ORSTOM-Noumea
Hydrology Section

Bureau of Water
Resources

OPERATIONAL HYDROLOGY IN PAPUA NEW GUINEA

1996-97

Report No. 2 - Primary network

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SUMMARY

The purpose of this second report is to put forward some recommendations regarding the recommissioning and maintenance of a minimum basic hydrological network, (also refered to in this report as a "primary network"), using modern data acquisition and remote monitoring methods.

After a first section dealing with network development and possible options, the second part addresses the main factors affecting runoff.

Parts three and four describe the stations which could form the primary network and discuss the observation equipment which could be used.

SOME BACKGROUND TO THE DEVELOPMENT OF HYDROLOGICAL NETWORKS

At the end of the International Hydrological Decade (1974), after a policy of reasonable expansion of hydrological networks, often linked to development requirements, many countries endeavoured to follow the very general recommendations of WMO regarding the density of hydrological stations in a minimum observation network.

Indiscriminately applied in Papua New Guinea, a country lying in the inter-tropical zone and containing many mountainous islands, these standards would have led to the introduction of a network comprising 250 to 350 stations and would have been totally unmanageable with existing infrastructure and technical resources.
A study of this kind (conducted at the end of 1970 ?) proposed the installation of 216 new stations including 183 requiring helicopter access.

HYDROLOGICAL NETWORKS IN PAPUA NEW GUINEA

The 1974 recommendations for a primary network

The excellent work carried out by SMEC on the request of the Department of Public Works (registered letter dated 28/08/1972) remains **the** reference, because it was based on a very homogeneous data set of around 700 station-years, almost 75% of which were processed.
The proposals regarding the number of primary stations and the growth of this basic network were especially realistic:

- 30 stations maintained as main stations of the 57 operated in 1972
- 3 stations to be reopened, including 1 used only for water level monitoring (Sepik at Angoram)
- 11 new stations to be set up, at a rate of 2 (or 3) per year.

The difficulties of conducting this programme with a smaller team are probably due to the fact that the BWR was also simultaneously responsible for engineering project studies and that it had also been proposed to include in the basic network:

- 11 secondary stations (including 8 new ones),
- and 10 representative catchments (benchmark stations), 10 to 100 km² in area to be equipped and monitored as primary stations.

Further, and although it had been stated that the "primary stations should be operated **indefinitely**", the realisation that mean annual discharges showed low variability and that there was a high degree of correlation between monthly discharge values from the larger basins prompted the decision makers to set up multiple measuring points and only monitor them for a few years.
This was why the Lorengau, one of the few rivers in the islands region, which had been monitored for more than 10 years but which had become hydroelectrically irrelevant (low water discharge too weak), was abandoned in 1974.

The UNDP recommendations and the survey of hydropower resources

Since 1980 and the UNDP proposal to establish 98 extra stations for a range of purposes, funded by private operators (mining companies, energy producers), efforts have essentially concentrated on the establishment of a network of tertiary stations.

The poor correlations between small basins, reported in 1974 by SMEC and reiterated by A.J. Hall in 1984, together with the need to rapidly have available hydrological data on many possible development sites (Hydropower Resource Inventory Study funded by the World Bank) explain this somewhat haphazard growth in the network (figure 1).

HYDROLOGICAL MEASUREMENTS AND PRIMARY NETWORK

While hydrological measurement and observation programmes should give priority to "national actions which have social and economic relevance" (WMO 1994), projects should nevertheless be adapted to needs.

- Small projects rarely require complete hydrometric stations.
  For a village water supply project or a micro power plant, some low-water gauging, possibly supplemented by limnimetric data, usually suffice.
- In order to gradually equip a river (Laloki, etc.) or monitor its environment (Ok Tedi, etc.), developers must from the outset ensure that certain equipment is available and that certain measuring work is carried out.

- **Secondary or tertiary stations set up as part of development projects should quickly be abandoned once the study phase has been completed.**
  Their upgrading into primary stations is only feasible if some of them, after proper calibration, prove to be highly representative of a particular area and if they can be included in the primary network at low cost (very little maintenance required, guaranteed stability of the control section).

Failure to observe these practical "rules" can explain the weakness of some samples in the flood estimation manual (SMEC 1990).
Although the hydrological network comprised over 40 stations in 1962 and this number continued to rise until 1989, the only ones remaining operational at that time were:

- 20 stations more than 10 years old,
- 5 stations over 20 years old.

Recommendations for a primary network

In order to be able to evaluate water resources in one or more development sites, using a series of low-water gaugings or operating results from secondary or tertiary stations monitored over a number of years, it is essential to have a number of reference stations from which observations can rapidly be processed.

From the national point of view, this basic hydrological network should be at least as important as the NWS synoptic stations.

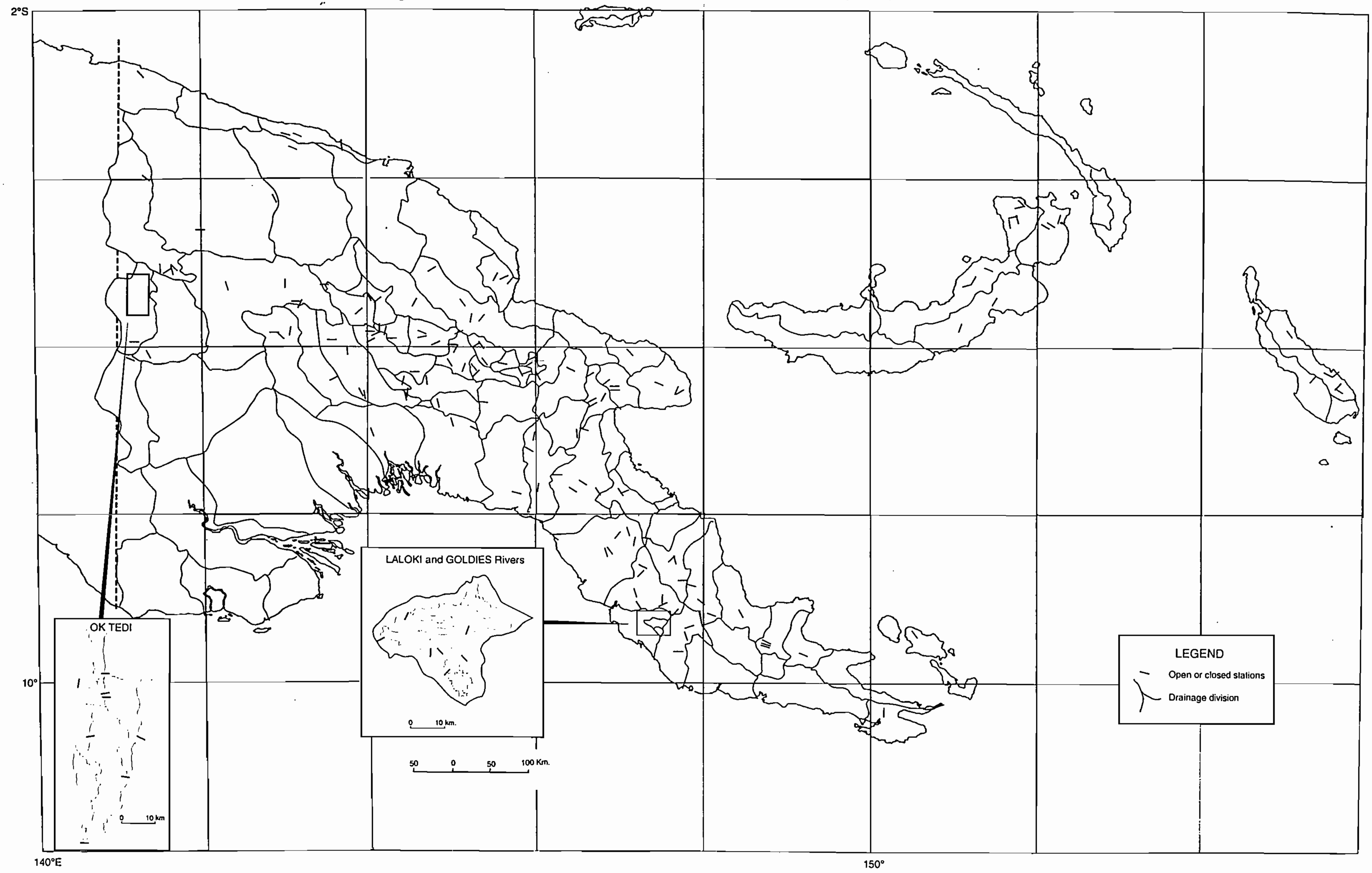
The primary stations in this network should include:

- the minimum number of stations required to be able (together with the precipitation data from a number of NWS stations), to extend the series and do some regional analysis;
- stations at the major development sites which are already known or planned for the medium to long term (Wabo damsite).

Benchmark stations

Work on representative or experimental basins needs major investment in term of equipment and technical staff.
It would no doubt be desirable for this research to be carried out as part of major international programmes (UNESCO IHP Humid Tropics Programmes), in conjunction with university teams.
After a phase covering installation and measurements in the field (3 years on average), making it possible to develop models, these stations should either be decommissioned or maintained with less equipment, but on a fully automatic basis, as benchmark stations.

Figure 1 PNG - HYDROMETRIC NETWORK



THE MAIN FACTORS AFFECTING HYDROLOGICAL REGIMES

Morphology and relief (figures 2 and 3)

The mainland, the islands of the Bismarck Archipelago (New Britain, New Ireland and Manus) and the North Solomons (Bougainville) are all mountainous, with over 50% of the land area lying at an altitude above 500 m.

The central cordillera which forms the backbone of the main island of Papua New Guinea rises to a highest point of 4509 m (Mount Wilhelm). Its width varies from 50 km at the border, in areas highly dissected by erosion (Yapsiei), to over 200 km in the Western Highlands (plateaux and intermontane basins).
The roughly east-west alignment of parts of this mountain range (from the frontier to Goroka in the Stanley range) and of the mountain ranges in the Huon Peninsula and New Britain, create strong topographical and climatic barriers due to their geographical orientation and altitude (over 1500 m).

The central ranges and the northern coastal ranges are separated by a large tectonic trough, poorly drained (swamps) by the Sepik, Ramu and Markham rivers.

In the South, the larger rivers (Fly, Kikori, Purari) flowing down from the central range, meet the shallow waters of the Gulf in wide estuaries.

Vegetation and evaporation

The extension of grasslands is an expression of human activity, sometimes dating back a very long time, as in the Highlands, but native forest still covers over 60% of the country.

The lowlands of the main island (Sepik depression, gulf coastal plains) are swampy and subject to regular flooding.

Potential evaporation has been measured by direct means (class A US evaporation pan) at ten locations around the country and at different altitudes (between 4 and 2240 m). It has also been evaluated using calculations (Penman formula) based on data from 18 climatological stations, distributed at altitude of between 4 and 2240 m (G. Keig et al., 1979).
After comparison, these results made it possible to establish an empirical formula using altitude, temperature, humidity and sunshine data to estimate potential evaporation at 64 locations (figure 4).

Figure 2 PNG - TOPOGRAPHIC BARRIERS

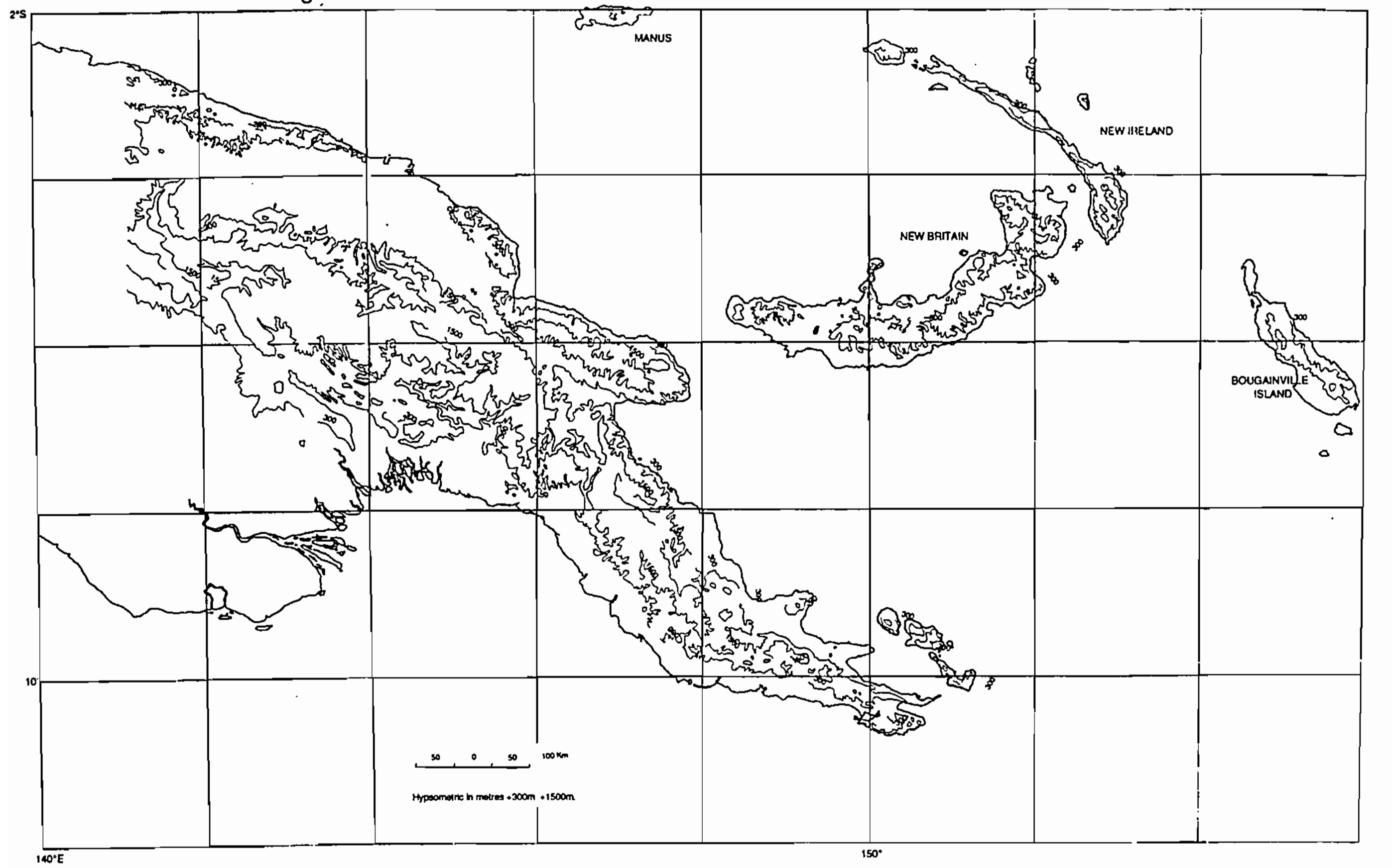


Figure 3 PNG - HYDROGRAPHY

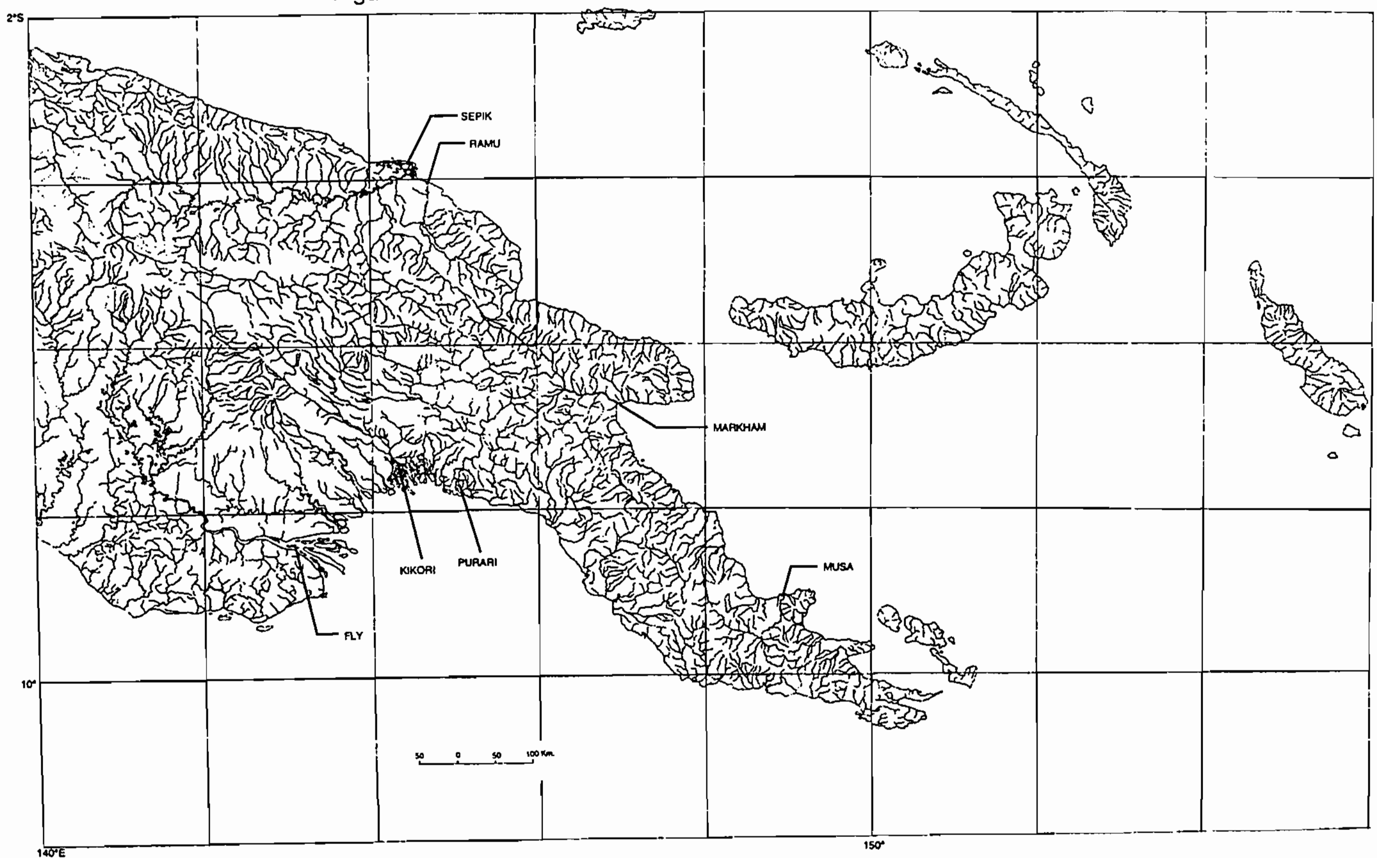


Figure 4 PNG - ESTIMED ANNUAL CLASS A PAN EVAPORATION

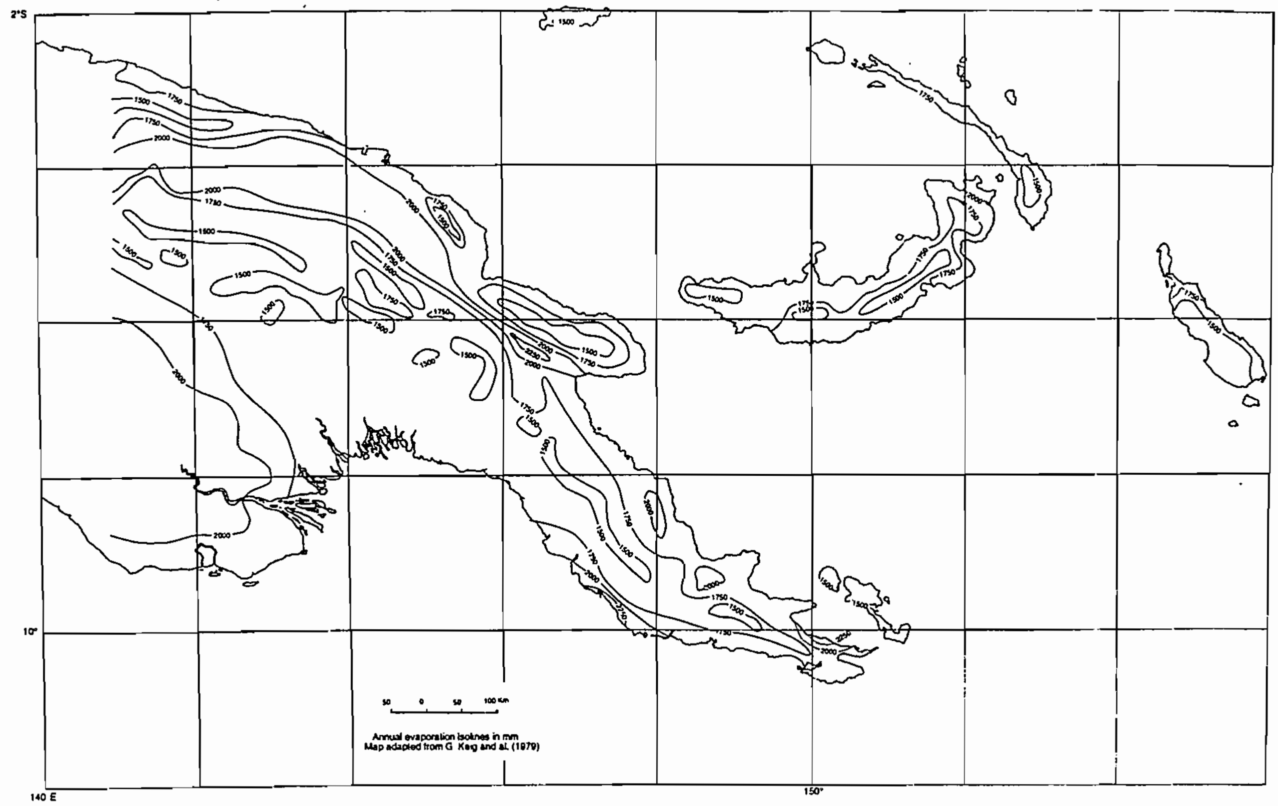
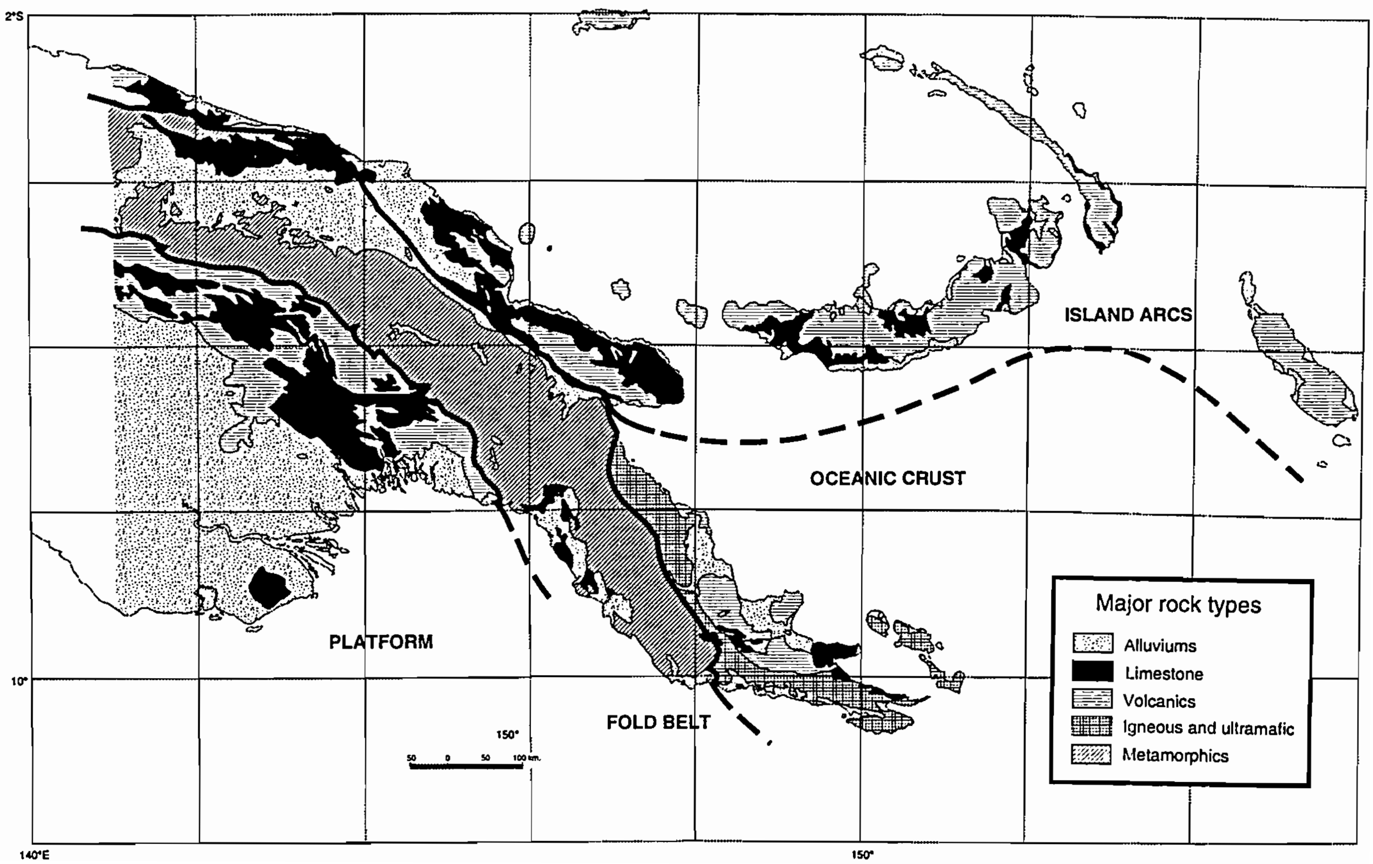


Figure 5 PNG - GEOLOGY



With both the correlation between pan evaporation and potential free water evaporation, and the possible relationship with altitude, interpretations differ between the 1972 results (A.P. Aitken) and the 1979 ones.

Generally speaking, pan evaporation decreases between 0 and 700 m, whether in a relatively dry area (2260 mm in Port Moresby + 35 m - 1450 m at Sirinumu + 460 m) or in a very wet area (1340 mm at Mananau + 35 m - 1110 mm at Panguna + 655 m).
From Lae to the highlands the same trend is observed (2140 mm in Lae + 10 m; 1810 mm at Bulolo + 750 m; 1200 mm at Aiyura +1570 m).

Geology

Four major geological units form the structure of the relief of Papua New Guinea (figure 5):

- The Australian platform, with thick sedimentary deposits (alluviums and limestone on the surface) in the south and volcanic effusions and more detrital sediments (sandstone) in the northern part, more faulted and folded.

- The central fold belt which runs down the middle of the cordillera is mostly formed of metamorphics (greenschist).

- The oceanic crust, characterised by basic and ultramafic igneous rocks (gabbro, peridotite).

- Essentially volcanic island arcs with very active northern and southern boundaries (earthquakes).
  The Ramu and Markham fault zone, which is the north-west extension of the New Britain Trench, stretches over hundreds of kilometres from Lae to the Sepik.

The aquifers

The metamorphic and igneous rocks usually form poor aquifers, except in fractured areas with open joints.
This is often the case with massive volcanic rocks, in the absence of buried alluviums or interbedded pumice tuffs.

Alluviums

Alluvial deposits, well represented on the Sepik and Fly rivers, are generally formed of sand and silt.

Braided gravel beds are mostly found in the high erosion areas of the upper Sepik basin or the Ramu-Markham fault zone.

Karst Limestone

Karst limestone formations cover large areas, whether of recent genesis (raised coral reefs) or older origin (Miocene limestone). These are well represented in the upper Fly basin, the Kikori and the Purari.

In very wet areas, the failures of limestone cliffs can be a source of localised major alluvial deposits (major collapse of the Hindenburg Wall and Ok Kam in January 1977).

Precipitation

In Papua New Guinea, as in most of the very wet countries of the equatorial zone, rainfall is usually very regular. Extensive research (Mc Alpine and coll. 1975, 1983; Aitken and coll. 1972; SMEC 1990) has demonstrated the low variability of annual rainfall figures and the relatively moderate character of daily precipitation averages.

Regarding annual rainfall, for 15 reference stations monitored for over 20 years, the relationship between quartiles is 1.17 to 1.41.

This constancy over time, drawn from a limited range of statistical data, should not mask the very high variations in space, which are connected with seasonal movements of the inter-tropical convergence zone (ITCZ) and orographic barriers.

General circulation

During the north west season (November to April) the ITCZ is stationary over Papua New Guinea or to the south of it. Convergence is at that time at its maximum and the westerly winds (north-west monsoon) partially surrounds Papua New Guinea.

During the south-east season winter (May to October) the ITCZ is located well to the North of Papua New Guinea and the south-east tradewinds bring the rain.

Figure 6 PNG - LOCATION OF RAINFALL STATIONS USED IN THIS REPORT

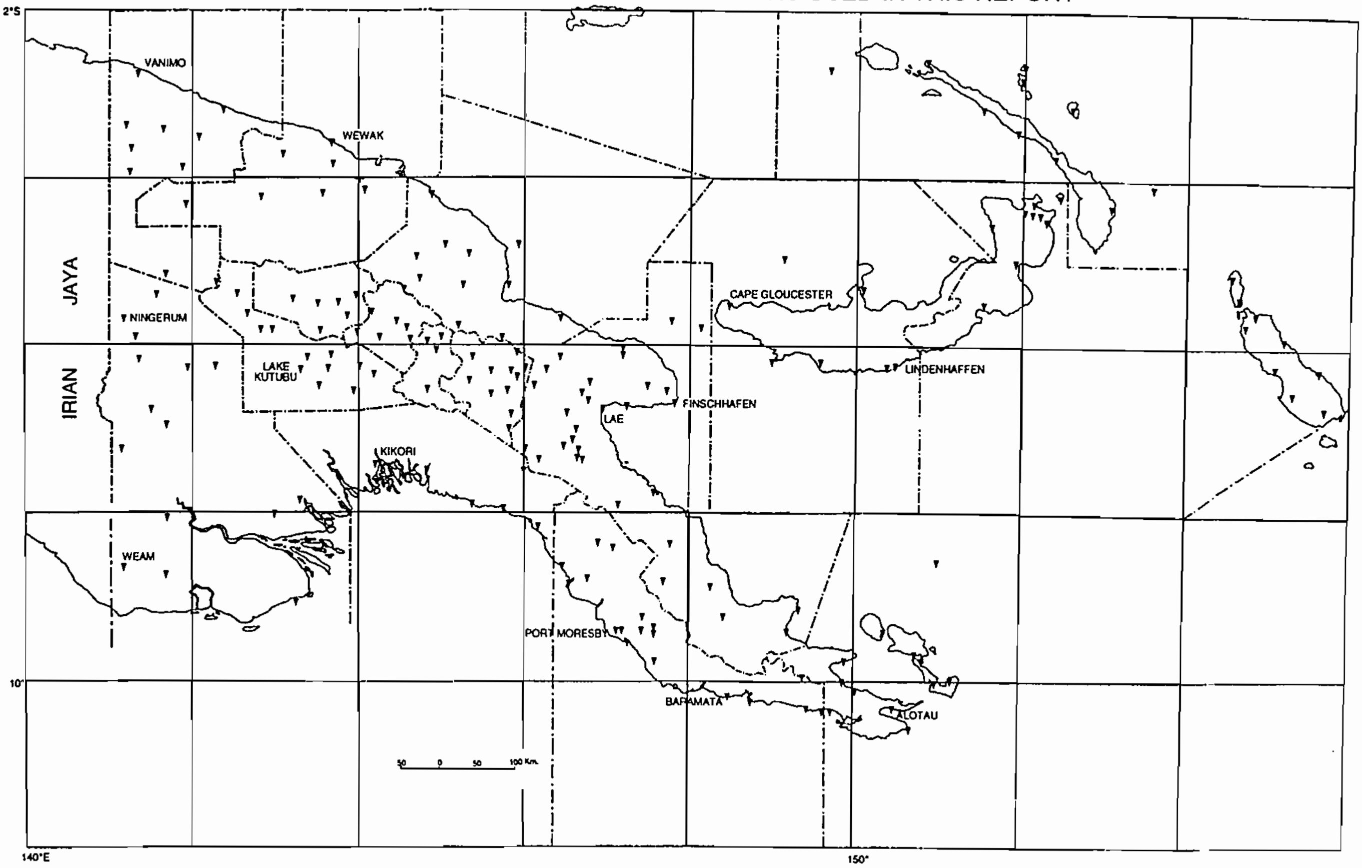


Figure 7 PNG - SEASONAL DISTRIBUTION OF RAINFALL

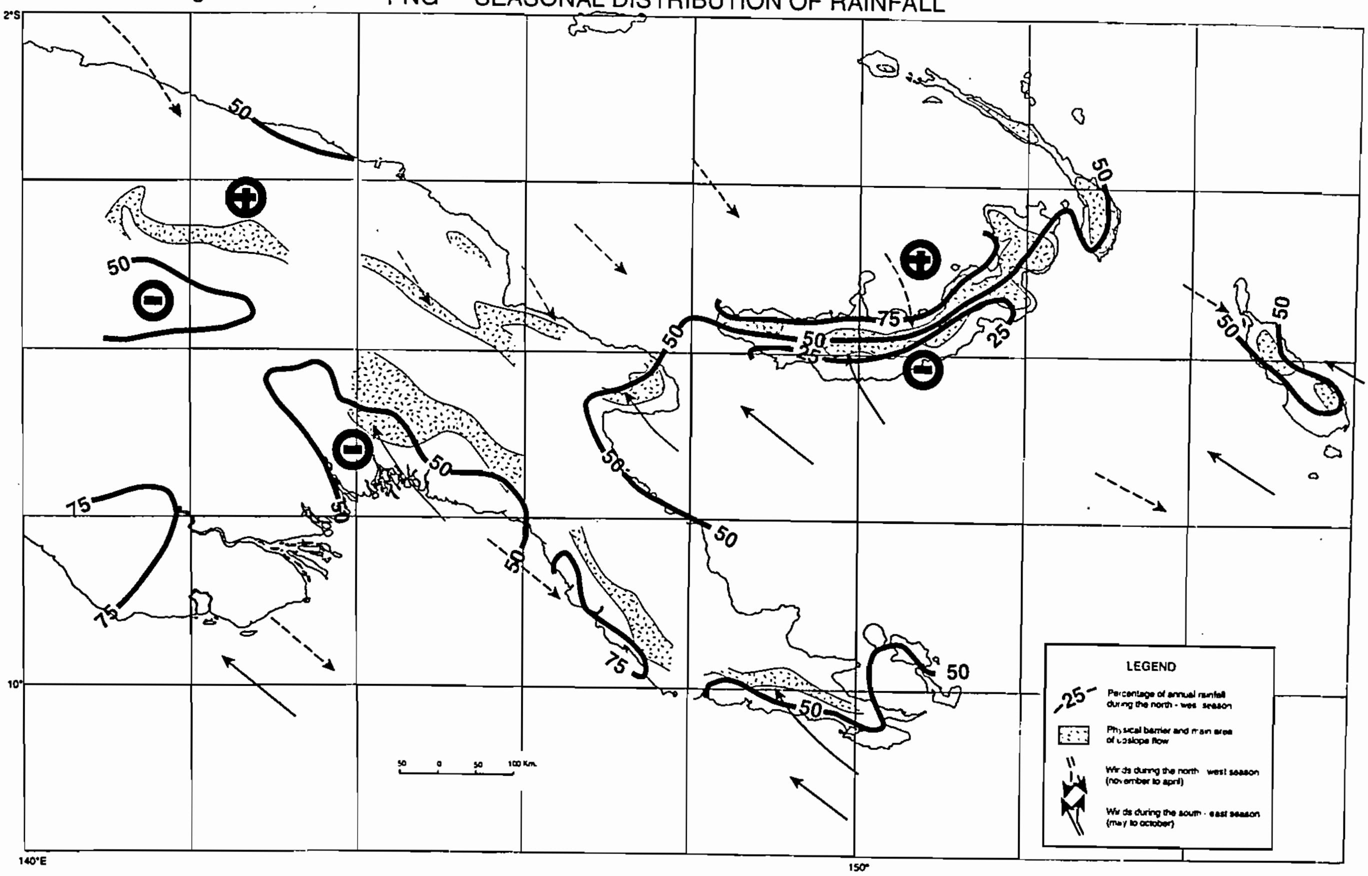


Figure 8 PNG - MEAN ANNUAL RAINFALL

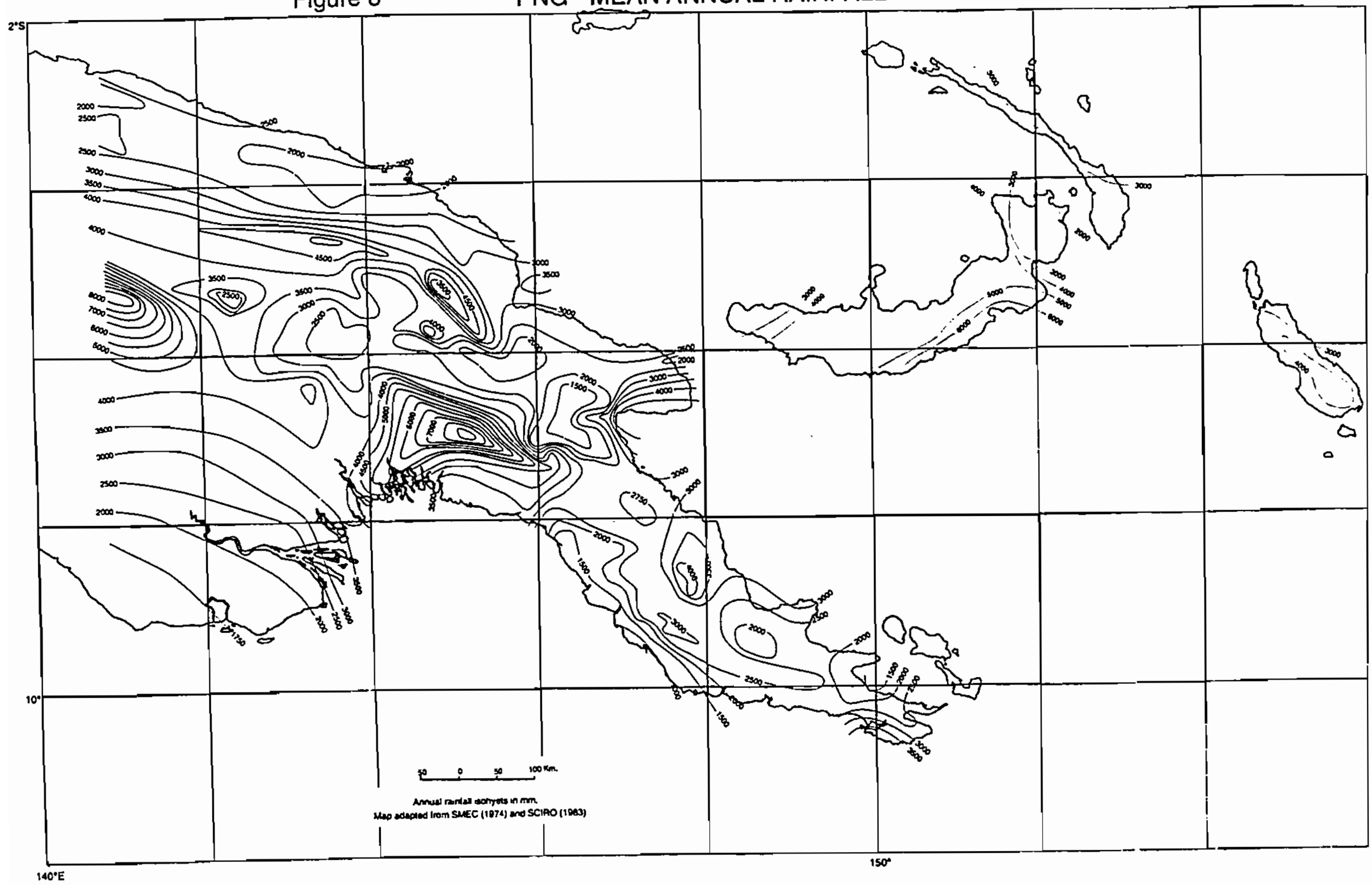
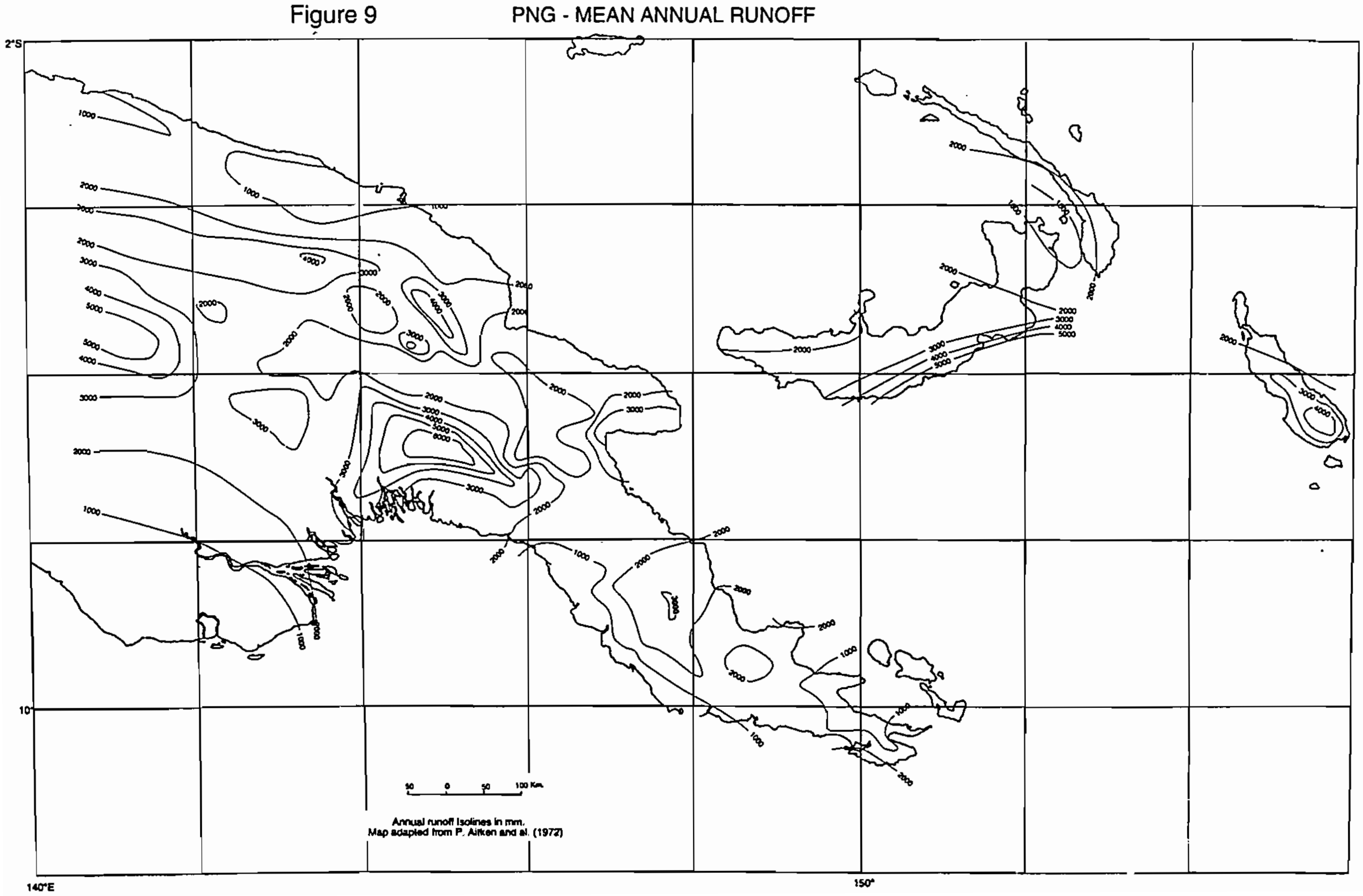


Figure 9 PNG - MEAN ANNUAL RUNOFF



Barrier effects

Mountain ranges acting as screens perpendicular to the prevailing winds form orographic convergences and upslope flows which accentuate rainfall on a localised basis.

The result is a particularly significant seasonal effect on an island such as New Britain, where the northern coast receives 75% of precipitation during the southern summer, whereas over 80% of the rain falls on the southern coast between May and October (figure 7).

The wettest areas (figure 8) are to be found in parts which receive both convection rainfall during the southern summer and orographic rain during the southern winter.
Conversely, the Port Moresby area, which is protected from the south-easterlies and not very much affected by the north-westerly monsoon, is one of the country's driest areas.

The 8000 mm isohyet was plotted from some foothill station records (Tabubil + 940 m) or plain locations (Wabo + 60 m) and precipitation has therefore in all likelihood been quite significantly underestimated for the southern slopes of the Star Mountains (Fly river basin) of the Murray Range and of Mont Bosavi (Purari and Kikori basins), as it has for the summits of the Whiteman Range in New Britain.

Evaluation of runoff depths

The low variability in precipitation, evaporation and discharges having been established, it was tempting, using various series of more or less reconstituted data, to appraise the runoff deficit and deduct the total runoff depths (figure 9).
These results in fact only give us an approximation for the total runoff depth from some large basins.

The very inaccurate plotting of isohyets for some areas, in the same way as the sometimes incomplete evaporation evaluations, should cause us to proceed with caution.
Using Penman's monthly rainfall and evaporation data Goroka, J.P Brunel (1994) determined a runoff coefficient of 0.29 for this area, whereas on the particularly well-researched neighbouring Ramu river basin at the dam (Yonki project; SMEC 1985), this coefficient rises to 0.55.

Goroka	**Ramu river basin** (A = 851 km^2)
P = 1932 mm	P = 2100 mm
Et Penman = 1414 mm	E (Aiyura tank) = 1200 mm
R = 555 mm	R = 1154 mm

ESTABLISHING A MINIMUM BASIC NETWORK

The conditions

"The basic network stations should be abble to operate continuously and indefinitely and to provide data for the appraisal of temporary trends".

In order to achieve these objectives, while keeping operating costs down, it is necessary for these stations, which need to be representative of the region concerned:

- if possible to have already been monitored for many years,
- not to raise insurmountable calibration difficulties,
- to be suitable for refitting for remote monitoring.

The representativeness of the stations

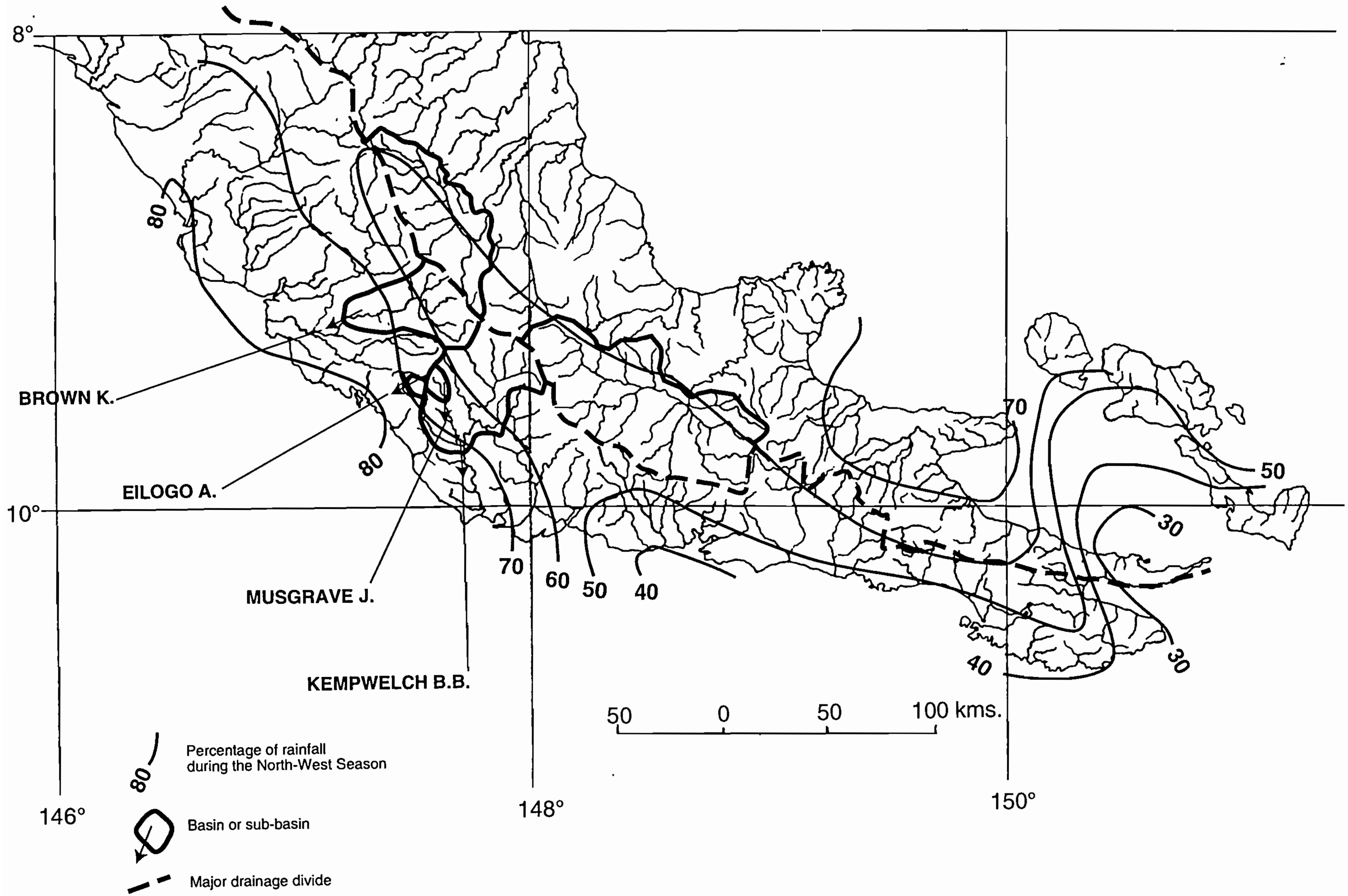
The seasonal distribution of rainfall, to which can be attributed the "high degree of variability from point to point" reported by many authors, can be used, as can the main topographical units, as one of the principal selection criteria.

The Port Moresby area, which has been quite extensively studied (many water engineering projects), is a model area for understanding this seasonality (figure 10).
In under 150 km along the coast (to either side of Hood Point), and within a hundred km inland, the rainfall patterns show quite distinct differences.
81 % of the rainfall in Port Moresby is registered during the southern summer, whereas the Abau post, exposed to the south-east, only receives 45 %.

These differences can be found in the sub-basins and basins, which one affected to varying degrees by these seasonal trends.
Simple linear regressions between mean monthly discharges yield reasonably good correlations for the main basins on the same slopes (Kempwelch - Brown r = 0.78) or small neighbouring sub basins (Musgrave - Eilogo r = 0.74), whereas correlations are much less marked beween sub-basins and basins (Musgrave - Kempwelch r = 0,63). The correlation coefficient only improves (r = 0.75) after eliminating the months of May to October (southern winter).

Among the other factors affecting the regimes, further criteria such as annual precipitation (rainfall above 4000 mm), geology (volcanic terrain, limestone) and vegetation (permanent wetlands, deforested highlands) may also be borne in mind.

Figure 10 South PAPUA - Seasonal distribution of rainfall



Calibration difficulties

Of the 24 stations which it is proposed to **gradually** re-fit to form the primary network, 14 are relatively well known because of the records available in the data bank (levels, gauging, calibrations).
Some data would however require reviewing (by calibration) or supplementing (level and gauging records) with the assistance of other parties (SMEC, OTML) and a certain amount of ground verification would also be needed (current accessibility, state of the control) before any decision could be taken.

Concerning the other stations:

- where stability is known and the resumption of data acquisition, as well as provision of fresh equipment, can be carried out with the assistance of an external agent, which previously operated it,
- or the choice (to find stable control) needs to be made at the installation date (new station),
- or a high degree of instability is known and requires more attention (more frequent gauging, more frequent checking).

Of the three stations reported as being highly unstable, two are accessible by road for part of the year and could be fitted with quite light equipment if the road access is reliable and permits regular gaugings.
For the third, upstream, from a confluence, much more equipment would be essential, both to carry out gaugings and monitor levels.

The options (figure 13)

North-facing slopes on the main island

The nine stations proposed correspond to 5 specific sub-units:
- Mountain basins showing little seasonality and partly formed of karst.
Typical station: Sepik at Telefomin (104500).

- Basins in the areas subject to north-westerlies, fed by the central cordillera and which have difficulty in draining the highly sedimented field valleys.
Typical stations: Sepik at Green River (104850).
Sepik at Ambunti (105950).
Ramu at Aiome (203800).

Figure 11 PNG - DEGREE OF CORRELATION BETWEEN STATIONS (r ≥ 0.70)

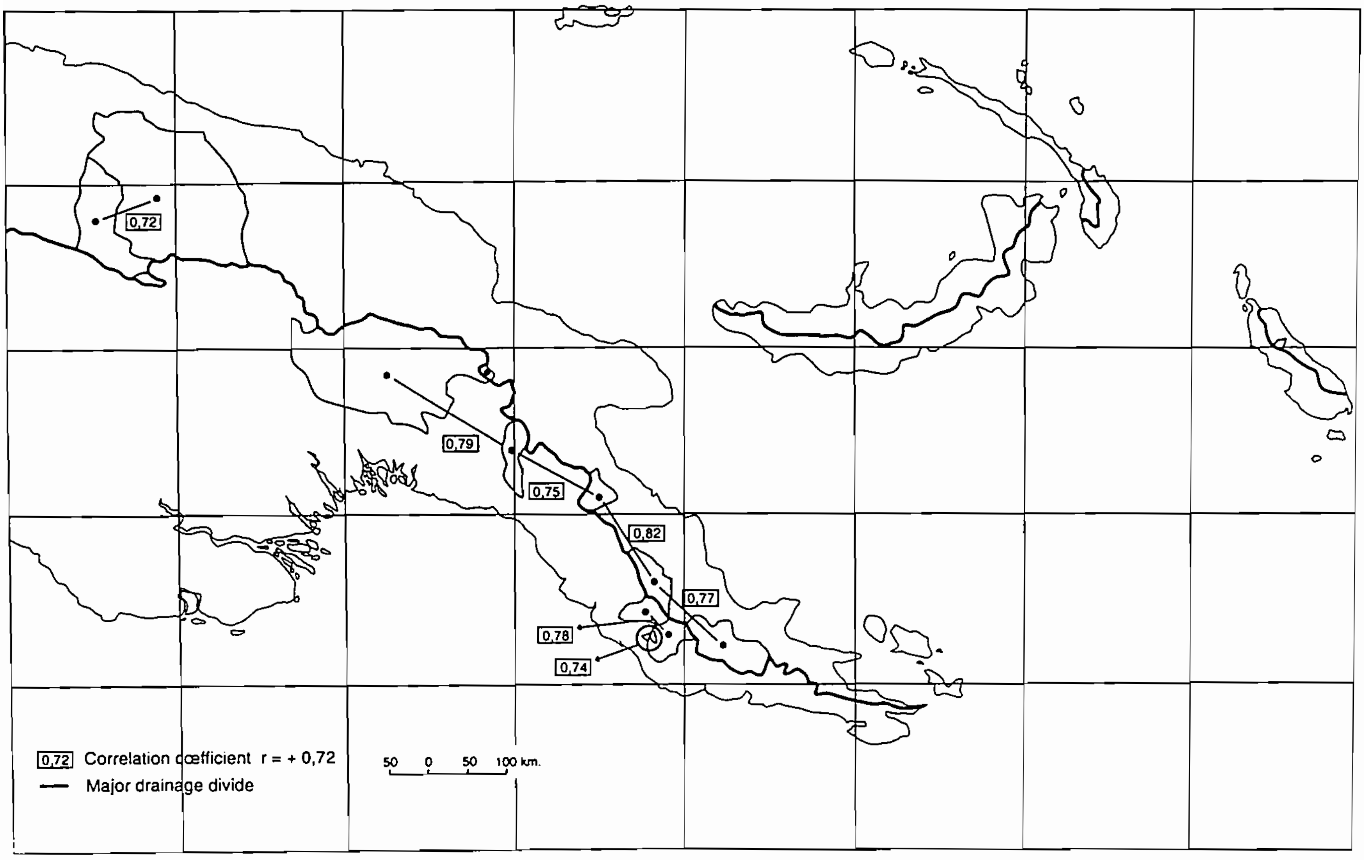
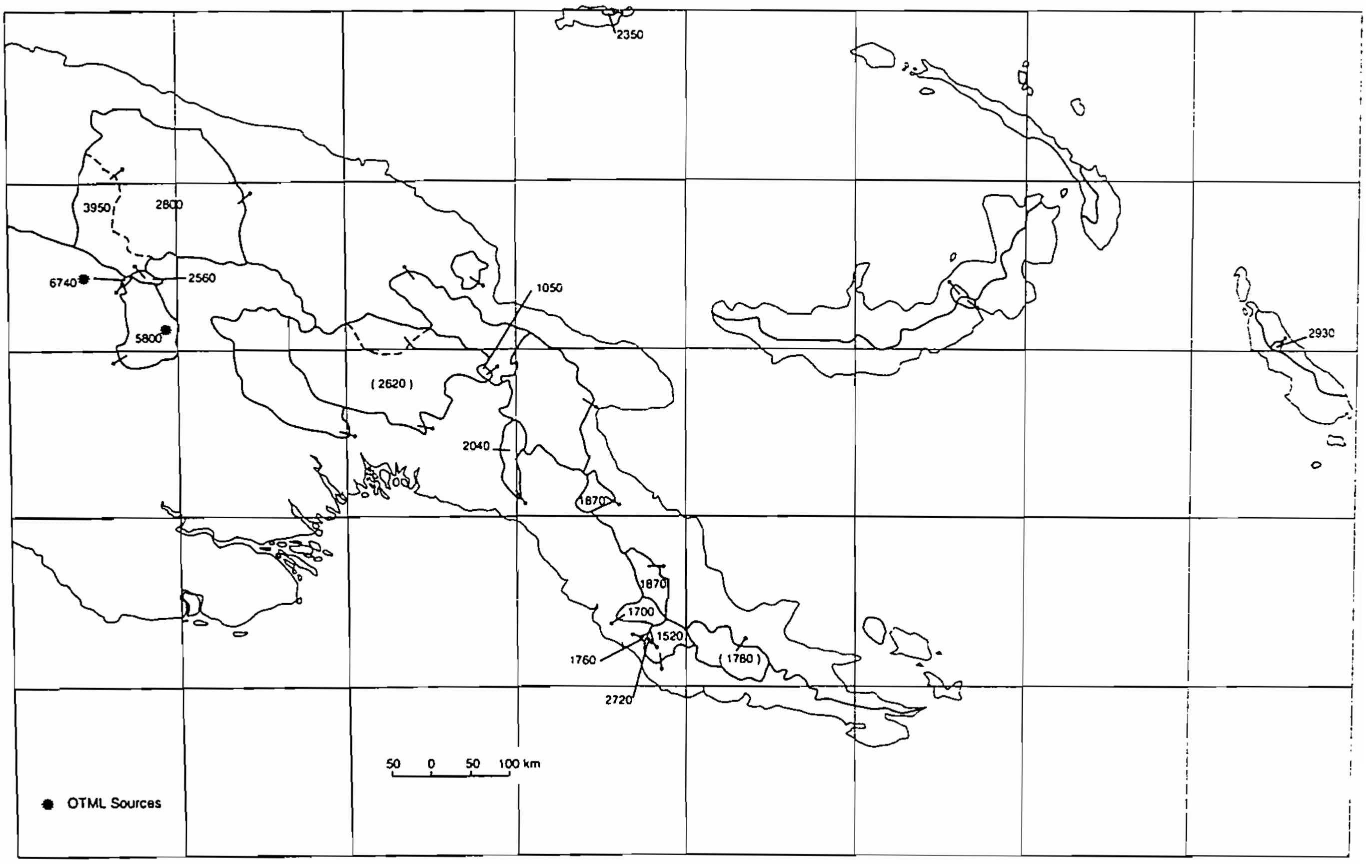


Figure 12 PNG - Runoff depths



- Basins subjects to regular north-westerlies which drain basic and ultra-basic soils in the eastern region.
Typical stations: Waria at Garaina (402490)
Mambare down stream from Chiribare (404820)
Musua 6 km down stream from Nadigabuna (409080)

- Basins fed by the coastal ranges and the cordillera receiving north-westerlies.
Typical station: Markham at the road bridge (309950)

- Basins in coastal ranges showing very little seasonal variation, draining volcano - sedimentary terrain.
Typical station: Gogol at Madang (206650)

The valleys of the Markham and Gogol rivers follow the route of active faults and are virtually impossible to monitor (major alluvial deposits, highly unstable river beds), except where there are road crossings.

The Highlands

Whether they flow to the north or towards the south, the Highlands rivers drain sparsely forested areas. Seasonal variation (north-west) is variable.
Typical stations: Ramu at Kainantu (201300)
Whagi at Kondiu bridge (703880).

Southern slopes of the main island

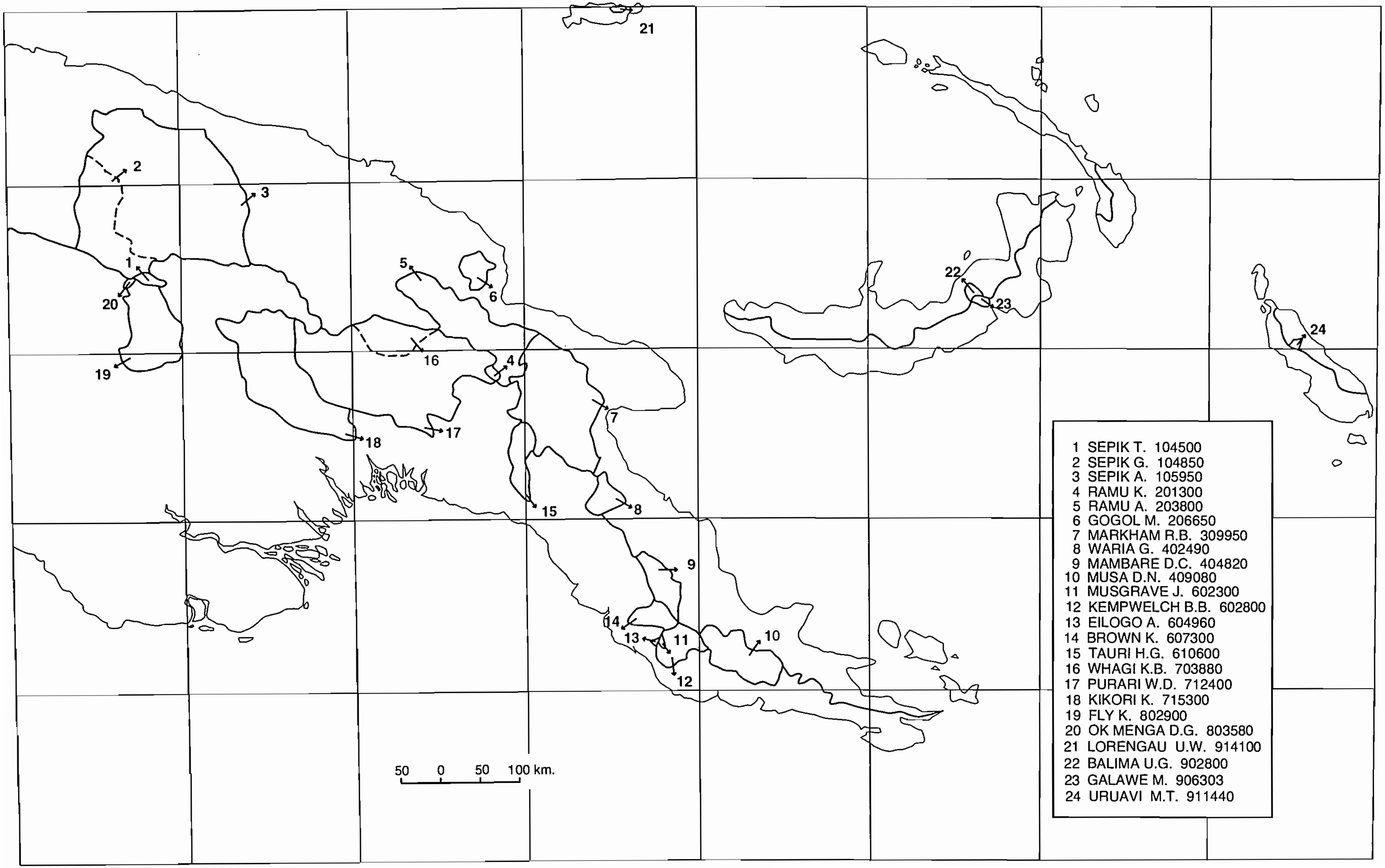
The 9 stations also proposed for the south-facing slopes can be divided into 5 sub-units.

- Small high-altitude basins subject to the north westerlies.
Typical stations: Eilogo at Arubaada (604960).
Musgrave at Jawarere (602300).

- Small high-altitude basins, receiving high rainfall and steeply sloping.
Typical stations: Ok Menga downstream from the gorges (803580).

- Large basins fed by the central range, with a more or less marked north-westerly wind pattern.
Typical stations: Kempwelch at Bannon bridge (602800).
Brown at Karema (607300).

Figure 13 PNG - MINIMAL BASIC NETWORK



- Large basins showing little seasonal variation, fed by the central range and the volcano-sedimentary terrain of the foot-hills.

Typical stations: Tauri at Hell's gate (610600).
Purari downstream from Wabo (712400).

- Large basins receiving south-easterlies.

Typical stations: Kikori at Kaiam (715300).
Fly at Kiunga (802900).

In order to properly monitor the last station referred to, which is located upstream from the confluence with the Alice River, the installation of a second station further downstream and a large number of gaugings would probably be necessary.

The volcanic islands

For islands with very low seasonal variations (Manus, Bougainville) one base station per island should be adequate, on a known site, whereas for New Britain, two new stations are needed (south facing and north facing slopes).

Typical stations: Lorengau above the waterfall (914100).
Uruavi on Mount Takapopor (911440).
Balima downstream from Gigipuna (902800).
Galowe at Maleu (906303).

The direct benefits of these stations for the development

Of the 24 proposed representatives stations, only 10 can be classified for general hydrology uses only:

- 10 are located on rivers and sites selected for hydroelectric-engineering schemes,
- 2 are beneficial for hydroelectricity and improvements in water supply systems,
- 2 are basis for a flood-warning system.

The importance of long time series

With reference to the national situation the value of a reference network formed of the synoptic posts of the NWS and the stations of a basic hydrological network operated by the BWR, should no longer need demonstrating, because the data they produce are essential for:

- studying floods and the feasibility of very large-scale engineering projects (Purari),
- validating short-term observations (from 1 to 3 years), made for other development projects.

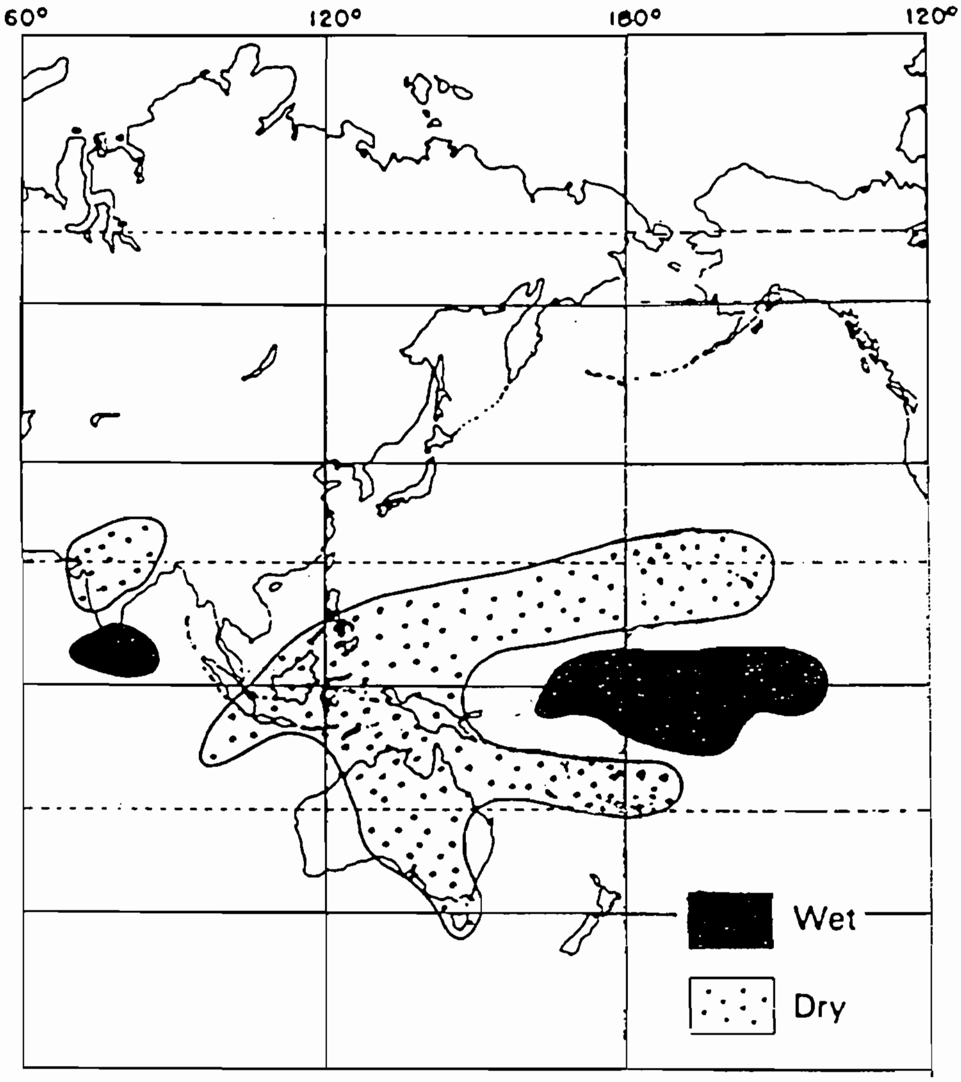
Internationally speaking, Papua New Guinea should become a fairly outstanding hydroclimatological observatory, both for the evaluation of certain climate trends and also for a better understanding of the correlation between the "Southern Oscillation" and certain strong seasonal trends.
Study of the rainfall systems of the same seasonality usually results in Papua New Guinea being classified in a single Enso (El Nino - Southern Oscillation) area of influence, whereas a rapid analysis of the series from two basins on the south and north facing slopes of the main island shows opposing variations to either side of the central range (figures 14 and 15).

Interannual and seasonnal runoff variabilities (standardised values)

Hydrological year	KEMPWELCH Bannon Bridge			SEPIK Green River			Mean Southern Oscillation Indice
	Annual (11-10)	N-W Season (11-04)	S-E Season (05-10)	Annual (11-10)	N-W Season (11-04)	S-E Season (05-10)	S-E Season (05-10)
1966-67	-	-	-	-	-	-	0,15
1967-68	-0,50	-0,52	-0,30	-	-	-	0,32
1968-69	0,21	0,68	-0,47	-	-	-	-0,77
1969-70	0,57	-0,37	1,63	0,28	0,34	0,04	0,43
1970-71	1,83	1,69	1,40	-0,34	-0,21	-0,24	0,92
1971-72	0,05	0,43	-0,48	-0,91	0,17	-1,35	-1,48
1972-73	-1,08	-1,08	-0,71	1,10	1,56	-0,04	0,77
1973-74	0,57	1,34	-0,64	-1,54	-0,53	-1,52	0,80
1974-75	0,45	-0,06	0,96	-1,50	-1,43	-0,62	1,62
1975-76	0,52	0,47	0,41	0,92	1,82	-0,51	-0,60
1976-77	0,18	0,04	0,30	2,06	-0,25	2,95	-1,27
1977-78	-1,20	-1,04	-1,01	0,94	0,92	0,37	0,22
1978-79	2,13	2,31	1,16	0,06	0,44	-0,34	0,18
1979-80	-1,32	-0,65	-1,76	0,65	-0,17	1,02	-0,30
1980-81	-0,70	-0,49	-0,75	0,68	0,73	0,20	0,43
1981-82	-0,04	0,28	-0,45	0,27	1,62	-1,18	-1,82
1982-83	-0,95	-1,15	-0,36	1,08	0,74	0,72	0,08
1983-84	1,47	1,89	0,41	0,26	-0,95	1,24	-0,22
1984-85	0,80	0,11	1,43	-0,65	-0,86	-0,04	-0,17
1985-86	0,36	0,86	-0,41	-0,90	0,14	-1,31	-0,13
1986-87	-1,46	-1,09	-1,47	-1,16	-1,16	-0,42	-1,42
1987-88	0,01	-0,60	0,82	0,75	0,38	0,62	1,10
1988-89	0,87	0,09	1,59	-0,37	-0,89	0,36	0,48
1989-90	0,41	0,10	0,68	-1,63	-1,91	-0,32	0,05
1990-91	-0,87	-0,94	-0,49	-0,04	-0,49	0,41	-1,07
1991-92	-0,57	-1,00	0,19	-	-	-	-0,65
1992-93	-1,69	-1,26	-1,68	-	-	-	-1,15
1993-94	-	-	-	1,41	-0,14	1,98	-1,48
1994-95	-	-	-	1,64	1,45	0,76	-0,12
1995-96	-	-	-	-	0,49	-	0,52

Intense El Nino	Dry year	Wet year	SO event

Figure 14 TELECONNECTIONS



Sources : Ropelewski and Halpert (1987)
U.S. Geological Survey (1988)

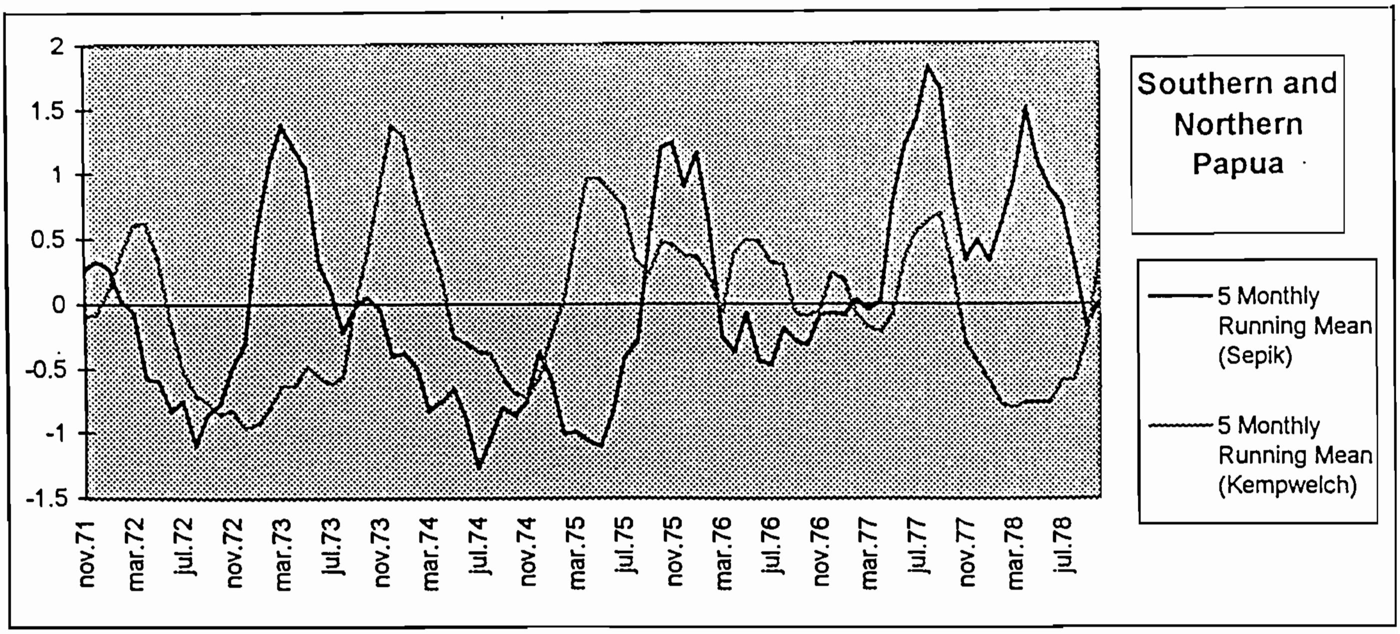


Figure 15 Sepik and Kempwelch discharges

FIXED STATION EQUIPMENT

Attempts to modernise and extend networks conducted in Papua New Guinea over the past ten years or more have shown how it difficult it was, even when considerable amounts of equipment and operational funding was available, to achieve certain objectives:

- without taking into account access and measurement difficulties,
- and without perfect understanding of new data acquisition and remote transmission techniques.

With its now limited operating budget, the BWR cannot commit itself to a restructuring phase for its network unless it first makes equipment-related choices and provides training for its staff.

Although certain methods and techniques for direct measurement of streamflow are now operational in rivers, the currently available equipment (Acoustic Doppler Current Probe) are specifically intended for boat-based gauging projects on the major rivers (such as the Fly or the Sepik).

At the present time in order to equip a minimum basic network, it is still as essential to seek reliable station sites (stable control), in order to restrict endeavours to ongoing monitoring of levels and reduce gaugings to a minimum.

Information storage

Whatever the types of equipment and the remote data transmission methods used, it is necessary for information about the site to be automatically and regularly recorded and then stored.

It is not desirable to be obliged to increase scrutiny time in order to give equipment several months independent operation.
Many manufacturers have in recent years put on the market acquisition units making possible one to five minutes scrutiny, with on-site saving of basic level information for more than six months.

Some recent multi-sensor platforms have a scrutation period programmable from 1 to 60 minutes for each sensor and the capacity of the removable memory card can be as high as 1 MByte.

The probes

When the stations are isolated and only infrequently visited, most problems whether concerning rainfall data or river level information, are due to the power supply to the data acquisition units or to the probes.

Unless the equipment includes float-actuated recording gauges and stilling wells in very good condition which could be modernised at little expense (encoder and data logger), it is often desirable, if the network is to include remote monitoring, to re-equip stations with a pressure probe and a unit permitting data storage and transmission.

Where pressure probes are concerned, a range of models of varying reliability (stability problems) are available on the market.
Theirs costs are relatively high when the piezo-resistive sensor is associated with an electronic card which formats the sensors' signals (limnimetric probe). This set-up makes it possible to transmit signals over a very long distance (several km) without damage to the accuracy or sensitivity.

Whenever it is necessary, to move the acquisition units several meters away from the in-river measurement point, in order to be sure that satellite remote transmission will be carried out properly this type of limnimetric probe should be recommended.

Real-time data collection

Where a direct data reception unit is available, the Argos system remains affordable for surveillance of a small number of stations for a period of several months, for specific studies of restricted scope.

In order to monitor and manage more than 20 stations in a basic network, it is definitely preferable to use the possibilities of remote dialogue offered by the standard C Inmarsart system (two directional connection), already in extensive use in Australia.

Some hydrometeorological data collection platforms, specially designed for the establishment of regional hydrological cycle observing systems (HYCOS), can be fitted with these limnimetric probes and transmitters for Inmarsat-C.

APPENDIX 1

Monthly and annual discharges

Station : 5801004500 TELEFOMIN (104500)
River : SEPIK
Country : PAPUA-NEW GUINEA
Basin : UPR SEPIK (104) Area 670 km2
DISCHARGE in M^3/S

year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1975/76	-	-	-	-	-	-	-	-	-	-	-	-	-
1976/77	-	-	65.3	-	-	44.1	63.2	66.3	82.5	-	-	-	-
1977/78	42.5	50.9	64.6	79.0	80.2	70.4	60.9	60.1	-	63.9	137.	74.9	-
1978/79	-	-	-	55.0	109.	42.2	94.3	83.4	58.5	45.5	68.5	28.5	-
1979/80	39.4	65.3	-	43.7	78.0	58.4	61.6	58.6	-	100.	50.7	44.6	-
1980/81	24.3	42.8	45.8	60.1	68.4	84.4	50.8	78.8	72.8	-	-	90.7	-
1981/82	92.9	60.9	59.0	48.5	57.7	47.8	50.8	37.6	11.6	22.3	11.3	12.9	42.8
1982/83	14.0	15.1	31.2	59.1	54.2	54.7	60.2	63.7	62.1	113.	-	-	-
1983/84	-	-	-	74.4	65.8	66.2	-	-	-	-	-	-	-
1984/85	39.5	65.7	51.9	60.7	54.2	45.4	44.8	49.1	48.3	90.3	81.3	63.6	57.9
1985/86	47.4	60.2	85.3	72.0	97.7	60.0	31.1	59.4	39.1	21.7	28.9	34.4	53.1
1986/87	37.3	16.9	49.2	45.2	55.4	52.8	37.1	46.3	28.8	38.0	43.2	46.7	41.4
1987/88	37.1	44.5	57.7	72.3	55.5	37.0	60.0	51.1	59.9	-	-	69.4	-
1988/89	38.6	42.2	21.8	24.9	25.4	-	-	23.5	37.5	-	-	-	-
1989/90	-	-	-	-	-	-	-	-	25.8	-	-	-	-
1990/91	41.7	44.0	50.8	90.6	76.5	80.3	33.1	20.7	77.4	128.	49.8	52.1	62.1
1991/92	48.7	44.4	32.8	64.7	88.7	73.2	-	43.5	-	-	-	44.7	-
1992/93	15.9	19.4	36.9	38.5	35.2	44.8	26.4	125.	82.7	25.8	40.3	43.8	44.6
1993/94	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	40.0	44.0	50.2	59.3	66.8	57.5	51.9	57.8	52.9	64.9	56.8	50.5	54.4

Station : 5801004850 GREEN RIVER (104850)
River : SEPIK
Country : PAPUA-NEW GUINEA
Basin : UPR SEPIK (104) Area 9500 km2
DISCHARGE in M^3/S

year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1969/70	-	-	-	1160.	1650.	1640.	1260.	-	-	-	-	-	-
1970/71	1460.	1310.	1660.	1140.	1190.	1080.	1030.	982.	-	-	-	-	-
1971/72	-	-	-	-	1390.	1110.	1090.	466.	733.	487.	941.	598.	-
1972/73	967.	1250.	1450.	1720.	2580.	1980.	1460.	731.	-	-	-	1060.	-
1973/74	1240.	1320.	1060.	1190.	1490.	1170.	740.	-	704.	575.	-	-	-
1974/75	-	-	-	1340.	945.	626.	918.	687.	569.	940.	1040.	-	-
1975/76	2160.	-	-	-	1990.	1370.	740.	833.	949.	743.	982.	1100.	-
1976/77	862.	1210.	1560.	1510.	1470.	1200.	972.	1130.	1310.	1690.	1150.	1510.	1300.
1977/78	1150.	1180.	1350.	1980.	1770.	1800.	-	-	571.	836.	1160.	864.	-
1978/79	-	-	-	-	-	1270.	-	-	1100.	-	745.	828.	-
1979/80	-	945.	-	1410.	1400.	1500.	1430.	1070.	952.	1320.	1390.	1060.	-
1980/81	797.	1270.	-	1600.	1710.	1890.	-	-	-	-	-	1500.	-
1981/82	1590.	1450.	1900.	1700.	1810.	1570.	1190.	839.	512.	662.	758.	562.	1210.
1982/83	674.	1270.	1620.	2050.	1870.	1530.	1130.	913.	852.	1580.	982.	1380.	1320.
1983/84	1300.	1160.	990.	1230.	1390.	-	-	1460.	-	-	-	-	-
1984/85	-	1490.	1350.	1360.	1160.	832.	756.	740.	745.	1100.	1110.	1470.	-
1985/86	1090.	-	-	-	1390.	1550.	689.	820.	812.	-	-	884.	-
1986/87	857.	580.	1720.	1960.	823.	850.	-	1090.	-	-	934.	1160.	-
1987/88	1030.	980.	1640.	1800.	1820.	1310.	1010.	-	-	-	-	-	-
1988/89	-	-	-	-	-	-	-	984.	-	-	-	-	-
1989/90	-	-	-	-	-	-	-	-	884.	1110.	1060.	1290.	-
1990/91	1060.	818.	1250.	1890.	1300.	1270.	863.	845.	-	-	-	-	-
1991/92	-	-	-	-	-	-	-	-	-	-	-	-	-
1992/93	-	-	-	-	-	-	-	1260.	1010.	715.	929.	863.	-
1993/94	-	1610.	1510.	1460.	1150.	1410.	-	-	-	-	1330.	970.	-
1994/95	1090.	1120.	1800.	1600.	2040.	2170.	-	1170.	907.	-	1190.	1460.	-
1995/96	1510.	1560.	1220.	1380.	1130.	1890.	-	1110.	-	-	-	1480.	-
Mean	1180.	1210.	1470.	1550.	1520.	1410.	1020.	952.	841.	980.	1050.	1110.	1191.

Station : 5801005950 AMBUNTI (105950)
River : SEPIK
Country : PAPUA-NEW GUINEA
Basin : MID SEPIK (105) Area 40922 km2
DISCHARGE in M^3/S

year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1966/67	-	-	-	-	-	-	-	-	-	-	-	-	-
1967/68	-	-	-	-	3710.	3700.	3450.	2070.	-	-	2720.	2770.	-
1968/69	2780.	3650.	4190.	4730.	5110.	-	-	-	2640.	2340.	3820.	4360.	-
1969/70	4250.	3770.	3850.	3360.	-	-	-	6870.	7520.	-	-	-	-
1970/71	-	-	-	-	-	-	-	-	-	-	-	3080.	-
1971/72	-	-	4080.	4100.	4540.	4390.	4190.	1730.	-	1720.	2930.	2170.	-
1972/73	3000.	3820.	4970.	5640.	6390.	6790.	6100.	3480.	-	2730.	3660.	3290.	-
1973/74	4170.	3910.	3370.	3100.	4670.	4030.	2710.	1960.	2070.	2060.	1420.	2670.	3010.
1974/75	2920.	2690.	3650.	4620.	5320.	-	-	3310.	1970.	2560.	2470.	3510.	-
1975/76	3250.	3690.	3800.	3390.	3980.	4740.	2890.	2630.	2400.	2090.	2620.	3120.	3220.
1976/77	3010.	-	4620.	5470.	5290.	4570.	3100.	3400.	3590.	4100.	3350.	3690.	-
1977/78	4430.	3730.	3690.	4420.	5170.	5440.	4640.	3680.	2420.	2220.	3190.	2930.	3830.
1978/79	3760.	4250.	4290.	-	-	5330.	4490.	2460.	3320.	2210.	1970.	2350.	-
1979/80	3630.	3340.	4330.	4290.	4430.	4510.	5350.	4010.	-	3120.	4080.	3640.	-
1980/81	2740.	3680.	4370.	4780.	4870.	4960.	4210.	3180.	2830.	2830.	2790.	3960.	3770.
1981/82	4690.	-	-	-	-	5040.	4240.	-	-	-	-	-	-
1982/83	1880.	3090.	4850.	5410.	5860.	5490.	4110.	3730.	3040.	3260.	2220.	4020.	3910.
1983/84	4570.	4270.	2620.	2500.	3400.	3000.	3620.	4110.	2980.	3410.	2350.	-	-
1984/85	-	-	4930.	4120.	4440.	4480.	-	-	-	-	2990.	3910.	-
1985/86	3290.	3650.	3730.	4310.	4010.	4460.	3480.	2380.	2440.	1800.	1970.	2780.	3190.
1986/87	3470.	1910.	3420.	5400.	-	-	-	2630.	2400.	-	2250.	3140.	-
1987/88	3190.	-	-	-	-	-	-	-	-	-	-	-	-
1988/89	-	-	-	-	-	-	-	4610.	-	-	2950.	-	-
1989/90	-	1990.	-	-	-	-	-	-	-	-	-	4460.	-
1990/91	4510.	4720.	4390.	3180.	-	-	-	-	-	-	3080.	-	-
1991/92	-	-	-	-	-	-	-	3420.	2360.	2810.	-	-	-
1992/93	-	-	-	-	-	-	-	-	3430.	2380.	2290.	2510.	-
1993/94	2130.	4170.	4770.	4670.	4470.	3970.	4580.	3590.	3740.	-	-	-	-
1994/95	-	-	-	-	-	-	-	-	-	-	-	-	-
1995/96	-	-	-	-	-	-	-	-	-	-	3620.	3670.	-
1996/97	3320.	3060.	-	-	-	-	-	-	-	-	-	-	-
Mean	3450.	3520.	4100.	4310.	4730.	4680.	4080.	3330.	3070.	2600.	2800.	3300.	3664.

Station : 5802001300 KAINANTU (201300)
River : RAMU
Country : PAPUA-NEW GUINEA
Basin : KAINANTU (201) Area 212 km2
DISCHARGE in M^3/S

year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1978/79	-	-	7.24	11.6	18.1	10.0	7.24	4.03	3.26	2.48	1.99	4.76	-
1979/80	9.59	7.46	13.1	6.04	9.39	7.65	5.73	3.09	3.88	2.59	5.86	2.98	6.45
1980/81	7.13	14.6	16.3	15.7	9.07	13.7	3.84	4.57	4.25	4.16	2.77	4.87	8.41
1981/82	6.43	17.7	18.7	19.5	17.0	9.89	-	-	-	-	-	3.17	-
1982/83	2.69	8.97	8.10	15.2	16.1	6.39	4.92	5.69	4.26	2.54	2.03	4.92	6.82
1983/84	9.62	13.1	4.04	2.86	-	7.71	9.11	4.32	3.21	2.78	2.29	-	-
1984/85	-	-	-	10.9	10.6	7.91	6.68	4.46	4.06	3.30	5.42	7.82	-
1985/86	9.46	10.0	12.4	12.8	8.58	14.1	6.29	4.21	3.31	3.24	4.06	2.43	7.57
1986/87	5.12	5.08	-	-	-	-	-	-	-	-	-	-	-
1987/88	-	-	2.77	13.2	7.63	-	3.27	4.10	-	-	1.11	6.09	-
1988/89	4.87	8.22	8.13	11.4	13.3	10.7	9.64	2.55	2.31	2.74	1.35	-	-
1989/90	-	8.53	12.9	5.88	7.42	5.58	4.92	5.37	3.37	3.90	-	-	-
1990/91	6.61	11.9	11.3	21.8	7.27	6.29	5.29	2.64	2.90	4.90	2.97	-	-
1991/92	11.4	10.2	10.4	22.9	15.4	16.4	6.73	5.28	+	2.38	1.96	3.62	-
1992/93	2.32	7.82	8.05	-	-	-	-	-	-	-	-	1.92	-
1993/94	4.35	13.4	10.8	5.47	3.19	5.86	7.88	3.06	-	-	-	-	-
1994/95	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	6.63	10.5	10.3	12.5	11.0	9.40	6.27	4.11	3.48	3.18	2.89	4.26	7.04

Station : 5804002490 GARAINA (402490)
River : WARIA
Country : PAPUA-NEW GUINEA
Basin : WARIA (402) Area 1500 km2
DISCHARGE in M^3/S

year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1957/58	-	-	-	-	-	-	-	-	-	-	56.2	101.	-
1958/59	92.4	46.7	57.2	42.9	37.2	76.3	71.2	64.0	61.6	104.	84.6	45.4	65.3
1959/60	42.8	45.7	74.0	125.	81.2	109.	51.3	64.5	40.5	43.3	43.8	85.4	67.2
1960/61	69.1	69.9	46.0	56.6	68.7	92.8	-	-	-	-	-	-	-
1961/62	-	-	-	-	-	-	-	-	-	-	-	-	-
1962/63													
1963/64	-	-	-	-	-	-	-	-	-	-	-	-	-
1964/65	67.0	-	81.3	86.6	-	85.7	105.	71.9	35.1	24.2	-	-	-
1965/66	-	-	-	-	-	-	-	-	52.5	71.6	-	-	-
1966/67	-	-	-	156.	122.	77.9	102.	75.9	92.7	105.	92.3	127.	-
1967/68	-	-	-	-	-	-	82.4	73.3	73.0	-	118.	127.	-
1968/69	89.1	136.	104.	84.2	106.	77.2	68.9	60.4	72.8	89.7	109.	164.	96.8
1969/70	127.	135.	83.1	94.2	97.7	95.5	110.	78.8	103.	84.0	92.5	147.	104.
1970/71	199.	-	-	-	120.	114.	106.	-	-	-	-	-	-
1971/72	-	58.7	71.6	87.8	110.	76.8	103.	49.1	52.0	-	-	-	-
1972/73	-	-	-	84.6	147.	143.	157.	-	-	107.	131.	141.	-
1973/74	-	107.	-	-	-	-	-	-	-	-	82.2	98.2	-
1974/75	78.7	61.9	68.2	88.0	142.	146.	141.	89.8	85.0	113.	109.	89.8	101.
1975/76	84.1	123.	-	-	-	-	-	62.9	62.9	49.5	71.8	102.	-
1976/77	74.4	89.7	100.	-	-	-	-	-	112.	127.	112.	248.	-
1977/78	153.	111.	83.1	139.	87.3	103.	112.	78.8	77.0	84.1	-	-	-
1978/79	-	-	-	-	-	-	-	83.6	55.8	37.1	56.3	91.9	-
1979/80	88.4	77.6	113.	96.8	101.	102.	-	-	-	-	-	-	-
1980/81	-	-	-	-	-	-	-	-	-	-	121.	145.	-
1981/82	-	-	-	-	-	-	107.	-	-	-	-	-	-
1982/83	-	-	-	34.2	78.0	112.	118.	106.	-	-	-	-	-
1983/84	-	-	-	-	-	-	-	-	-	-	-	-	-
1984/85	-	-	-	-	-	-	-	-	-	-	-	-	-
1985/86	-	-	-	94.4	108.	-	81.7	70.8	66.8	58.5	53.9	60.6	-
1986/87	83.9	43.8	92.2	86.1	76.5	88.6	79.0	53.3	31.7	-	61.6	66.5	-
1987/88	59.0	74.3	65.2	100.	119.	70.2	77.5	83.3	98.2	111.	-	-	-
1988/89	-	-	-	-	-	-	-	-	-	-	-	-	-
1989/90	-	-	-	-	-	-	-	-	-	-	-	-	-
1990/91													
1991/92													
1992/93	-	-	-	-	-	-	-	-	-	-	-	-	-
1993/94	-	152.	53.8	73.7	60.2	67.2	127.	-	-	-	-	-	-
1994/95	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	93.4	88.8	78.1	90.0	97.8	96.3	100.	72.9	69.0	80.6	87.2	115.	89.1

Station : 5804004820 Downstream CHIRIBARE (404820)
River : MAMBARE
Country : PAPUA-NEW GUINEA
Basin : MAMBARE (404) Area 2019 km2
DISCHARGE in M^3/S

year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1961/62	-	-	208.	265.	318.	347.	297.	181.	183.	244.	288.	276.	-
1962/63	246.	238.	164.	177.	300.	236.	142.	-	124.	263.	232.	267.	-
1963/64	236.	240.	358.	246.	284.	260.	278.	136.	141.	220.	295.	236.	244.
1964/65	287.	170.	253.	262.	359.	210.	238.	-	-	56.6	124.	148.	-
1965/66	116.	281.	286.	411.	306.	222.	283.	173.	90.8	116.	200.	416.	242.
1966/67	333.	285.	304.	379.	222.	166.	230.	169.	155.	157.	234.	360.	250.
1967/68	211.	214.	260.	198.	233.	208.	196.	132.	156.	203.	313.	302.	219.
1968/69	235.	330.	270.	324.	338.	282.	176.	193.	156.	144.	187.	354.	249.
1969/70	-	403.	204.	221.	349.	271.	254.	-	-	-	-	-	-
1970/71	-	-	-	314.	255.	347.	253.	247.	203.	-	-	285.	-
1971/72	-	151.	146.	172.	288.	212.	227.	91.0	83.2	47.4	62.6	-	-
1972/73	-	-	368.	301.	403.	371.	-	157.	147.	-	303.	301.	-
1973/74	498.	309.	390.	-	-	-	-	182.	211.	127.	204.	-	-
1974/75	-	-	-	-	-	-	-	-	-	-	-	-	-
1975/76													
1976/77													
1977/78													
1978/79													
1979/80													
1980/81													
1981/82													
1982/83													
1983/84													
1984/85													
1985/86													
1986/87													
1987/88													
1988/89	-	-	-	-	351.	301.	223.	149.	170.	-	-	-	-
1989/90	-	-	-	-	-	-	-	-	-	-	-	-	-
1990/91	-	-	-	-	-	-	-	101.	133.	281.	94.5	281.	-
1991/92	270.	192.	156.	-	-	441.	416.	320.	265.	189.	121.	176.	-
1992/93	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	270.	256.	259.	273.	308.	277.	247.	172.	158.	171.	205.	284.	240.

Station : 5804009050 NADI GABUNA (409050)
River : MUSA
Country : PAPUA-NEW GUINEA
Basin : MUSA (409) Area 4792 km2
DISCHARGE in M^3/S

year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1957/58	-	-	-	-	-	-	-	-	-	-	290.	310.	-
1958/59	193.	207.	224.	271.	409.	531.	230.	314.	262.	-	-	-	-
1959/60	186.	169.	-	474.	379.	349.	262.	323.	175.	143.	153.	131.	-
1960/61	195.	165.	216.	271.	237.	287.	463.	356.	340.	222.	231.	333.	276.
1961/62	171.	227.	254.	443.	497.	471.	396.	235.	248.	254.	414.	207.	318.
1962/63	193.	224.	242.	184.	348.	298.	160.	123.	111.	278.	222.	216.	217.
1963/64	-	164.	332.	275.	306.	263.	297.	158.	169.	228.	341.	-	-
1964/65	-	-	-	-	502.	272.	274.	152.	95.5	74.8	72.3	98.8	-
1965/66	70.3	208.	408.	466.	324.	181.	204.	132.	81.1	72.4	124.	276.	212.
1966/67	205.	226.	414.	481.	-	-	-	174.	247.	261.	182.	396.	-
1967/68	246.	223.	478.	375.	-	232.	235.	156.	-	-	-	-	-
1968/69	-	346.	389.	413.	389.	379.	225.	-	-	-	-	-	-
1969/70	267.	304.	247.	241.	479.	237.	304.	-	-	-	-	491.	-
1970/71	487.	453.	395.	379.	339.	392.	-	-	-	-	247.	256.	-
1971/72	143.	151.	204.	197.	434.	286.	374.	176.	-	-	76.4	73.3	-
1972/73	-	-	238.	244.	460.	292.	269.	164.	148.	212.	205.	242.	-
1973/74	546.	463.	467.	479.	437.	341.	203.	200.	-	-	-	-	-
1974/75	292.	216.	261.	425.	578.	458.	452.	-	-	-	337.	228.	-
1975/76	256.	402.	277.	-	-	-	-	261.	-	-	-	-	-
1976/77	-	-	350.	346.	201.	170.	-	-	-	-	-	-	-
1977/78	265.	-	-	-	-	-	-	-	-	-	-	-	-
1978/79	-	-	-	-	510.	301.	-	-	-	-	-	-	-
1979/80	-	-	305.	279.	225.	-	-	-	-	-	-	-	-
1980/81	-	-	327.	-	-	-	-	-	-	-	-	287.	-
1981/82	291.	-	-	-	-	-	-	-	-	-	-	-	-
1982/83	-	-	-	-	442.	-	-	-	-	-	-	-	-
1983/84	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	250.	259.	317.	347.	395.	319.	290.	209.	188.	194.	223.	253.	270.

Station : 5804009080 6Km downstream 409050 (409080)
River : MUSA
Country : PAPUA-NEW GUINEA
Basin : MUSA (409) Area 4813 km2
DISCHARGE in M^3/S

year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1981/82	-	-	-	-	-	-	-	-	-	-	-	-	-
1982/83	-	119.	277.	384.	551.	-	280.	308.	187.	196.	-	-	-
1983/84	309.	391.	285.	360.	539.	534.	570.	618.	239.	230.	236.	-	-
1984/85	-	-	-	447.	326.	355.	255.	313.	304.	268.	405.	395.	-
1985/86	432.	284.	416.	-	510.	393.	236.	230.	132.	118.	102.	76.3	-
1986/87	-	-	-	-	-	189.	143.	-	-	-	-	-	-
1987/88	-	-	-	-	-	-	-	270.	270.	341.	378.	357.	-
1988/89	310.	202.	296.	399.	502.	322.	299.	172.	156.	-	-	-	-
1989/90	-	-	-	-	-	-	-	-	-	-	435.	349.	-
1990/91	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	350.	249.	319.	398.	486.	359.	297.	319.	215.	231.	311.	294.	319.

Station : 5806002300 JAWARERE (602300)
River : MUSGRAVE
Country : PAPUA-NEW GUINEA
Basin : RIGO (602) Area 88.0 km2
DISCHARGE in M^3/S

year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1960/61	-	-	-	-	-	-	-	-	-	-	-	-	-
1961/62	7.13	9.24	29.7	6.12	6.62	14.3	11.1	8.77	6.88	12.4	21.8	8.50	11.9
1962/63	7.21	5.78	11.0	12.9	11.0	5.96	7.85	6.86	8.91	11.5	14.6	4.96	9.04
1963/64	2.47	6.63	5.29	3.68	8.95	9.91	12.5	8.36	7.58	8.46	9.86	9.39	7.76
1964/65	13.8	5.19	4.46	5.43	4.47	7.42	4.37	3.08	1.85	2.11	1.82	2.27	4.69
1965/66	1.18	4.80	3.07	10.6	8.63	5.36	5.82	7.28	-	-	-	8.34	-
1966/67	3.22	2.81	11.2	10.1	11.3	5.53	10.2	9.93	-	12.4	8.37	11.7	-
1967/68	4.05	4.94	4.89	2.51	8.42	5.40	6.52	6.28	3.84	6.44	6.67	6.10	5.51
1968/69	3.42	8.34	9.73	5.03	9.74	-	-	8.99	4.14	3.18	3.35	3.16	-
1969/70	5.00	8.16	4.66	7.89	4.85	5.44	9.19	4.70	9.61	14.6	20.3	20.2	9.55
1970/71	15.9	9.13	7.99	7.14	4.44	11.2	15.0	19.9	13.3	5.54	13.1	9.23	11.0
1971/72	8.10	4.15	1.91	6.91	10.7	9.67	11.8	4.67	4.55	2.18	1.90	3.42	5.83
1972/73	4.45	2.79	6.76	4.22	7.36	8.10	6.25	6.37	4.02	5.43	8.78	7.38	5.99
1973/74	13.2	-	9.40	10.7	4.44	10.0	8.53	10.0	8.16	3.21	4.86	5.20	-
1974/75	3.31	2.74	-	-	-	9.84	17.6	11.7	12.1	8.30	8.84	7.94	-
1975/76	13.1	10.6	7.07	-	-	7.08	7.36	16.6	-	-	-	-	-
1976/77	-	5.09	2.16	5.00	-	-	-	5.53	14.1	12.9	-	-	-
1977/78	-	-	-	-	-	-	-	-	-	-	7.81	3.63	-
1978/79	10.6	11.2	-	-	7.56	5.09	17.5	-	-	3.28	2.03	3.16	-
1979/80	4.42	8.32	-	4.19	2.68	4.09	4.06	3.86	3.76	-	-	-	-
1980/81	-	-	-	-	-	-	-	-	-	-	-	8.46	-
1981/82	6.92	8.41	6.34	2.80	9.70	5.78	-	-	-	4.16	1.26	.944	-
1982/83	.870	1.39	.936	2.37	3.41	9.27	8.72	9.70	6.38	5.63	3.60	7.58	4.99
1983/84	9.54	12.7	14.6	13.8	9.44	11.5	22.1	-	10.8	-	-	-	-
1984/85	-	4.58	4.75	8.29	3.75	14.0	9.86	13.5	13.9	8.75	25.3	13.1	-
1985/86	16.3	8.73	8.96	3.63	8.21	17.3	6.28	8.52	3.66	3.85	2.45	2.46	7.53
1986/87	1.54	2.15	-	2.47	5.02	8.32	5.34	2.53	1.96	1.27	3.95	2.52	-
1987/88	2.38	4.63	4.46	5.67	8.81	6.45	12.3	14.4	9.22	6.14	10.6	16.7	8.48
1988/89	5.08	4.78	6.24	3.31	8.14	9.44	8.57	11.5	8.22	13.5	8.17	-	-
1989/90	-	-	-	-	-	8.28	12.8	6.55	6.56	-	-	-	-
1990/91	-	-	-	-	-	-	-	3.45	5.70	9.65	3.90	9.51	-
1991/92	12.2	3.79	2.41	4.93	-	-	6.47	-	-	-	-	-	-
1992/93	-	-	-	-	-	-	-	-	-	-	-	-	-
1993/94	3.68	9.04	2.80	-	-	-	-	-	-	-	-	-	-
1994/95	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	6.89	6.30	7.12	6.24	7.29	8.59	9.92	8.52	7.36	7.17	8.41	7.33	7.60

Station : 5806002800 BANNON bridge (602800)
River : KEMPWELCH
Country : PAPUA-NEW GUINEA
Basin : RIGO (602) Area 2400 km2
DISCHARGE in M^3/S

year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1966/67	-	-	-	-	-	-	-	-	92.8	104.	92.2	188.	-
1967/68	95.9	112.	116.	84.7	147.	-	-	72.2	46.2	80.0	88.1	93.2	-
1968/69	-	144.	201.	201.	-	256.	158.	110.	52.7	38.5	42.3	49.0	-
1969/70	68.0	121.	107.	146.	175.	150.	117.	51.9	81.3	117.	159.	384.	140.
1970/71	317.	254.	230.	214.	157.	203.	-	202.	146.	57.5	83.0	133.	-
1971/72	70.8	85.3	114.	175.	-	-	211.	82.3	45.5	27.1	-	-	-
1972/73	-	41.8	89.7	39.3	151.	181.	128.	56.4	42.6	39.4	50.7	81.4	-
1973/74	242.	210.	265.	274.	128.	159.	-	125.	64.5	36.9	34.8	-	-
1974/75	-	71.0	87.4	-	256.	240.	311.	179.	-	75.6	70.2	53.8	-
1975/76	162.	236.	169.	121.	129.	193.	-	-	78.9	42.5	35.0	81.1	-
1976/77	-	-	124.	186.	143.	141.	129.	77.0	122.	119.	81.0	91.2	-
1977/78	80.6	-	85.2	-	-	-	-	65.3	59.7	37.5	50.3	30.4	-
1978/79	-	-	-	-	-	-	-	-	-	35.0	-	32.1	-
1979/80	43.9	97.5	-	135.	126.	78.1	45.0	26.9	25.7	25.0	24.6	18.9	-
1980/81	32.8	-	265.	73.5	68.5	154.	81.8	89.4	53.8	33.3	31.4	-	-
1981/82	123.	203.	175.	102.	197.	-	-	-	47.2	67.8	-	-	-
1982/83	-	-	35.3	105.	140.	181.	145.	109.	59.4	43.9	32.1	86.7	-
1983/84	102.	276.	241.	272.	303.	239.	186.	127.	95.4	69.7	63.7	103.	173.
1984/85	63.0	146.	158.	218.	143.	186.	150.	138.	170.	-	188.	147.	-
1985/86	255.	157.	193.	120.	252.	402.	124.	91.8	-	-	36.4	33.4	-
1986/87	30.8	54.2	129.	70.1	109.	159.	70.0	39.2	31.4	22.5	33.7	34.3	65.3
1987/88	33.0	69.5	95.2	167.	211.	-	-	145.	96.5	53.0	82.9	179.	-
1988/89	118.	90.1	105.	-	-	-	-	113.	96.4	146.	113.	152.	-
1989/90	172.	126.	190.	120.	133.	162.	149.	124.	90.5	84.0	130.	127.	134.
1990/91	108.	79.7	103.	98.5	86.6	123.	-	68.0	59.2	61.4	51.8	51.6	-
1991/92	56.9	60.2	+	184.	101.	120.	210.	83.1	68.6	70.1	52.1	111.	-
1992/93	137.	130.	74.0	54.9	45.3	60.6	42.7	31.2	26.9	28.6	29.1	25.4	57.1
1993/94	42.2	110.	-	-	-	-	-	-	-	-	-	-	-
1994/95	-	-	-	-	-	-	102.	65.9	43.9	40.1	63.1	-	-
1995/96	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	112.	131.	146.	144.	153.	178.	139.	94.7	71.9	59.8	68.7	99.4	116.

Station : 5806004960 ARUBAADA (604960)
River : EILOGO
Country : PAPUA-NEW GUINEA
Basin : SIRINUMU (604) Area 31.0 km2
DISCHARGE in M^3/S

year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1978/79	-	-	1.70	1.27	3.78	1.85	5.55	-	-	-	-	-	-
1979/80	-	1.16	2.05	1.69	-	-	1.12	1.71	.878	.867	.775	.692	-
1980/81	.825	1.13	3.71	1.44	1.90	2.81	1.63	-	-	.975	.950	1.73	-
1981/82	2.10	2.28	1.72	1.35	2.01	1.26	1.23	1.02	.914	1.11	.782	.728	1.38
1982/83	.677	.710	.604	.635	-	-	-	1.15	1.01	1.07	1.00	1.42	-
1983/84	1.80	2.92	3.12	3.38	3.36	2.07	4.84	1.67	1.43	-	-	-	-
1984/85	-	2.39	2.22	-	3.13	4.54	3.31	1.99	2.09	1.61	3.74	2.39	-
1985/86	3.16	2.34	-	-	-	-	2.29	1.44	1.17	-	-	.634	-
1986/87	-	-	2.52	-	-	-	-	-	-	-	-	-	-
1987/88	1.04	1.03	1.46	1.75	3.20	2.16	2.11	2.56	1.76	1.16	2.20	-	-
1988/89	-	-	-	-	-	-	-	-	-	1.67	-	-	-
1989/90	3.30	1.64	-	2.28	2.16	1.87	-	-	1.63	1.16	1.45	1.93	-
1990/91	1.36	.981	.980	-	-	-	-	-	-	1.27	1.05	1.61	-
1991/92	1.78	.838	-	-	-	-	1.46	.980	.915	.772	.895	.631	-
1992/93	.608	1.51	1.83	1.46	1.16	3.04	1.55	-	-	-	-	.955	-
1993/94	1.21	1.89	1.11	1.63	3.29	2.37	3.28	1.48	1.19	1.64	1.15	1.07	1.78
1994/95	.856	.849	1.02	1.76	1.36	-	2.26	1.22	.899	.846	-	-	-
1995/96	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	1.56	1.55	1.85	1.70	2.54	2.44	2.55	1.52	1.26	1.18	1.40	1.25	1.73

Station : 5806007300 KAREMA (607300)
River : BROWN
Country : PAPUA-NEW GUINEA
Basin : BROWN-VANAPA 607 Area 1400 km2
DISCHARGE in M^3/S

year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1980/81	-	-	-	-	-	-	60.6	49.4	-	-	-	46.8	-
1981/82	43.7	102.	93.4	42.7	242.	119.	78.7	49.5	37.1	34.9	28.2	25.0	74.7
1982/83	23.3	32.7	39.8	104.	169.	132.	92.4	51.2	32.1	27.4	26.0	41.4	64.3
1983/84	76.2	165.	97.4	161.	199.	121.	89.0	46.2	34.5	25.0	28.8	32.3	89.6
1984/85	26.4	114.	177.	121.	145.	119.	78.4	56.2	51.7	34.0	71.7	74.8	89.1
1985/86	100.	105.	139.	129.	174.	-	-	-	35.8	32.1	31.6	-	-
1986/87	26.6	29.6	81.1	69.1	109.	100.	43.2	27.7	23.5	19.7	21.9	21.0	47.7
1987/88	25.4	-	-	118.	119.	102.	60.3	49.3	34.7	27.8	31.9	86.0	-
1988/89	56.7	80.0	93.0	-	151.	156.	91.8	49.7	37.1	34.8	38.9	-	-
1989/90	-	71.6	166.	135.	112.	-	-	-	-	-	53.3	50.8	-
1990/91	46.3	50.4	-	-	-	-	-	34.5	30.3	32.8	27.8	-	-
1991/92	-	50.5	47.4	84.7	117.	128.	73.3	-	-	-	-	-	-
1992/93	-	-	-	-	-	-	-	-	-	-	-	20.0	-
1993/94	27.1	67.7	103.	123.	132.	101.	134.	57.7	46.1	63.1	71.5	43.5	80.8
1994/95	37.0	61.0	128.	216.	174.	151.	85.7	50.0	36.4	28.5	28.9	41.2	86.5
1995/96	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	44.4	77.5	106.	119.	154.	123.	80.7	47.4	36.3	32.7	38.4	43.9	75.3

Station : 5806100600 HELLS GATE (610600)
River : TAURI
Country : PAPUA-NEW GUINEA
Basin : TAURI (610) Area 2410 km2
DISCHARGE in M^3/S

year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1976/77	-	-	199.	188.	138.	-	195.	123.	-	118.	142.	354.	-
1977/78	-	-	-	-	-	-	-	-	-	-	-	-	-
1978/79													
1979/80	-	-	-	-	-	-	-	-	-	84.7	118.	-	-
1980/81	-	198.	216.	-	-	-	-	-	68.8	55.1	85.6	298.	-
1981/82	173.	235.	-	216.	181.	-	-	-	-	-	-	-	-
1982/83	-	-	76.2	81.7	181.	200.	222.	191.	104.	107.	111.	206.	-
1983/84	235.	-	-	214.	190.	170.	195.	235.	126.	75.4	118.	189.	-
1984/85	103.	203.	203.	269.	237.	-	187.	147.	189.	86.7	229.	-	-
1985/86	223.	171.	225.	171.	252.	267.	-	-	-	-	85.3	68.3	-
1986/87	93.6	41.0	156.	161.	176.	170.	100.	64.0	46.0	34.0	83.0	76.8	100.
1987/88	82.9	166.	-	-	-	-	-	142.	83.3	58.3	94.3	258.	-
1988/89	115.	181.	159.	125.	259.	-	-	64.3	55.4	166.	90.6	187.	-
1989/90	-	-	-	-	-	-	-	151.	95.4	135.	243.	218.	-
1990/91	105.	-	-	-	-	-	-	-	-	-	-	-	-
1991/92	-	82.6	93.7	-	-	-	-	-	71.3	-	-	-	-
1992/93	-	-	-	-	-	-	-	-	-	-	61.9	94.3	-
1993/94	143.	245.	141.	159.	172.	136.	288.	105.	-	-	-	-	-
1994/95	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	142.	169.	163.	176.	198.	189.	198.	136.	93.2	92.0	122.	195.	156.

Station : 5807102400 Upstream WABO Cr.Junction (712400)
River : PURARI
Country : PAPUA-NEW GUINEA
Basin : LWR PURARI (712) Area 28738 km2
DISCHARGE in M^3/S

year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1960/61	-	-	-	-	-	-	-	-	-	-	-	-	-
1961/62	-	-	-	-	-	-	-	-	-	-	-	-	-
1962/63	-	-	-	-	-	-	-	-	-	-	-	-	-
1963/64	-	-	-	-	-	-	-	-	-	-	-	-	-
1964/65	-	-	-	-	-	-	-	-	-	-	-	-	-
1965/66	-	-	-	-	-	-	-	-	-	-	-	-	-
1966/67	-	-	-	-	-	-	-	-	-	-	-	-	-
1967/68	-	-	-	-	-	-	-	-	-	-	-	-	-
1968/69	-	-	-	-	-	-	-	-	-	-	-	-	-
1969/70	-	-	-	-	-	-	-	-	-	-	-	-	-
1970/71	-	-	-	-	-	-	-	-	-	-	-	-	-
1971/72	-	-	-	-	-	-	-	-	-	-	-	-	-
1972/73	-	-	-	-	-	-	-	-	-	-	-	-	-
1973/74	-	-	-	-	-	-	-	-	-	-	-	-	-
1974/75	-	-	-	-	-	-	-	-	-	-	-	-	-
1975/76	-	-	-	-	-	-	-	-	-	-	-	-	-
1976/77	-	-	-	-	-	-	-	-	-	-	-	-	-
1977/78	-	-	-	-	-	-	-	-	-	-	-	-	-
1978/79	-	-	-	-	-	-	-	-	-	-	-	-	-
1979/80	-	-	-	2230.	-	-	-	-	-	-	-	-	-
1980/81	-	-	-	-	-	-	1900.	-	-	-	-	-	-
1981/82	-	-	-	-	-	-	-	-	-	-	-	753.	-
1982/83	618.	1360.	1110.	2160.	2770.	3060.	2690.	2560.	1790.	3050.	1860.	2170.	2100.
1983/84	2890.	3290.	2160.	2840.	-	-	-	-	2320.	1990.	2310.	3000.	-
1984/85	1300.	-	-	-	-	2940.	-	-	3150.	2390.	3900.	3100.	-
1985/86	2140.	2360.	-	-	-	3460.	1880.	2060.	-	-	-	-	-
1986/87	-	-	-	-	-	-	-	-	1290.	1130.	2390.	1660.	-
1987/88	1930.	2150.	1790.	3950.	3410.	2180.	-	-	2200.	1750.	-	-	-
1988/89	-	2380.	-	-	3940.	-	-	-	1240.	2110.	-	-	-
1989/90	-	-	-	-	-	-	-	-	-	-	-	-	-
1990/91	-	-	-	-	-	-	-	-	-	-	-	-	-
1991/92	-	-	-	-	-	-	-	-	-	-	-	-	-
Moy.	1780.	2310.	1690.	2800.	3370.	2910.	2160.	2310.	2000.	2070.	2620.	2140.	2347.

Station : 5809101440 MOUNT TAKAPOPOR (911440)
River : URUAVI
Country : PAPUA-NEW GUINEA
Basin : KIETA (911) Area 215 km2
DISCHARGE in M^3/S

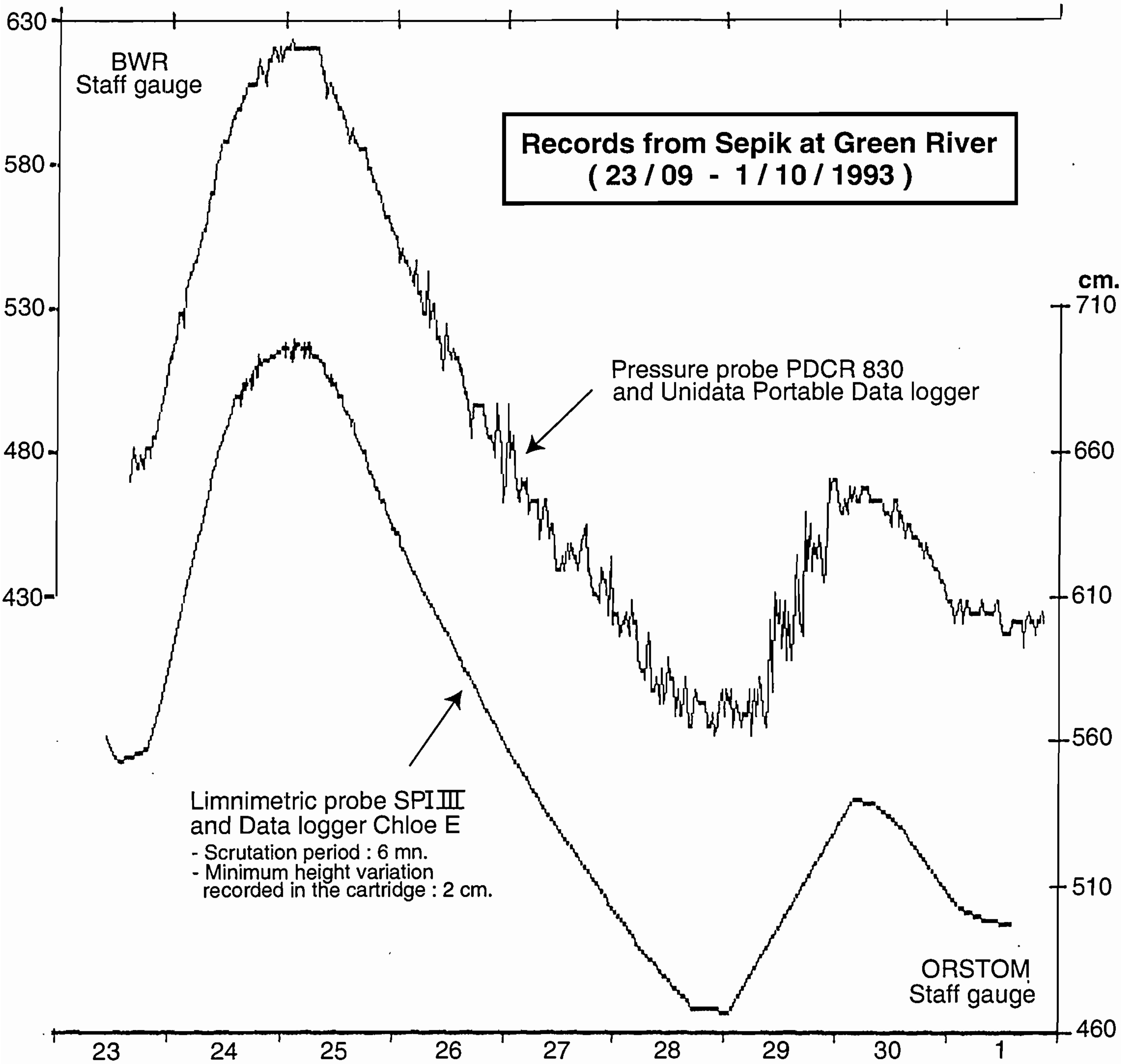
year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1980/81	-	-	-	18.0	10.9	16.3	11.5	15.0	-	23.1	25.3	27.8	-
1981/82	20.9	26.5	-	-	-	-	-	-	19.3	19.7	12.6	21.0	-
1982/83	-	-	13.3	15.2	22.0	25.0	14.3	23.3	24.8	23.6	25.9	25.3	-
1983/84	-	25.7	13.7	13.4	20.8	23.0	16.3	13.4	-	-	-	15.6	-
1984/85	-	-	-	-	-	21.7	19.2	14.1	14.2	14.2	14.7	22.3	-
1985/86	23.7	26.1	20.9	23.0	16.7	25.3	18.8	22.0	18.7	-	-	27.2	-
1986/87	18.5	12.6	11.6	12.9	17.5	16.1	17.5	10.8	-	17.8	23.6	-	-
1987/88	-	-	23.6	27.6	23.8	16.0	20.4	23.2	28.8	26.9	25.5	33.1	-
1988/89	19.2	16.2	23.3	-	-	-	-	-	-	-	-	-	-
1989/90	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	20.6	21.4	17.7	18.4	18.6	20.5	16.9	17.4	21.2	20.9	21.3	24.6	20.0

Station : 5809104100 Upstream waterfall (914100)
River : LORENGAU
Country : PAPUA-NEW GUINEA
Basin : North MANUS 914 Area 11.0 km2
DISCHARGE in M^3/S

year	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	annual
1979/80	-	-	-	-	-	-	-	-	-	-	1.03	.874	-
1980/81	-	-	-	-	-	-	-	-	-	.637	.715	1.02	-
1981/82	.991	1.84	1.30	1.37	.731	.487	.427	1.42	.418	.295	.173	-	-
1982/83	.791	.955	1.01	.304	.822	.573	.971	1.34	1.92	1.20	.689	.743	.943
1983/84	1.16	.608	.175	.270	.456	.142	1.21	.391	.931	.533	.542	1.38	.650
1984/85	.447	2.03	-	-	1.29	.410	.456	.264	.670	.901	1.02	-	-
1985/86	-	-	-	.746	.287	1.22	.870	.619	1.15	.704	1.22	.481	-
1986/87	1.21	.559	1.12	.323	.810	.410	.732	1.66	.678	.283	-	-	-
1987/88	-	-	-	-	-	-	-	-	-	.237	.607	.853	-
1988/89	1.10	1.52	.393	.494	.586	-	-	-	-	-	-	-	-
1989/90	-	-	-	.978	1.02	1.07	-	-	-	-	-	-	-
1990/91	-	-	-	-	-	-	-	-	-	-	-	.544	-
1991/92	.441	-	-	-	-	-	-	-	-	-	-	-	-
Mean	.877	1.25	.800	.641	.750	.616	.778	.949	.961	.599	.750	.842	.818

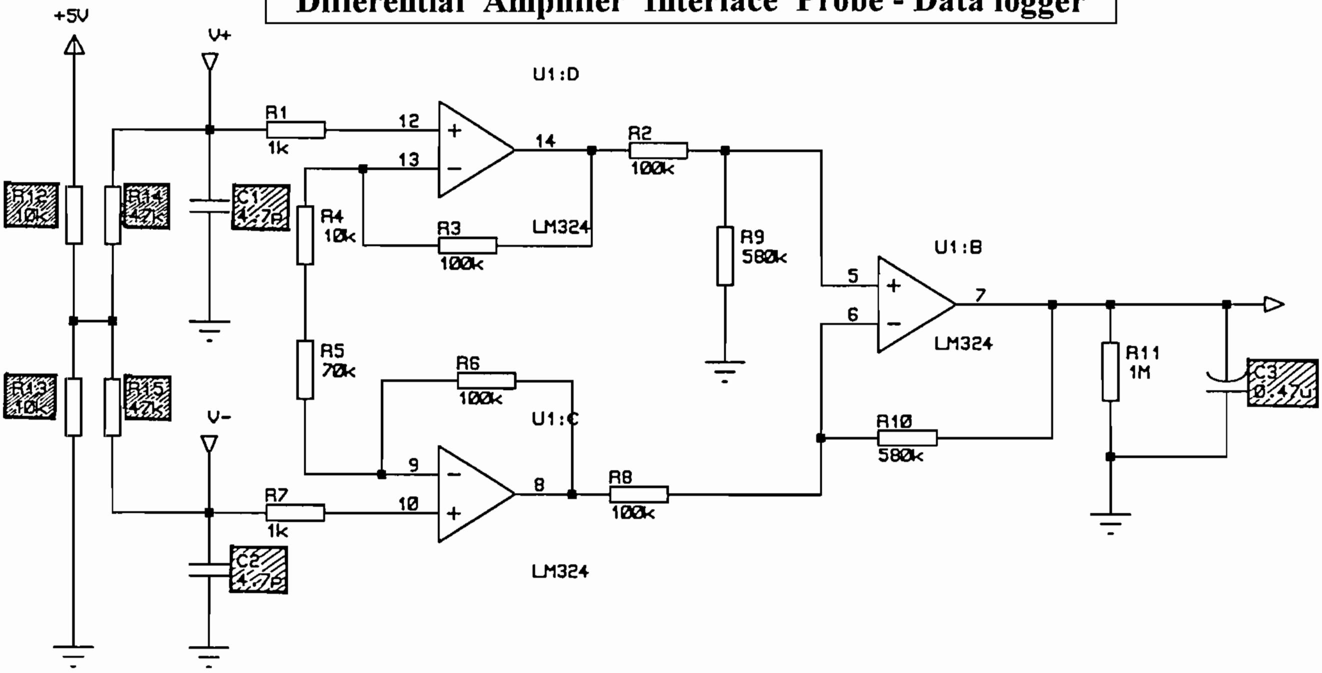
APPENDIX 2

Stability of data logger

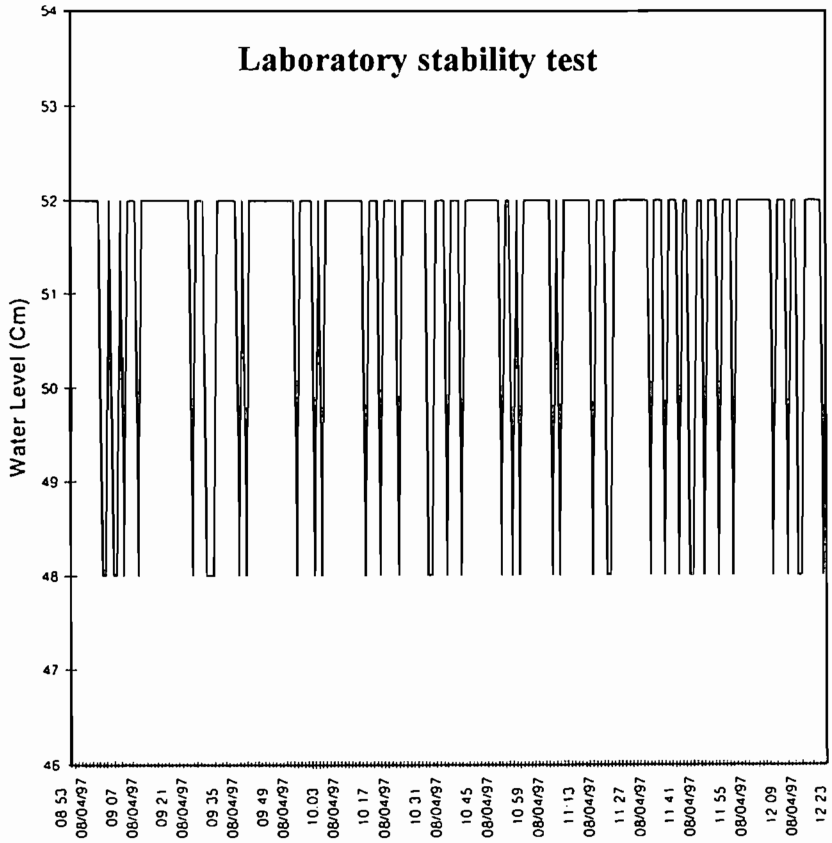


Records from Sepik at Green River
(23 / 09 - 1 / 10 / 1993)
BWR
Staff gauge
Pressure probe PDCR 830
and Unidata Portable Data logger
Limnimetric probe SPI III
and Data logger Chloe E
- Scrutation period : 6 mn.
- Minimum height variation
recorded in the cartridge : 2 cm.
ORSTOM
Staff gauge
cm.
630
580
530
480
430
710
660
610
560
510
460
23
24
25
26
27
28
29
30
1

Differential Amplifier Interface Probe - Data logger



Modifications made to the interface card presently used by BWR to improve overall stability (D. Varillon, May 1997)



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Acronyms

BWR	Bureau of Water Resources
CEIS-TM	French Company for data transmission networks (SRDA and SRDM receiving stations, HYCOS platforms,...)
CLS	Collect Location Satellites (Argos,...)
DWR	Direction of Water Resources
ELCOM	Papua New Guinea Electricity Commission, Port Moresby
GCOS	Global Climate Observing System
GS	Gauging Station
HYCOS	Hydrological Cycle Observing Systems
IHP	International Hydrological Programme
NWS	National Weather Service
OTML	Ok Tedi Mining Limited
ORSTOM	French Institute of Scientific Research for Development throughy Co operation
SMEC	Snowy Mountains Engineering Corporation
UNESCO	United Nations Educational, Scientific and Cultural Organization
WHD	World Hydrological Decade (1965-1974)
WMO	World Meteorological Organization
WWW	World Weather Watch