study of potable water master plan refers to both quality of raw water that is extracted for treatment as well as the supplied (treated) water for households and other consumers.

At present, both the Laloki river and its tributary Goldie river are utilized, as the major potable raw water sources, in and around the NCD area.

Laloki river, with its intakes at Rouna Pond and Bomana, serves as the sole raw water source of NCDC water supply. The Rouna intake is about 14km upstream of the Bomana intake and pump house along Laloki river. The water treatment plant Mt Eriama, common to both intakes, receives the raw water by gravity and pump transmission mains from Rouna and Bomana intakes, respectively.

Goldie river is the source of water supply for the Army Barracks at Tank Hill, that lies beyond the NCD area in the Central Province. This is a private water supply entirely owned and managed by the PNG Defence Force.

The water quality of raw water sources, river waters, and that of treated water are essentially different, though they are interrelated. Accordingly, they are dealt with separately below, as raw water quality and treated water quality, where possible. However, at times both these are dealt with integrally due to their inherent relationship.

2. Raw Water Quality

2.1 General

The potential surface water sources for potable water supply development, that could be exploited reasonably for the NCD area until the target year of this master plan in 2012, are the following rivers:

1) Laloki river, the existing raw water source
2) Goldie river
3) Brown river

Other rivers are geographically too remote from the NCD area for economic exploitation. The water quality of these rivers is investigated to confirm their suitability as potable water sources, both by using available data as well as by conducting water quality sampling and analysis.

No recent data on the water quality of these rivers except Laloki river at a few locations, are available.

In fact, there is no water quality monitoring programme by any concerned government agency like Bureau of Water Resources, in any of these three rivers.

However, the rivers are of good water quality considering their remoteness and sparse population density in their drainage basins. The potential sources of pollution in these rivers are industrial and agricultural run-offs, due to significant changes in land use of the watershed, rather than anything else, even on a long term basis.

Such a change in land use is already evident in the upper reaches of Laloki basin in Sogeri and Koitaki plantation areas. The land use of these areas has been changed from forestry type rubber plantation to savanna, and grassland for cow grazing, in recent years. It is to be noted that savanna type land use is suited for semi-arid areas, though Sogeri and Koitaki with an annual rainfall exceeding 3000 mm cannot be categorized as semi-arid. Even though no proven evidence is available, this savanna type land use is suspected to be causing increased soil erosion, and hence the increased sediment loads in the tributary of Laloki river, the Eworogo Creek.

Laloki River is very important because of the benefits it offers by way of water supply, hydro-power, irrigation and others. An effective watershed management of the river basin is required to sustain the beneficial uses of the river. Establishment of water quality monitoring stations in Laloki river basin, by concerned agencies like Bureau of Water Resources (BWR), must be given high priority.

The Department of Environment and Conservation of Bureau of Water Resources is responsible for the surveillance/monitoring of water quality in the country. In fact water resource allocation for beneficial uses, including the quality, falls under the jurisdiction of the Bureau of Water Resources.

2.2 Available Data

The only available recent water quality data is the monitored data in Laloki river at about 5km along Hubert Murray Highway from the Boundary of NCD and Central Province, in the river reaches of Central Province, at Hugo Cannery and Bluffin Motel areas. This is a commendable industrial pollution monitoring program in Laloki river by Bureau of Water Resources, though the programme requires further refinement to ensure validity.

The water quality monitoring locations in the river are shown in Fig. B.1. The monitoring locations shown in river, A, B, and C, are approximate. These were established by the Study Team based entirely on the identification carried out with the guidance of Hugo Cannery staff engaged in sampling work.

The monitoring locations are as follows (ref. Fig. B.1).

A: Laloki River upstream of Bluff-in Motel
B: Laloki River downstream of Bluff-in Motel
C: Laloki River downstream of Hugo Cannery
D: Effluent discharge location in Hugo Cannery

This water quality monitoring, a monthly monitoring programme, is being carried out since March 1989, while the Hugo Cannery itself commenced operation in 1987, according to information available with the Bureau of Water Resources.

This water quality monitoring in Laloki River (and the effluent discharge from Hugo Cannery), is established essentially to monitor and hence to regulate, if necessary, the wastewater discharge by the cannery. The sampling itself is done entirely by the Cannery staff.

The Bureau of Water Resources is yet to verify the sampling locations on the site, not to mention the supervision of sampling. However, the samples collected are analyzed independently by the National Analysis Laboratory of Papua New Guinea University of Technology in Lae. Hence the results could be considered as independently verified, though the sampling itself is never subjected to an independent verification.

At present, this monitoring programme is essentially carried out by the Hugo Cannery.

The Bureau of Water Resources must supervise the sampling by Hugo Cannery at least two times a year once each during low river stage (July - September) and high river stage

(February - March) on site so that the data can be independently verified. Such a verification will become an integral part of any future monitoring programmes.

The water quality parameters monitored monthly are as follows:

pH, total suspended solids (TSS), total dissolved solids (TDS), BOD_5, total coliform (TC) and fecal coliform (FC).

Recently, available data, encompassing a continuous span of more than two years, from February 1990 to March 1992, was provided to the Study Team by the Bureau of Water Resources. This data is incorporated in the Data Book.

The stream river water quality data obtained by monitoring, and the evaluation of results are summarized in Table B.1.

Time series variations of the most significant pollution indicator, BOD_5, in all three locations of A, B and C are graphically illustrated in Fig.B.2.

No significant trend in river water quality over this two year period is seen in the reaches of Bluffin - Hugo Cannery. The river water quality is good and suited for potable use with conventional treatment, though these river locations probably account for one of high pollution load receiving reaches of Laloki.

The effect of pollution load discharge on the stream river water quality, either by Bluffin Motel or Hugo Cannery at present, is not significant.

2.3 Sampling by JICA

Due to the lack of recent data on water quality and also to substantiate the available data, the Study Team conducted water quality sampling and analysis, two times in an interval of 10 days, during October 1992 at five sampling locations.

The sampling locations covered all three rivers with potability potential, Laloki, Goldie and Brown rivers. The existing and potential raw water intake sites of these rivers as well the existing water treatment plant at Mt. Eriama are selected as sampling locations. They are shown in Fig. B.3 and summarized as follows:

1. Brown river under the Hiritano Highway bridge near the existing water stage gauge.

2. Goldie river at the existing raw water intake for Army Barracks water supply near Tank Hill.

3. Laloki river at the existing raw water intake for NCD water supply at Bomana Pump Station.

4. Rouna 1/3 head pond, diversion of Laloki River at Rouna Falls for hydropower generation and NCD water supply, near the intake gate of the raw water gravity transmission main to treatment plant.

5. Water treatment plant at Mt Eriama of NCD water supply.

At location No.5, water treatment plant, two sampling locations are selected to assess the overall treatment efficiency of the plant. The waters sampled are clarified water and filtered water before chlorination. They are referred to as location No. 5a and 5b, respectively.

The 5a sample was directly obtained from the central clarifier (Stage 2 clarifier) which is a sludge blanket type clarifier. While the filtered water was sampled from Filter No.3 through the sampling tap in the laboratory of the treatment plant. The filters were of closed type, unlike the clarifiers, hence inaccessible for direct sampling.

Strictly speaking, the treatment plant samples are not raw water but partly treated water samples. Since they are not disinfected/chlorinated, and yet be supplied, they are grouped in raw water. In principle, disinfected water is only considered "treated" and potable.

The water quality parameters analysed in the field and laboratory are as follows.

1) Field parameters

- Ambient temperature
- Water (sample) temperature
- Odour
- pH
- Electric conductivity (EC)

2) Laboratory parameters

- Colour		- BOD_5
- Turbidity		- COD (Cr)
- Total solids	(TS)	- COD (Mn)

- Iron (Fe)
- Manganese (Mn)
- Total hardness
- Chloride (Cl)
- FC (Fecal coliform)
- T-N (Total nitrogen)
- NO_2-N
- NO_3-N
- TC (Total coliform)

All locations sampled were aesthetically appeasing with no odour. The water was essentially clean and colourless, indicating good water quality.

The ambient temperature and water temperature during both samplings were in the range of 26 - 32^oC and 26 - 30^oC, respectively.

The results of analysis are summarized in Table B.2. The arithmetic average of both sampling results was used to arrive at the values shown in the table above.

3. Treated Water Quality

3.1 General

Treated water is defined as water that is potable and could be supplied to customers without further treatment. Water delivered from the treatment plant at Mt Eriama to the distribution system, as well water obtained at distribution taps, fall into this category.

The quality of water delivered from Eriama is monitored regularly in the laboratory at the treatment plant. This also includes monitoring of the raw water quality entering the treatment stream.

Moreover, water distribution taps, the treatment plant and some others such as swimming pools, water service reservoir, sewage treatment ponds, and coastal sea water at Port Moresby are being monitored independently for their bacteriological water quality by the Health Division of NCDC. Though this monitoring programme has room for improvement, it is adequate for an overall assessment of the bacteriological water quality.

The Study Team also conducted independent sampling and analysis of existing taps to substantiate and verify the above available information, as described in subsequent sections.

3.2 Available Data

The available data of treated potable water quality is due to two independent monitoring programmes by NCDC- one at the point of bulk supply, the treatment plant, and the other at the end user taps and treatment plant by the Division of Health.

The operation and maintenance of treatment plant, including the self monitoring of supplied water quality is under the Department of Technical and Engineering of NCDC, while the monitoring of end user tap and treatment plant water quality by the Division of Health is under the Department of Community Service of NCDC.

The self-monitoring programme of the treatment plant and that of the Division of Health, and the relevant recent available data are described below.

3.2.1 Treatment Plant

1) Self Monitoring in Plant

The treatment plant is equipped with all necessary basic equipment and amenities in the attached laboratory to monitor the basic water quality parameters on line for self monitoring. Sampling taps are provided so that samples from any sub-treatment unit can be collected for analysis in the laboratory.

The treated bulk water supplied from the treatment plant is hourly monitored on a 24-hour basis for pH and residual free chlorine.

A pH value in the range of 7.0 - 8.5, and residual free-chlorine in the range of 0.5 - 1.5 mg/l has benn ensured in the supplied water through hourly monitoring.

Moreover, daily monitoring is conducted at 9.00am for some additional parameters. Nevertheless, the laboratory does not possess the necessary facilities to conduct bacteriological analysis.

The daily analysis results, conducted for the raw and treated water, are entered in a log sheet and compiled. A copy of the log sheet results is incorporated in the Data Book.

The major parameters of this daily monitoring programme at the treatment plant according to the type of water, are given below.

a) Raw water entering the Plant

- Water temperature
- Turbidity
- pH
- Total alkalinity
- Calcium hardness
- Total hardness

b) Settled water (Clarifier effluent)

- pH

c) Treated water prior to bulk supply

- Water temperature
- pH (also hourly monitored)
- Total alkalinity
- Calcium hardness
- Total hardness
- Residual free chlorine (also hourly monitored)

Based on the above daily monitoring results, monthly summary reports are compiled. The average value of a parameter over a specific time frame is recorded in the summary reports with relevant remarks. However, compilation of such summary reports is irregular, and is reported to be due to staff limitations in the treatment plant.

The summary report of July 1992, contained the following average water quality in that month for the raw and treated waters, respectively .

a) Raw water quality in July 1992

Appearance	:	Very clear
Water temperature:		27^oC
Turbidity	:	10 NTU
pH	:	7.3
Total alkalinity	:	31 mg/l as $CaCO_3$
Total hardness	:	25 mg/l as $CaCO_3$
Calcium hardness	:	20 mg/l as $CaCO_3$

It was noted in the remarks of this monthly summary report for July 1992, that in the dry season the raw water was "quite clear" with low turbidity. This is also evident from the sampling results of this Study as described in the previous section on Raw Water Quality.

b) Treated water quality in July 1992

Appearance	:	Very clear
Water temperature	:	25°C
Turbidity	:	0 - 5 NTU
pH	:	7.5
Total alkalinity	:	30 mg/l as $CaCO_3$
Total hardness	:	28 mg/l as $CaCO_3$
Calcium hardness	:	25 mg/l as $CaCO_3$
Residual free chlorine	:	1 mg/l

As noted in the remarks, the above measured parameters of treated water quality is in conformity with the W.H.O Drinking Water Standards, adopted for PNG according to the Statutory Instrument, No.8 of 1984, the Public Health (Drinking Water) Regulation (ref. Annex-1).

The recorded monthly range of the measured water quality parameters in the treatment plant for ten months in 1991, except April and May for which data is not available, is given in Annex-2 for reference.

2) Monitoring by Health Division

The bacteriological water quality in the plant for all types of water from raw water to treated water, including settled and filtered water, is monitored independently by the Division of Health as a part of overall water quality monitoring programme for sanitation, covering city water distribution taps and others.

The samples are sent to National Public Health Laboratory attached to Port Moresby General Hospital for bacteriological analysis.

The bacteriological parameters analysed are as follows:

total bacterial count, total coliform (TC), fecal coliform (FC) and E.Coli.

The frequency of monitoring in general, is at least once a month. At times, it was even once a week, according to the recent evaluation of random past data since 1987 provided to the Study Team by Division of Health, NCDC. At present in 1992, the sampling frequency is once a month which is adequate.

None of the treated water sample results evaluated, contained any trace of bacterial pollution including total bacterial count, indicating excellent bacteriological water quality of the treated water for bulk supply in Eriama.

Even the raw water contained less than 1000 FC/100 ml, most of it less than even 100 FC/100 ml, a fine bacteriological quality for raw water prior to treatment.

3.2.2 Distribution Tap

Monitoring the water quality in distribution taps is a part of the above-mentioned overall monitoring programme for sanitation by the Division of Health, NCDC. This is also essentially a bacteriological water quality monitoring programme, although pH and residual free chlorine are also measured at sampling taps on site. This is the sole monitoring programme targeting the distribution/service taps.

There are 57 number distribution (service) tap sampling locations spread throughout the NCD water distribution system. These tap location are shown in Fig. B.4. The above figure also shows two other major bacteriological water quality monitoring locations by the Division of Health, the swimming pools and coastal sea waters. Moreover, water service reservoirs in the NCD distribution system are also monitored at random.

The distribution tap monitoring programme has the aim of covering all the 57 locations, once, for a complete cycle, each month. However, this target is yet to be met.

Very often prior to the completion of one cycle covering all 57 locations, repeat sampling at locations that were sampled were carried out. This is because irrespective of meeting the target of all 57 locations in a month, sampling in one particular month independent of the previous month.

Nevertheless, based on a random evaluation of distribution tap sampling conducted since 1987, it was clear that most of the time except in very rare cases, the bacteriological water quality was excellent, with no bacterial count with respect to all four parameters measured namely, total bacterial count, total coliform (TC), fecal coliform (FC) and E. Coli, same as the treatment plant.

Hence, it was concluded that both the treated water quality at the treatment plant and water distributed at taps are of good quality and potable.

For imploving the existing distribution tap monitoring by the NCDC Health Division, it is recommended that every effort be made to cover all 57 locations in a month, set as the target. Irrespective of meeting the monthly target, one cycle to cover all 57 locations must be continued even in the following month, before commencing the cycle for the following month. In other words, the target in the following month may be increased so that all 57 locations be covered twice in two months, and so on.

3.3 Sampling by JICA

As an independent verification of distribution tap water, the Study Team conducted water quality sampling and analysis at five (5) distribution/service taps in the NCD water distribution area. The five (5) distribution tap locations are one each at Gerehu, Gordon and Boroko, the three (3) Model Areas for comprehensive evaluation of existing water supply conditions, and Tokarara and Town. These locations are identified with respect to their streets as follows:

1. Gerehu Model Area - Household yard tap in Udia St. and Gahuna Cres. intersection.

2. Gordon Model Area - Household yard tap at the end of Heni Pl.

3. Boroko Model Area - Household yard tap at the end of Siale Pl.

4. Tokarara Area - Household wash tap at Gaibodubu St. and Manoka Pl. intersection.

5. Town Area - Tea room tap inside Town Police Station at Musgrave St.

The locations of these sampled taps are shown in Fig. B.5. The sampling was conducted two (2) times at each locationduring October 1992 similar to that of rivers and treatment plant (ref. section 2.3) .

The water quality parameters analysed are basically the same as those of raw water sampling. However, residual free chlorine and residual total chlorine are also incorporated as additional parameters of field measurement. These parameters determine the effectiveness of disinfection for potable use by chlorination.

The parameters of field and laboratory measurements are given below.

1) Field parameters

- Ambient temperature
- Water (sample) temperature
- Odour
- pH
- Electric conductivity (EC)
- Residual free chlorine
- Residual total chlorine

2) Laboratory parameters

- Colour
- Turbidity
- Total solids (TS)
- Iron (Fe)
- Manganese (Mn)
- Total hardness
- Chloride (Cl)
- FC (Fecal coliform)
- BOD_5
- COD (Cr)
- COD (Mn)
- T-N (Total nitrogen)
- NO_2-N
- NO_3-N
- TC (Total coliform)

All sampled waters were odourless, colourless, clear and apparently potable. Moreover, all contained residual free and total chlorine, hence could be assessed as truly potable.

The ambient and water temperatures during both samplings were in the range of 27 - 32^oC and 27 - 32^oC, respectively.

The results of analysis, are summarized in Table B.3 as the arithmetic averages of both samplings.

As evident from Table B.3, the measured bacteriological parameters of total coliform (TC) and fecal coliform (FC) were nil at all five (5) locations, during both samplings. Hence, the bacteriological water quality fully satisfies the requirement of water for potable use.

4. Water Quality Standards

4.1 General

The standards related to raw and treated water quality for potable use, including required sampling frequency of potable water at points of end user, and distribution/service taps, have been in use since 1984 in Papua New Guinea.

The Statutory Instrument - No. 8 of 1984, the Public Health (Drinking Water) Regulation, established under the Public Health Act, stipulates the required Water Quality Standards.

This Statutory Instrument is given in Annex-1. The standards stipulated by this Instrument for raw and treated waters are described in subsequent sections.

4.2 Raw Water

The "Standard for Raw Water", given in Schedule-1 of Statutory Instrument (ref. Annex-1), is defined with respect to three (3) broad parameters of Microbiology, Toxic Contaminants and Aesthetic Quality. The standard limitations are given below.

Standards for Raw Water (1984)

1) Micro-Biological Standards — Maximum Allowable

Coliform Bacteria (Total Coliform - TC)	20,000 per 100 ml

2) Toxic Contaminants Standards

	Substances		Maximum Allowable
a)	Arsenic	(as As)	0.05 mg/l
b)	Cadmium	(as Cd)	0.01 mg/l
c)	Cyanide	(as Cn)	0.05 mg/l
d)	Lead	(as Pb)	0.10 mg/l
e)	Mercury	(total as Hg)	0.001 mg/l
f)	Selenium	(as Se)	0.01 mg/l
g)	Nitrate		45.0 mg/l
h)	Silver		0.05 mg/l
i)	Fluorides	(as F)	1.5 mg/l

3) Aesthetic Quality Standards

Substance or Characteristics		Maximum Allowable
a)	Colour	50 units *
b)	Odour	Unobjectionable
c)	Taste	Unobjectionable
d)	Iron	1 mg/l
e)	Manganese	0.5 mg/l
f)	Sulphate	400 mg/l
g)	Total Dissolved Solids	1 500 mg/l
h)	Chemical Oxygen Demand (COD)	10 mg/l
i)	Bio-Chemical Oxygen Demand (BOD)	6 mg/l
j)	Mineral Oil	1 mg/l

* On the platinum-cobalt scale.

The above standards are adequate for potable use of surface water with treatment.

However, it is recommended that Item 1) of Microbiological Standards be modified as Biological Standards with re-arrangement of COD and BOD standards from Item 3) to this Item 1). Then the modified Item 1) of Biological Standards would be as follows:

1) Biological Standards	Maximum Allowable
a) Chemical Oxygen Demand (COD)	10 mg/l
b) Bio-chemical Oxygen Demand (BOD)	6 mg/l
c) Coliform Bacteria	20,000 per 100 ml

The above arrangement would facilitate assessment of water quality, as the above three (3) parameters are indicators of biological pollution.

Moreover, the limitations on total hardness and chloride that are virtually unaffected by conventional water treatment, must be incorporated in raw water standards as well under Item 3). As evident from the subsequent section, the Standards for Drinking Water stipulates limitations on these two (2) parameters.

4.3 Treated Water

The Treated Water Standards are stipulated in Schedule 2 of the above Instrument (1984) as "Standards for Drinking Water" (ref. Annex-1).

The standards were adopted from the WHO International Standards for Drinking Water (1971), with necessary modifications to suit the local conditions in Papua New Guinea.

Similar to the "Standards for Raw Water", these Drinking Water Standards are also defined with respect to the three (3) broad parameters of Microbiology, Toxic Contaminants and Aesthetic Quality. The standard limitations are given below.

Standards for Drinking Water (1984)

1) Micro-Biological Standards

a) Chlorinated or disinfected water supplies.

(i) For water entering the distribution system, the coliform count shall be zero in any 100 ml sample.

ii) For water in the distribution system;

a) Throughout any year, 90% any 100 ml sample shall not contain any coliform organism

b) There shall be no E. Coli in any sample of 100 ml sample

c) No sample shall contain more than 10 coliform organisms per 100 ml;

d) Coliform organisms shall not be detected any two (2) consecutive 100 ml samples.

b) Non-disinfected water supplies:-
(Individual or Small Community Supplies).

i) There shall be no E. Coli in any 100 ml sample.

ii) If E. Coli is absent, no sample shall contain more than 3 coliform organisms per 100 ml.

2) Toxic Contaminants Standards

Drinking water shall not contain the following substances in amounts exceeding the stated upper limit of concentration.

Substances			Upper Limit of Concentration
a)	Arsenic	(as As)	0.05 mg/l
b)	Cadmium	(as Cd)	0.01 mg/l
c)	Cyanide	(as Cn)	0.05 mg/l
d)	Lead	(as Pb)	0.1 mg/l
e)	Mercury	(as Hg)	0.001 mg/l
f)	Selenium	(as Se)	0.01 mg/l
g)	* Nitrate		45.00 mg/l
h)	* Silver		0.05 mg/l

3) Aesthetic and other quality standards

Substances or Characteristics		Highest Desirable Level	Maximum Permissible Level
a)	Colour	5 units	50 units **
b)	Odour	Unobjectionable	Unobjectionable
c)	Taste	Unobjectionable	Unobjectionable
d)	Suspended Matter (Turbidity)	5 units	25 units ***
e)	Total Solids	500mg/l	1,500 mg/l
f)	pH range	7.0 - 8.5	6.5 - 9.2
g)	Mineral Oil	0.01 mg/l	0.30 mg/l
h)	* Total Hardness	200 mg/l ($CaCO_3$)	600 mg/l ($CaCO_3$)
i)	Calcium (as Ca)	75 mg/l	200 mg/l
j)	* Chloride	200 mg/l	600 mg/l ($CaCO_3$)
k)	Copper (as Cu)	0.05 mg/l	1 000 mg/l
l)	Iron (Total as Fe)	0.1 mg/l	1.0 mg/l
m)	Magnesium (as Mg)	Not more than 30 mg/l if there are more than 250 mg/l of sulphate	150 mg/l

n)	Manganese (as Mn)	0.05 mg/l	0.5 mg/l
o)	Sulphate	200 mg/l	400 mg/l
p)	Zinc (as Zn)	2.0 mg/l	15 mg/l
q)	* Fluoride	1.0 mg/l	1.5 mg/l

Note: * Papua New Guinea requirements as distinct from WHO
** On the platinum-cobalt scale
*** Jacksons Turbidity Units (J.T.U)

4.4 Conclusion

Combination of standards of Raw Water and Treated Water (Drinking Water) mentioned above ensures potability of water extracted, treated and supplied in Papua New Guinea.

The above standards stipulated by the Statutory Instrument - No.8 (1984) are used in this Master Plan Study.

5. Water Quality Evaluation

The water quality of potential raw water sources of rivers for potable water supply and of the treatment plant, and the treated water in distribution/service taps are evaluatedbased on the available water quality data and the sampling results of Study Team.

The Papua New Guinea Standards for Raw Water and Drinking Water (Treated Water) described in the previous Chapter are used as the basis of comparison for respective water quality parameters.

The treated water quality at the treatment plant at Mt. Eriama for bulk supply and that distributed in taps are evaluated and found to be in conformity with the Standards for Drinking Water (1984), with respect to all measured parameters, irrespective of the type and source of data.

The available data from the plant and Health Division of NCDC monitoring programmes, as well as independent sampling results of all paraments measured by the Study Team (ref. Table B.2 and Table B.3) are within the limitations stipulated in the Standards for Drinking Water.

All bacteriological and chemical parameters measured by the Study Team during both sampling were well within the Standard limitations. The consistent availability of residual free chlorine and the absence of coliform organisms guaranteed the distribution tap water quality for potable use (ref. Table B.3) from the public health (microbiological) view point.

The very fact that treated water satisfying the physical, chemical and biological parameter limitations for potable use, is produced with conventional water treatment at Eriama, is in itself, a testimony to the suitability of Laloki River as a potable raw water source.

The same can be said of Goldie River since it serves as the potable raw water source for Army Barracks water supply with conventional treatment at the Tank Hill treatment plant.

The sampling results of the Study Team on raw river water quality, other than the partially treated treatment plant effluents of clarifier and filter, indicated relatively higher BOD and total fecal coliform levels.

The average BOD levels measured in all four (4) river sampling locations were around 10 mg/l. In a strict sense these levels exceeded the raw water standard limitation of 6 mg/lBOD of Statutory Instrument No.8. However, these values represented the water quality under critical, dry weather, river flow conditions with low discharge.

Similar high BOD levels were noted during the Hugo Cannery sampling as well, during October 1990 in Laloki River reaches (ref. Fig. B.2), even though 70% of the times the BOD levels did not exceed 5 mg/l during a two (2) year period from February 1990 to March 1992 (ref. Table B.1).

Accordingly, the river water quality is assessed to be suitable for use as a potable water source, under the existing conditions.

Nevertheless, a watershed management plan initially targeting the Laloki River basin, is recommended, in order to regulate industrial and agricultural based run-off and to control potential soil erosion in the basin.

Table B. 1 (1) Results of Hugo Cannery Monitoring in Laloki River (Feb 1990 - March 1992)

1) A: Laloki River Upstream of Bluffin Motel

Parameters	Parameter Range	No. of Data	Remarks
pH	7.0 - 7.8	19	Good water quality.
Total Suspended Solids (TSS) (mg/l)	2 - 73	21	Good water quality.
Total Dissolved Solids (TDS) (mg/l)	25 - 113	21	Good water quality.
BOD_5 (mg/l)	0 - 37	21	About 70% of data did not exceed 5mg/l. Good water quality.
Total Coliform (TC) (No./100ml)	50 - 12,000	21	About 70% of data did not exceed 1000 No./100ml. Good water quality.
Fecal Coliform (FC) (No./100ml)	0 - 1,800	21	About 70% of data did not exceed 100 No./100ml. Good water quality.

Table B.1 (2) Results of Hugo Cannery Monitoring in Laloki River (Feb 1990 - March 1992)

2) B: Laloki River Downstream of Bluffin Motel.

Parameters	Parameter Range	No. of Data	Remarks
pH	6.9 - 7.9	19	Good water quality.
Total Suspended Solids (TSS) (mg/l)	4 - 51	21	Good water quality.
Total Dissolved Solids (TDS) (mg/l)	37 - 122	21	Good water quality.
BOD_5 (mg/l)	0 - 14	21	About 60% of data did not exceed 5mg/l. Good water quality.
Total Coliform (TC) (No./100ml)	70 - 5,000	21	About 70% of data did not exceed 1000 No./100ml. Good water quality.
Fecal Coliform (FC) (No./100ml)	0 - 2,100	21	About 70% of data did not exceed 100 No./100ml. Good water quality.

Table B.1 (3) Results of Hugo Cannery Monitoring in Laloki River (Feb. 1990 - March 1992)

3) C: Laloki River Downstream of Hugo Cannery

Parameters	Parameter Range	No. of Data	Remarks
pH	6.8 - 7.9	18	Good water quality.
Total Suspended Solids (TSS) (mg/l)	3 - 60	20	Good water quality.
Total Dissolved Solids (TDS) (mg/l)	20 - 141	20	Good water quality.
BOD_5 (mg/l)	0 - 14	20	About 60% of data did not exceed 5 mg/l. Good water quality.
Total Coliform (TC) (No./100ml)	20 - 11,000	20	About 70% of data did not exceed 1000 No./100ml. Good water quality.
Fecal Coliform (FC) (No./100ml)	0 - 3,200	20	About 30% of data did not exceed 100 No./100ml. Significant fecal pollution. yet satisfactory in the overall sense.

Table B.2 Raw Water Quality Sampling Results by JICA (Oct. 1992)

Location No.	Field Parameters			Laboratory Parameters															
	Odour	pH	EC (US)	Colour (Pt-Co)	Turbidity (FTU)	TS (mg/l)	Fe (mg/l)	Mn (mg/l)	Total Hardness as $CaCO_3$ (mg/l)	Cl (mg/l)	BOD_5 (mg/l)	COD (Cr) (mg/l)	COD (Mn) (mg/l)	T-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TC (No./ml)	FC (No/ml)
1	Nil	7.9	75	15	3	84	0.27	0.28	35	12	9	11	0.4	5	0.010	3.2	64	33
2	Nil	8.0	95	19	5	110	0.30	0.34	43	7	11	13	0.5	4	0.180	2.8	88	51
3	Nil	7.5	70	27	5	74	0.37	0.26	48	8	11	15	0.5	7	0.241	3.9	470	243
4	Nil	7.6	60	20	3	33	0.31	0.31	41	9	11	13	0.6	5	0.087	3.1	90	55
5a	Nil	6.9	65	3	1	33	0.19	0.30	44	9	2.2	5	0.6	4	0.028	1.8	Nil	Nil
5b	Nil	6.8	80	8	3	32	0.09	0.07	37	9	1.9	4	0.6	4	0.035	1.7	Nil	Nil

Note:

Location No:

1. Brown River at Hiritano Highway Bridge
2. Goldie River at Army Barracks Intake (Tank Hill)
3. Laloki River at Bomana Pump Intake
4. Laloki River at Rouna 1/3 Gravity Intake

5a. Eriama Treatment Plant - Stage 2 Clarrifier

5b. Eriama Treatment Plant - Filter No.3

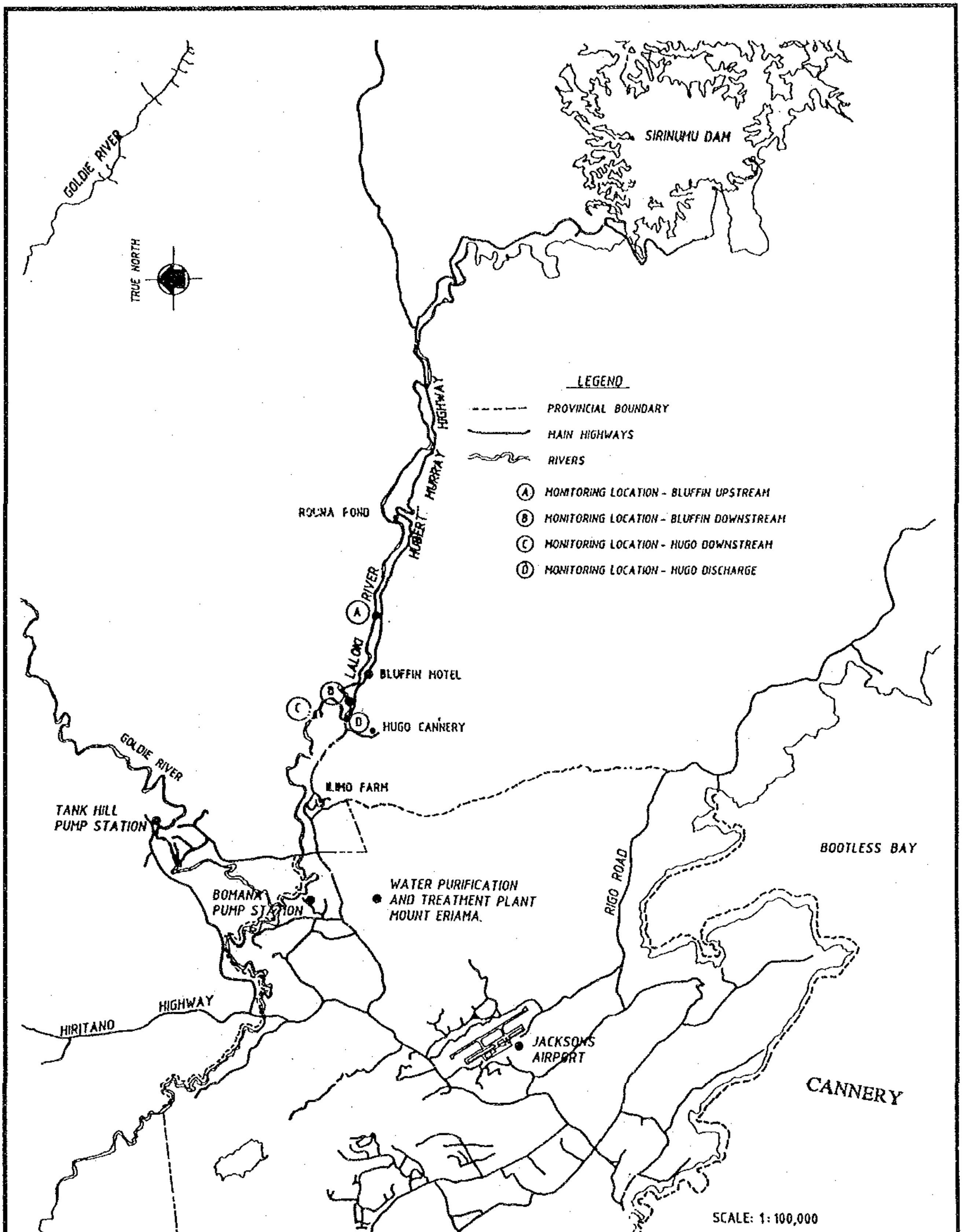
Table B.3 Distribution Tap Water Sampling Results by JICA (Oct. 1992)

Location	Field Parameters					Laboratory Parameters														
No.	Odour	pH	EC(US)	Residual Free Cl_2 (mg/l)	Residual Total Cl_2 (mg/l)	Colour (Pt-Co)	Turbidity (ftu)	Ts (mg/l)	Fe (mg/l)	Mn (mg/l)	Total Hardness as $CaCO_3$	Cl (mg/l)	BOD_5 (mg/l)	COD (Cr) (mg/l)	COD (Mn) (mg/l)	T-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	TC (No./ml)	FC (No./ml)
1	Nil	8.1	90	0.4	0.5	3	5	44	0.03	0.08	37	12	1.8	3.3	0.5	2	0.005	1.9	Nil	Nil
2	Nil	7.7	85	0.5	0.5	2	3	43	0.03	0.10	36	8	1.3	2.7	0.5	3	0.008	1.7	Nil	Nil
3	Nil	7.9	85	0.4	0.5	1	0	43	0.03	0.16	37	8	1.1	1.1	0.4	3	0.007	2.3	Nil	Nil
4	Nil	7.8	85	0.5	0.5	4	2	47	0.03	0.18	38	8	1.5	3.3	0.6	3	0.006	2.5	Nil	Nil
5	Nil	7.7	85	0.3	0.5	3	2	45	0.03	0.10	42	8	1.5	2.7	0.4	3	0.008	2.1	Nil	Nil

Note:

Location No.

1: Gerehu Model Area - Household yard tap at Udia St.
2: Gordon Model area - Household yard tap at Honi Pl.
3: Boroko Model Area - Household yard tap at Siale Pl.
4: Tokarara Area - Household wash tap at Manoka Pl.
5: Town Area - Tea room tap in Police Station at Musgrave St.



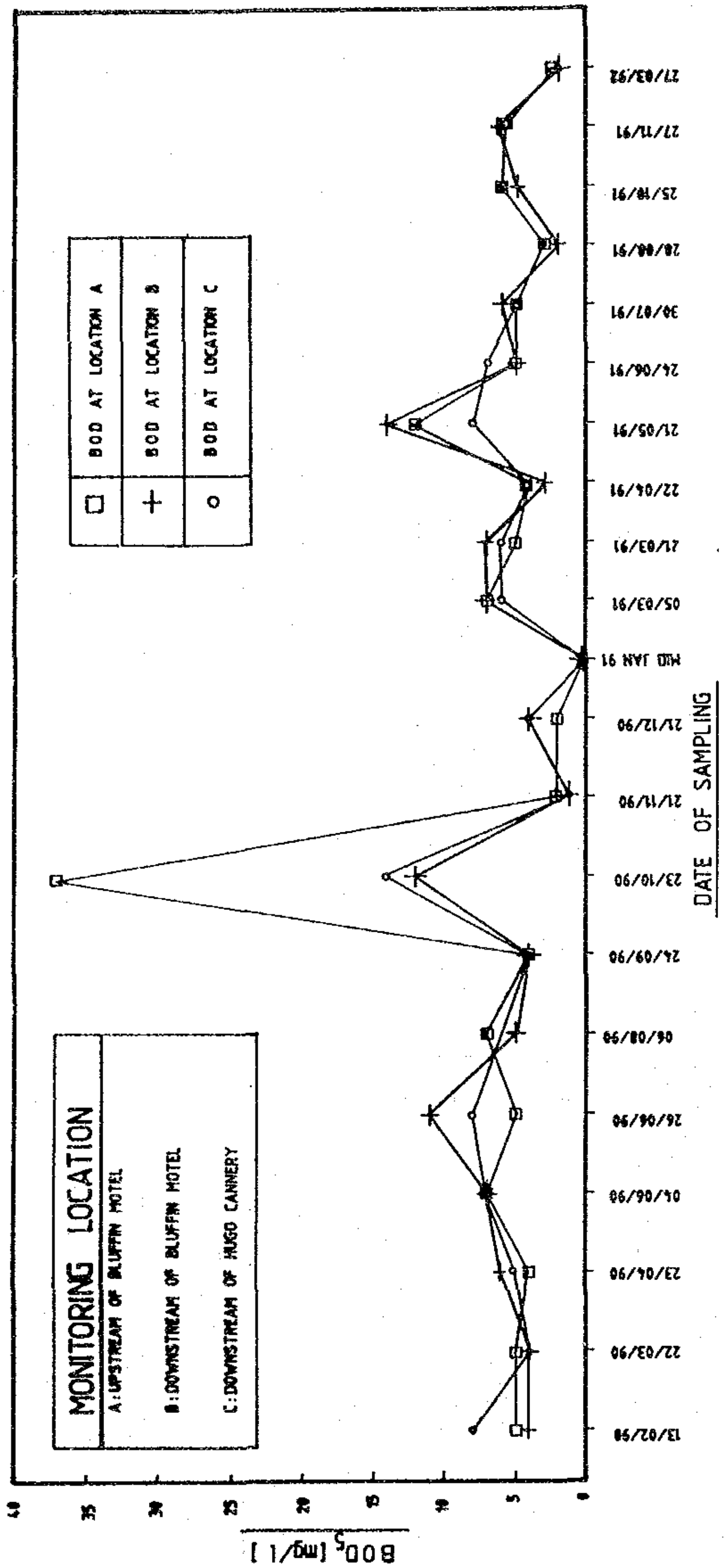
TITLE

MONITORING LOCATION OF LALOKI RIVER QUALITY BY HUGO

Fig. No. **B.1**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



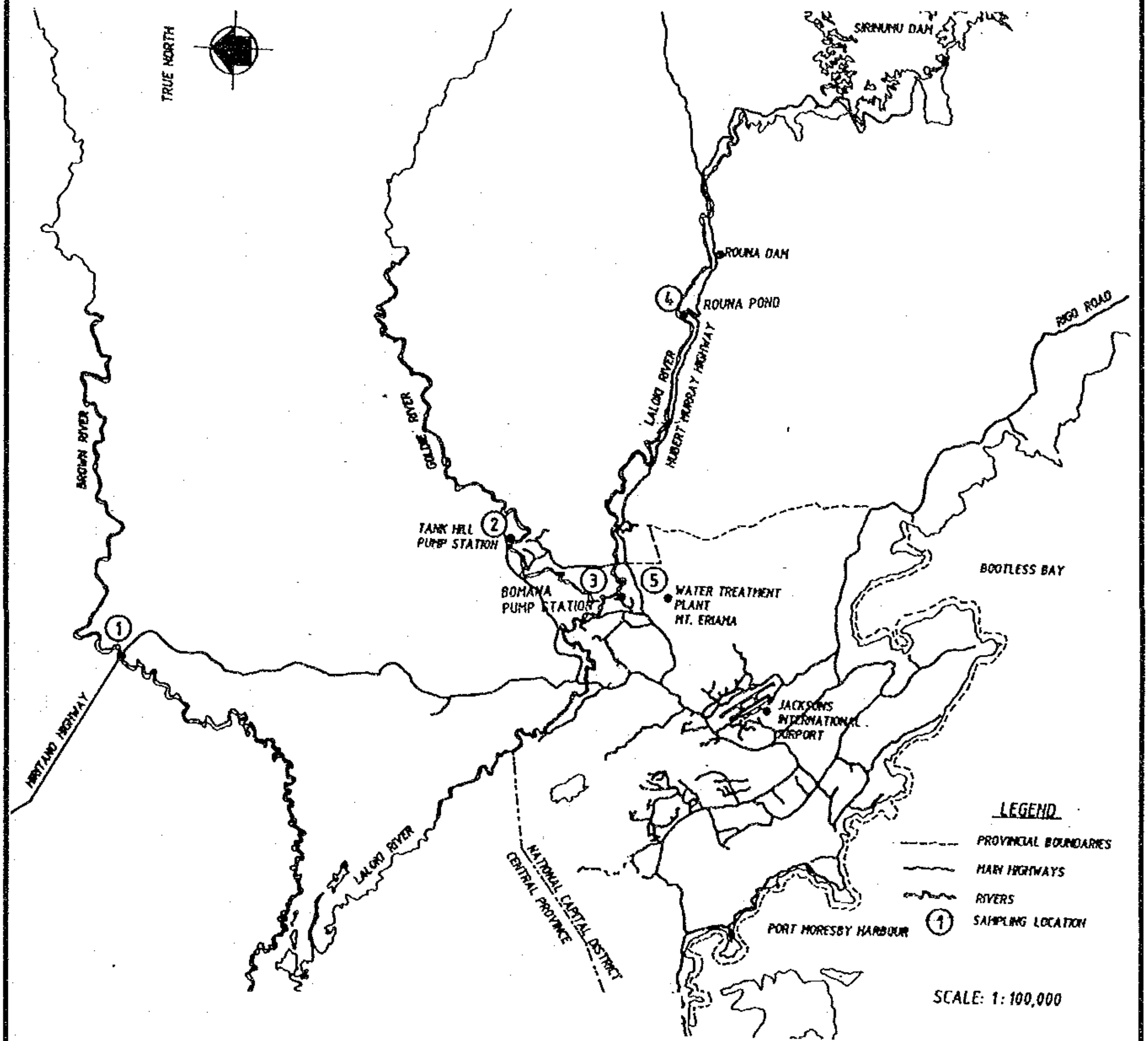
TITLE

TIME SERIES VARIATION OF LALOKI RIVER WATER QUALITY-BOD

Fig. No. **B.2**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

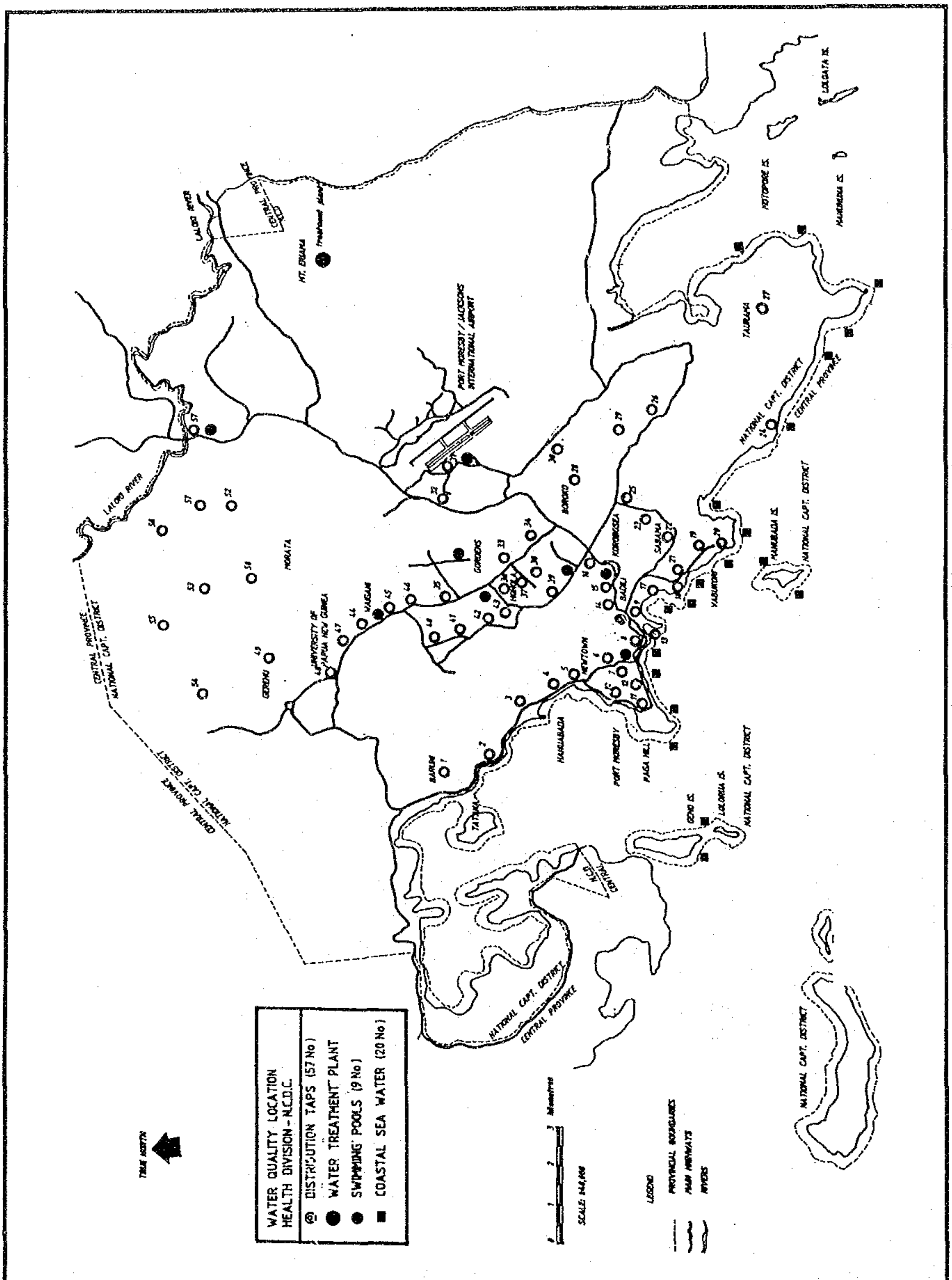
Fig. No.

RAW WATER QUALITY SAMPLING LOCATION BY JICA

B.3

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

MONITORING LOCATION BY NCDC HEALTH DIVISION

Fig. No.
B.4

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

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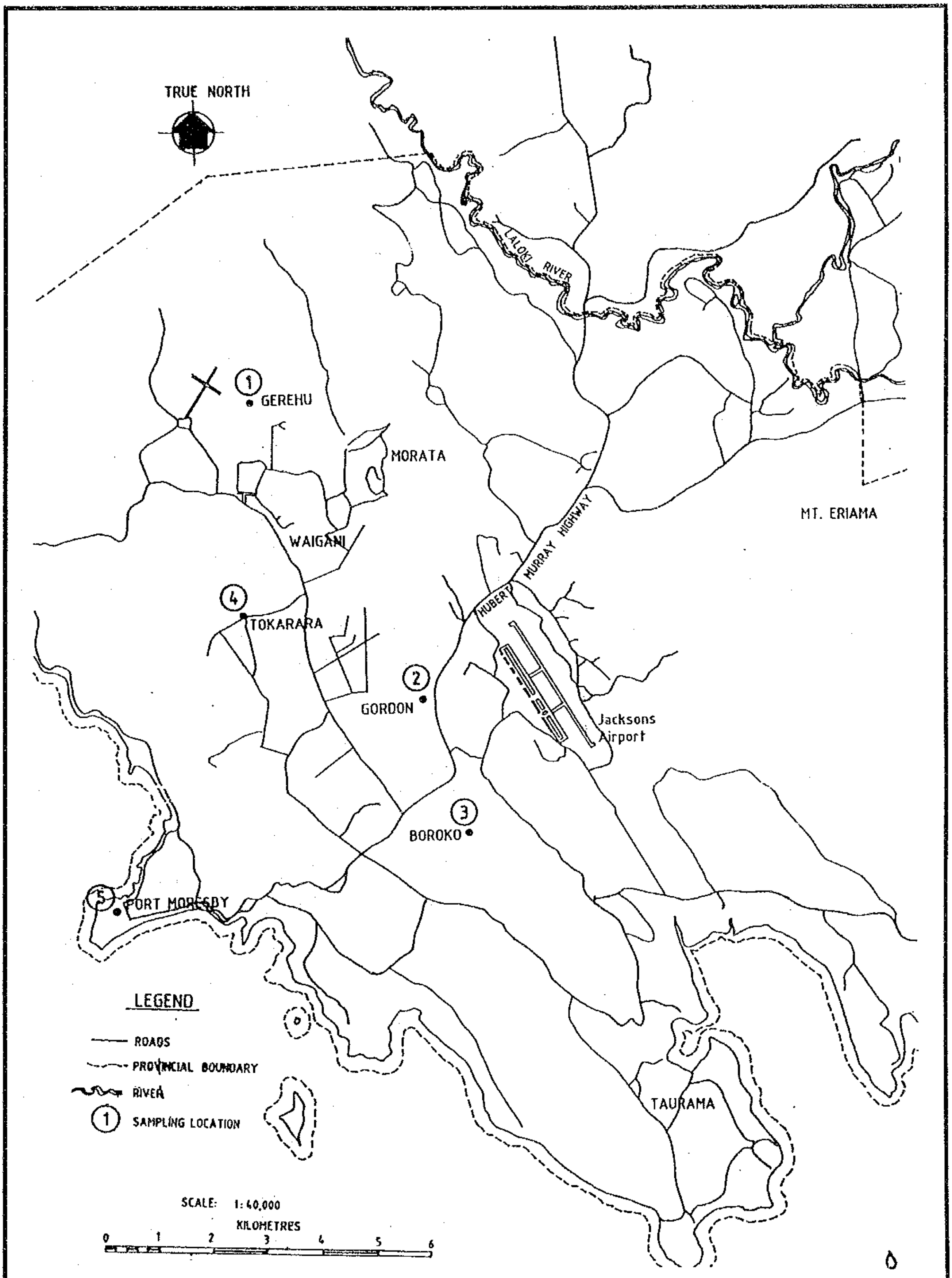

TITLE

DISTRIBUTION TAP WATER QUALITY SAMPLING LOCATION BY JICA

Fig. No. **B.5**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL