# 4. Forest Land Conservation Survey

## 4.1. Rainfall Characteristics

The area upstream of Kuala Belalong at the entrance to the Ulu Temburong Natontional Park has steep mountainous topography and the Park is expected to show meteorological conditions differnet from those of the plateuau area in the downstream part of the river.

Brunei Darussalam is seldom hit by earthquakes or severe tropical storms and rainfalls feature highly among the causes of mountain devastation in the country. The rainfall data was used in order to understand the characteristics of rainfalls in the area when considering suitable precautions and other matters relating to forest land conservation.

### 4.1.1. Rain gauge installation, location and observation method

The survey area was not easily accessible and had no facilities to accommodate personel over a long period of time. Thus, a system that would allow unattended observation over a long interval was selected.

The rain gauge was installed on a terrace at Kuala Belalong on the right bank immediately downstream from the entrance to the National Park, which is used by the Forestry Department for lodging and other purposes. This site was selected after studying the conditions, to ensure that there were no obstructions to intercept rainfall such as crowns or winds, and for ease of equipment maintenance. (See Figure -32).

The system records rainfall in increment of 0.5mm.

### 4.1.2. Observation results and rainfall characteristics

(1) Measurement results

Observations were conducted for a total of 268 days (approximately nine months) as follows:

| | |
|---|---|
| September 11 to November 2, 1992 | 54 days |
| November 17 to December 31, 1992 | 45 " |
| January 1 to June 18, 1993 | 169 " |

During observations, a wiring fault occurred and rainfall could not be measured until this prooblem could be remedied.

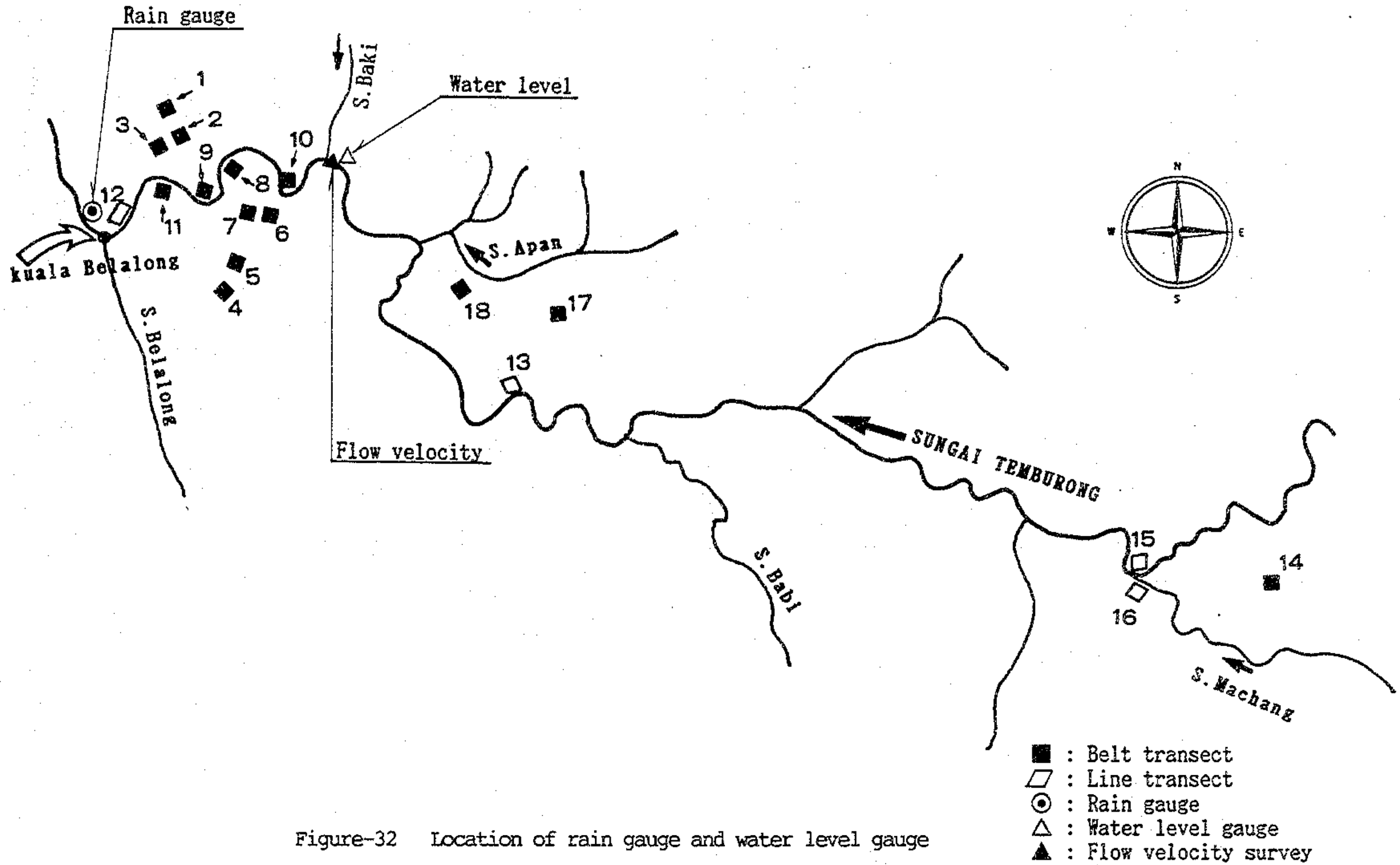



Figure-32 Location of rain gauge and water level gauge

Table-23 General rainfall

| YEAR: | 1992 | | | | 1993 | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| Total | 243 | 374 | 420 | 322 | 181 | 213 | 330 | 378 | 622 | 94 | | | 3,174mm |
| | 400 | 381 | 478 | 431 | 365 | 257 | 258 | 349 | 410 | 294 | 290 | 250 | 4,162 |
| Max. (Day) | 51 | 92 | 142 | 106 | 52 | 44 | 66 | 78 | 75 | 23 | | | 142mm |
| | | | | | | | | | | | | | 145 |
| Max. (Hour) | 27 | 70 | 49 | 37 | 19 | 23 | 42 | 35 | 66 | 14 | | | 70mm |
| Num. of rainy day | 13 | 27 | 13 | 22 | 13 | 19 | 18 | 23 | 29 | 6 | | | 183 |
| | 16 | 17 | 21 | 12 | 13 | 12 | 11 | 11 | 17 | 12 | 11 | 10 | 169 |
| Num. of observ. | 21 | 31 | 16 | 31 | 31 | 28 | 31 | 30 | 31 | 18 | | | 268 |

The results are summarised in App. Tables-1 to 11 as annual tables of daily rainfall and monthly reports of hourly rainfall. Table-23 summarises these tables. The average rainfall over the past 20 years and the average of rainfall days between 1989 and 1991 at the Selangan Agriculture Station are also shown in the middle and lower parts of the table.

The total rainfall over the 268-day period was 3,174mm. During this period, the maximum daily rainfall was 142.0mm. The maximum monthly rainfall was recorded in May, 1993 when the rainfall was 621.5mm. In November, 1992, data could not be taken for 14 days. However, a total of 419mm of rain fell and this month was estimated to have had about the same rainfall as that of May, 1993.

(2) Rainfall characteristics

The general rainfall characteristics are described below using the data gathered and comparing it with the data from the downstream area (Selangan Agriculture Station). App. Tables-12 to 15 show datailed data gathered by the station.

a. Number of rainy days and rainfall depth

The periods from the end of September to December and from April to May are the rainly seasons. The number of rainy days totalled 22 to 29 days per month, indicating that it rained alomost every day. The monthly average number of rainy days in the downstream area was about 20 days even in the rainy season and the number of rainy days in the upstream area was considerably greater. In terms of the number of rainy days, the upstream area had already 183 rainy days in nine months, a very large number.

In rainfall depth, howerve, the figures for the total rainfall, maximum daily rainfall depth and maimum hourly rainfall of the upstream area were comparable to those of the downstream area.

The periods from January to February and from mid-June to August can be considered to be the dry seasons, although the monthly rainfall was still about 200mm. One of the characteristics of these periods was that it did not rain for about ten days and this greatly affected the stream flow. Noevertheless, it rained about two weeks per month and high rainfalls of 40 to 60mm in one day and 20 to 30mm in one hour were recorded.

The number of rainy days was high in the furthest down-stream area of the National Park area, but a clear difference between this and the general downstream area could not be found.

b. Continuation hours and rainfall intensity

The general characteristic of rainfalls in the tropical region is due to moving squalls. Table-24 shows hours of continuous rainfall based on daily reports plotted on an hourly basis.

Table-24 Frequency of rainfall,(mm)

| Rainy hour | Frequency | % |
|---|---|---|
| 1 | 144 | 46.8 |
| 2 | 74 | 24.0 |
| 3 | 39 | 12.7 |
| 4 | 17 | 5.5 |
| 5 | 15 | 4.9 |
| 6 | 8 | 2.6 |
| 7 | 5 | 1.6 |
| 8 | 2 | 0.7 |
| 9 | 2 | 0.7 |
| 10 | 0 | 0.0 |
| 11 | 2 | 0.7 |
| Total | 308 | 100 |

Table-25 Maximum rainfall,(mm)

| Order | Max.rainfall/day | | | Max. rainfall ／hour |
|---|---|---|---|---|
| | ／day | Continuous time(hour) | ／hour | |
| 1 | 142.0 | 5～9 | 49.0 | 69.5 |
| 2 | 105.5 | 5～7 | 37.0 | 65.5 |
| 3 | 92.0 | 9 | 69.5 | 61.5 |
| 4 | 85.0 | 5 | 38.0 | 49.0 |
| 5 | 77.5 | 7 | 20.5 | 46.5 |
| 6 | 75.0 | 3 | 65.5 | 44.0 |
| 7 | 71.0 | 3 | 61.5 | 43.0 |
| 8 | 66.0 | 9 | 42.0 | 42.0 |
| 9 | 65.5 | 5～8 | 24.5 | 38.0 |
| 10 | 57.5 | 4 | 46.5 | 37.0 |

Rainfalls continuing for one or two hours were dominant, accounting for 71% of the total. According to rainfall daily reports, 0.5 to 1mm were dominant as rainfalls lasting less than one hour. These were mostly squalls lasting several minutes.

Generally, hourly rainfall of more than 10mm is called heavy rain and of more than 20mm, a downpour. Rainfalls of about 10 to 20mm in one hour were relatively frequent. Rainfalls exceeding 10mm totalled 87 and those exceeding 20mm, 34. Table-25 shows the top ten ranks. Top daily rainfalls and the maximum hourly rainfall for those days on which top daily rainfalls were recorded, are also shown.

c. Rainfall time zones

During observations at the survey site, it rained from evening into the night on many days. This tendency is summarised below as the number of rainy days and rainfall depth for time zones 0:00 to 5:00 to 14:00 and 14:00 to 24:00.

Table-26 Rainfall (hour zone),(mm)

| Time | 0:00~5:00 | | 5:00~14:00 | | 14:00~24:00 | |
|---|---|---|---|---|---|---|
| Month | Days | Rainfall | Days | Rainfall | Days | Rainfall |
| 9 | 3 | 40.0 | 3 | 2.0 | 10 | 200.5 |
| 10 | 8 | 35.5 | 6 | 49.5 | 24 | 289.0 |
| 11 | 2 | 2.0 | 5 | 10.5 | 12 | 407.0 |
| 12 | 3 | 8.0 | 3 | 19.0 | 6 | 294.5 |
| 1 | 2 | 1.0 | 7 | 13.0 | 9 | 167.0 |
| 2 | 5 | 25.5 | 7 | 34.0 | 16 | 153.0 |
| 3 | 5 | 12.0 | 5 | 11.5 | 16 | 306.5 |
| 4 | 6 | 6.5 | 2 | 15.5 | 22 | 355.5 |
| 5 | 6 | 28.0 | 4 | 24.0 | 27 | 569.5 |
| 6 | 3 | 22.0 | 3 | 12.5 | 6 | 59.5 |
| Total | 43 | 180.5 | 45 | 191.5 | 148 | 2,802.0 |

Rainfalls between 14:00 and the night accounted for 63% in the number of rainy days and 88%, or 3,174mm, in total rainfall and were dominant. Rainfalls during the time zones 0:00 to 5:00 and 5:00 to 14:00 were very light. During the rainy season, rainfalls would continue for about three hours in these time zones. However, most of the rainfalls were squalls of short duration and rainfalls that continued for several hours were almost zero. These characteristics of rainfall time zones are clearly shown in the statistics.

Figure-33 translates rainfalls into hourly totals. The diagram shows that rains started to fall between 14:00 and 15:00 and that rains fell in concentration until 20:00 at night. This trend was noticed during both the rainy and dry seasons.

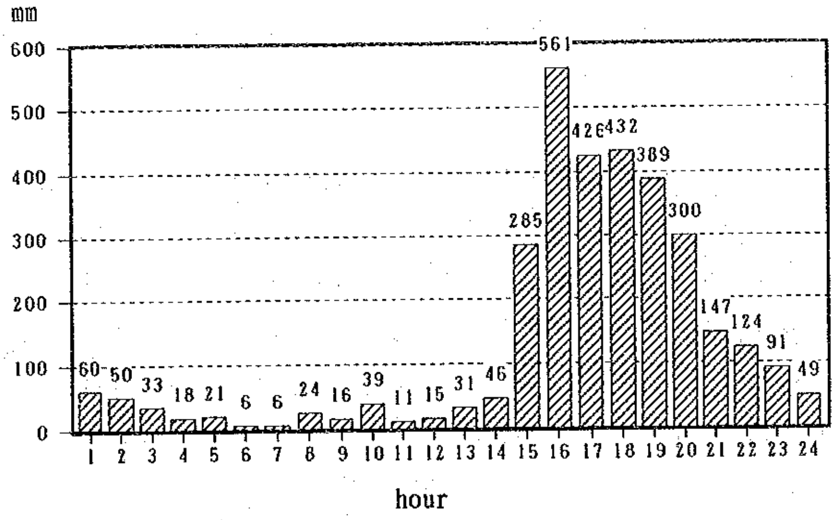



Figure-33 Total rainfall in each hour

As mentioned above, the furthest downstream part of the Ulu Temburoung National Park did not have a clear distinction in rainfall characteristics when compared with the low-lying plains area further downstream even though the National Park is located in a mountainous area. However, as the following characteristic tendencies were observed:

(1) During the dry season, it did not rain about ten days.

However, the rainfall intensities during the dry seson were as intense as those of the rainy season.

(2) Rain did not last for the whole day even during the rainy season. Rains of 70 to 140mm fell for three hours to half a day.

(3) Rainfalls were concentrated very intensely for several hours from 14:00 till night-time.

(4) Rainfall during the day was light, althrough there were intermittent squalls.

## 4.2. Flood Characteristics of the Main Stream of the Temburong River

The Temburong River inside the National Park has a watershed area of about 26,000ha and flows on down after merging with Sg. Belalong at the entrance to the National Park. The Temburong River is the only means of transportation in the areas upstream of Batang Duri. Identifying flood conditions of the river is very important in using the National Park. This data will also be useful in studying the torrent stability, characteristics of the entire watershed and rainfall conditions. The water level was measured continuously to identify the hydrological characteristics of the Temburong River watershed.

### 4.2.1. Water gauge installation, location and measuring method

The data logger measured the water level at ten minute intervals, in mm, unattended over a long period of time (about one year).

After stdudying conditions for a location near the National Park entrance that would always have water even during the low water season and that would be safe during floods, a location on the right bank upstream from the confluence of Sg. Baki was selected. (See Figure-32.)

It should be noted that the water level is measured from the point where the gauge was installed, to the water surface.

### 4.2.2. Measurement results and flood characteristics

(1) Measurement results

The measurement started at 13:00 on September 12, 1992 and finished on September 17, 1993. On December 10, 1992, interim data was recovered.

The data was plotted as graphs for visual presentation of water level fluctuations during the 365-day period. Monthly graphs were prepared as shown in App. Figures-1 to 5. The water level is based on data taken every ten minutes. The scale divisions on the X-axis is in day units (00:00 a.m.).

In addition to the maximum (MAX), minimum (MIN) and average (AVG) water levels for each month, App. Table-16 also shows average water levels during the day (7:00 to 18:00, D_AVG) and during the night (19:00 to 6:00 on the following day N_AVG). The data can also be used for an analysis of the utilisation of the National Park for ecotours required later as water level fluctuations during the day were slight, while fluctuations were prominent due to rainfall during the night during the survey period.

The average water level for each month varied from 1.9 to 2.9m, averaging 2.31m. The averages during the day and night were 2.25 and 2.36m. The value for the night was about 10cm higher, reflecting the rainfall trend.

The minumum and maximum water levels during drought were 1.72m (September, 1992) and 5.84m (September, 1993).

(2) Flood characteristics

The water-level graphs clearly show fluctuations. After the rainfalls started to increase during the second half of September, 1992, the water level repeated upward and downward fluctuations, over a range of about 1m almost everyday. The water level increased considerably during the night, reaching a maximum around midnight (0:00). Fluctuations during the day were not drastic. The water level increased very rapidly during heavy rains which occurred frequently, sometimes increasing by as much as almost 3m at a time. In months in which rainfalls were frequent, these rapid floods occurred every several days. Noevertheless, the water level would rise due to sudden heavy rain even after a prolonged dry spell, when the level had stabilised. Camping on riversides and riverbanks needs caution.

As mentioned above, changes in the water leve could be correlated with rainfalls in Kuala Belalong to some extent. Rains started to fall around 14:00 or 15:00 and continued till the night. Matching this trend, the water level started increasing from evening into the night and early morning.

Graphs were prepared to show the top six water levels recorded every hour three days before and after the level reached the maximum value during the sruvey period to analyse the trends of rises and falls. (See App. Figures-6 to 11.)

The six examples show that rapid water level rises occurred in one hour and that the maximum water level was reached in two hours after water level rises were recorded. The water level rose 2.3m in two hours. In one example, the water level rose 2.6m in three hours from the minimum water level (November 22 to 24, 1992) and 3.4m in maximum within a one-hour period (from 2.3m to 5.73m on September 1, 1993).

Figure-34 shows the rainfall on September 1 and 2, 1993, in 10-minute intervals when the water reached the highest level. The water level rose by as much as 3.43m in only 40 minutes. The level rose 1.64m in the first ten minutes and another 1.13m in the subsequent ten minutes.

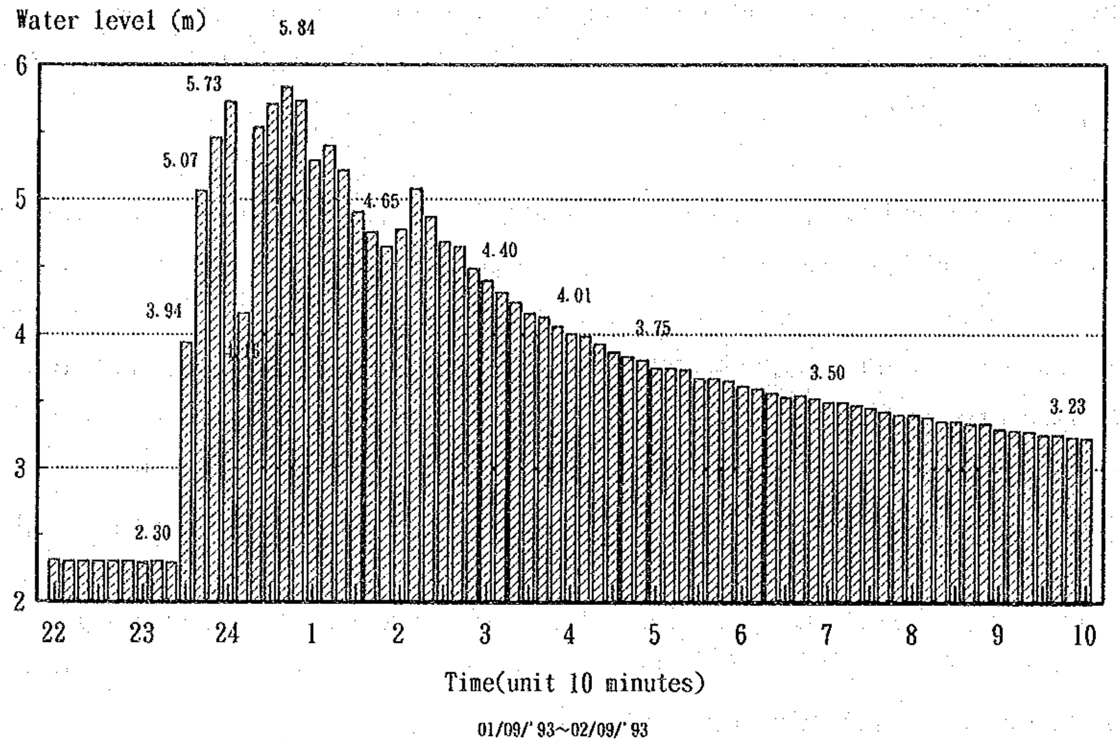



Figure-34 Stage-graph(every 10 minutes)

The water level fell nearly 1m in three or four hours, then returned to a stable level in 20 to 30 hours, shown by a gentle downward curve. Subsequent rainfall cause the water to return to a high level, and the up and down cycle is repeated.

As observed above, the water level rises very rapidly by a considerable height because the watershed is formed by sedimentary rocks of the Tertiary period with surface soil which is very shallow and thin. It is also assumed that heavy rains fall over a very wide area.

## 4.3. Flow Velocity and Discharge of the Temburong River Main Stream

Flood characteristics were studied in the previous section by mesuring fluctuations of the water level by water gauge, in order to identify hydrological characteristics of the watersheds of the Temburong River. The discharge was measured to produce a quantitative analysis of these characteristics.

### 4.3.1. Measurement results

Fixed survey lines (Survey Lines A and B) were installed about 20m downstream from the water gauge, and the discharge was calculated from the flow velocity measurements with respect to the river sectional topography.

Measurement dates and water-guage water levels (hereinafter referred to as the "water level") were as follows:

| | | | | | |
|---|---|---|---|---|---|
| 1st Measurement | Sept. | 21 '92 | 13:00 | Survey Line B | WL 1.83m |
| 2nd " | Nov. | 17 '92 | 10:30 | Survey Line A | " 2.14 |
| 3rd " | " | 21 '92 | 10:30 | Survey Line A | " 2.50 |
| 4th " | Dec. | 10 '92 | 10:30 | Survey Line A | " 2.10 |

*WL: Water level

The table shown below shows the results of discharge calculations, water level during measurement and specific discharges (liters/sec/km$^2$). The catchment area at the flow velocity survey point was 25,500 ha (255km$^2$).

Table-27 Results of the flow velocity survey

| Waterlevel (m) | Water depth(m) | Area (m$^2$) | Mean flow velocity (m/sec) | Maximum flow velocity (m/sec) | Discharge (m$^3$/sec) | Specific run-off (ℓ/sec/Km$^2$) |
|---|---|---|---|---|---|---|
| 1.83(B) | 1.85 | 12.16 | 0.27 | 0.48 | 3.29 | 12.9 |
| 2.14(A) | 1.30 | 21.74 | 0.69 | 0.95 | 14.96 | 58.7 |
| 2.50(A) | 1.70 | 30.39 | 1.14 | 1.52 | 34.61 | 135.7 |
| 2.10(A) | 1.25 | 20.73 | 0.61 | 0.95 | 12.59 | 49.4 |

Of four measurements, the first measurement recorded a water level of 1.83m which was below 1.90m recorded as the average water level for September and was halfway between the average and minimum water level of 1.72m. The water levels in the second and fourth meaurments at 2.14 and 2.10m were near the minimum water levels for November and December. The water level in the third measurement at 2.50m was near the average water levels for November and December.

The volume of data was small and discharges at water levels of 2.5 to

1.83m or lower can be estimated to some extent. However, the water levels during floods increased nearly 2.5m above the 2.5m mark, which was the highest water level recorded. The discharges at these water levels are difficult to estimate.

### 4.3.2. Hydrological characteristics viewed from drought water discharge

The water yield function which forests have is evaluated by inferring the relationship between rainfall and runoff in terms of flood control action or by measuring drought water discharge in terms of drought alleviation. Drought water discharge can be measured easily during the drought season. The Temburong River is used as a transportation means, and a low water level would directly affect river transportation. It is more realistic to take the discharge during the drought season into consideration.

During the survey period, the water level continued to be low during the middle part of September, 1992 (September 10 to 21) recording the lowest water level of the year at 1.72m. The water level in the first measurement (1.83m) was 0.11m higher than the minimum level. According to an interview survey in the survey area, the water level during the drought season can be considered to be about 1.80m. (See App. Figure-1 Transistion of water Level.)

The discharge at this time could be converted to 12.9 liters/sec/km$^2$ in specific discharge, which is a value halfway between 10 liters/sec/km$^2$, the specific drought water discharge of Japan (discharge in 355 days per year does not fall below a discharge of roughly this level) and 13.9 liters/sec/km$^2$ on average in a Neogene area.

Considering the fact that the drought discharge of a tropical rain forest area, which has no clear distinction between the rainy and dry seasons, is similar to that of an example from Japan where it does not rain for a considerably long period of time, this value can be said to be low.

This indicates that the watershed has geologically low permeability, that the direct outflow runoff during rainfall is large. The importance of virgin forests in the Ulu Temburong National Park which covers the headwaters area, must be appreciated.

## 4.4. Forest Land and River Conservation

### 4.4.1. Landslides and bank landslides

(1) Survey method

Landslide sites were surveyed by a combination of aerial photo interpretation and field survey. The aerial photo interpretation covered the entire area of 10,000ha. In the ground survey, landslide sites located inside the areas, which were walked over during forest and other surveys, were directly observed.

Conversely, in many cases, aerial photo interpretation of small landslides such as bank landslides was not possible as they were obstructed by large crowns. Therefore, landslides were observed by surveys from a boat or by reconnaissance on foot.

a. Aerial photographs

As in interpreting forest types, the aerial photographs taken in 1982 were used. The zones which could not be interpreted by these photos because of clouds were interpreted using aerial photographs taken in 1975.

The scale of the aerial photographs from 1992 was 1:40,000 which was small. Furthermore, the photo condition was poor and interpretation with the same precision as that of the 1982 photographs was not possible. Nevertheless, large landslides (80m x 80m, about 2mm x 2mm in photos) could be interpreted. This was useful in examining new landslides which occurred after 1982, and the transition of landslides.

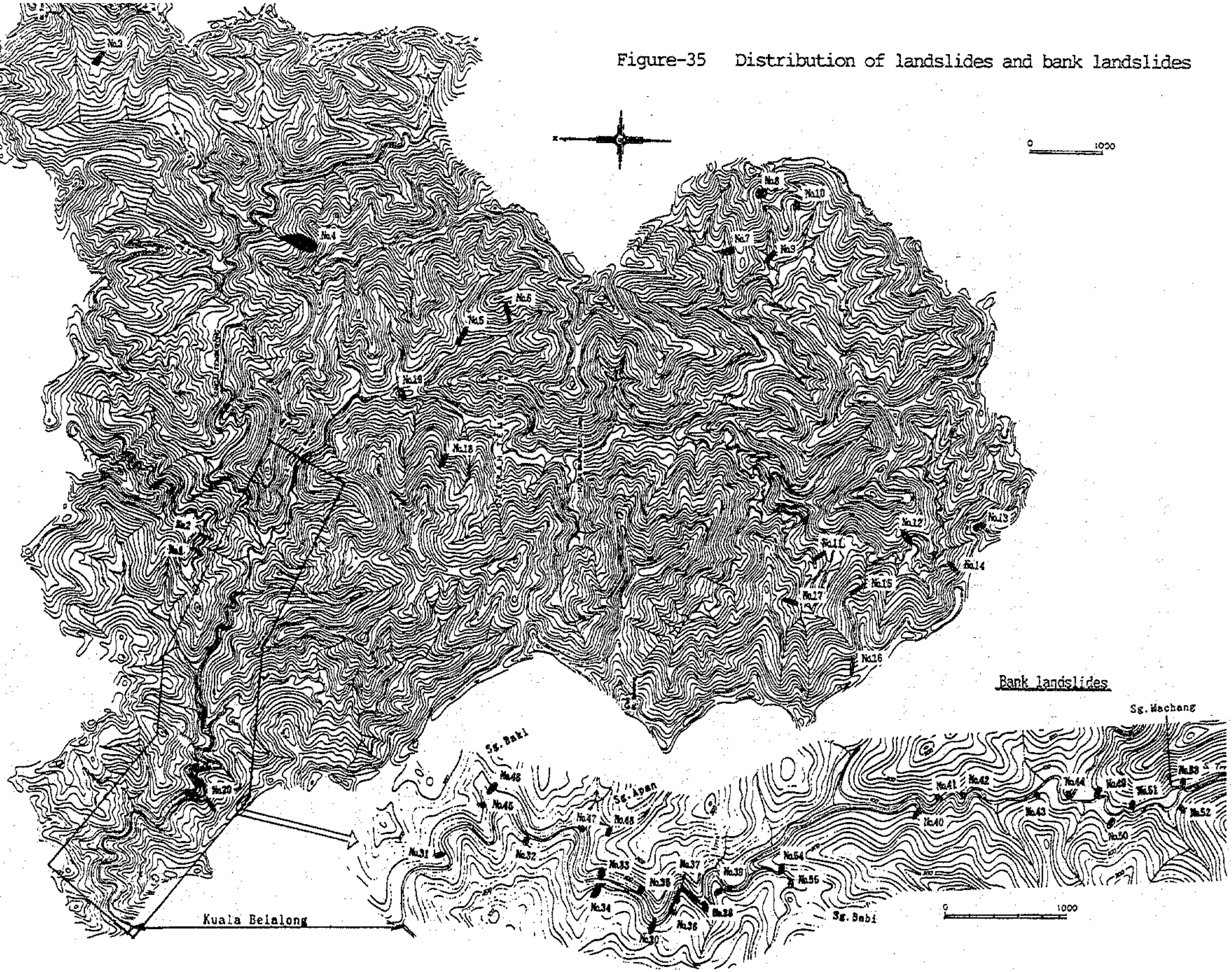
b. Field survey

As mentioned above, scales of landslides (inclinations, slope lengths and widths, etc.), vegetation condition, soil properites, and other items were surveyed. Torrents in Sg. Baki (about 300m from the entrance), Sg. Apan (about 500m), Sg. Babi (about 500m) and Sg. Machang (about 1,200m) were surveyed to identify their condition. A block of about 1,000m to Sg. Babi_2 along the main stream of the Temburong River was surveyed from a boat.

(2) Survey results

Tables-28 and 30 present the survey results by dividing landslides into landslides and bank landslides. Landslides are shown by dividing hillside slopes into upper, middle and lower parts of slopes and indicating positions of

Figure-35 Distribution of landslides and bank landslides



the landslides. The vegetation recovery condition is shown by the covering rate (%). The distribution of these landslides is shown in Figure-35.

a. Landslide sites

The survey area contained 20 landslide sites broken down into 18 places (No. 3 to 20) interpreted using the aerial photographs and two places additionally confirmed by a field survey (No. 1 and 2), totaling 12.22 ha in area.

Nearly all of them were landslides due to surface slip or creep. The No. 4 landslide was a deep landslide on the valley head of a small torrent facing the Temburong River and was different from the other landslides in nature. The scale of this landslide was large and its slope length exceeded 600m. It had an area of 4.70 ha representing 38% of the total landslide area.

Table-28 Landslides in the survey area

Survey area 11,100ha

| No. | Location | Slope (°) | Slope length (m) | Plane length (m) | Width (m) | Plane area (ha) | Vegetation (%) | Note | River (Catchment) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Upper | 50 | 50 | 32 | 20 | 0.06 | | Line like | Sg.Temburong |
| 2 | Upper | 50 | 120 | 77 | 30 | 0.23 | | Line like | Sg.Temburong |
| 3 | Upper | 40 | | 120 | 40 | 0.48 | | Line like | Sg.Sekurop |
| 4 | U-M | 35 | | 470 | 100 | 4.70 | | Land slide | Sg.Temburong |
| 5 | Lower | 40 | | 70 | 50 | 0.35 | 60 | Platy | Sg.Machang |
| 6 | Upper | 40 | | 60 | 40 | 0.24 | 60 | Platy | Sg.Machang |
| 7 | Lower | 40 | | 120 | 80 | 0.96 | 80 | Platy | Sg.Machang |
| 8 | Lower | 35 | | 40 | 80 | 0.32 | 80 | Platy | Sg.Machang |
| 9 | Lower | 35 | | 100 | 80 | 0.80 | 60 | Platy | Sg.Machang |
| 10 | Lower | 40 | | 30 | 30 | 0.09 | | Platy | Sg.Machang |
| 11 | Lower | 35 | | 100 | 40 | 0.40 | | Platy | Sg.Machang |
| 12 | U-L | 40 | | 150 | 30 | 0.45 | | Line like | Sg.Machang |
| 13 | Lower | 40 | | 30 | 40 | 0.12 | | Line like | Sg.Machang |
| 14 | Upper | 40 | | 80 | 30 | 0.24 | | Line like | Sg.Machang |
| 15 | Lower | 40 | | 100 | 30 | 0.30 | | Line like | Sg.Machang |
| 16 | Upper | 40 | | 130 | 30 | 0.39 | | Line like | Sg.Machang |
| 17 | Lower | 35 | | 160 | 60 | 0.96 | | Platy | Sg.Machang |
| 18 | Middle | 35 | | 120 | 30 | 0.36 | | Platy | Sg.Machang |
| 19 | Middle | 35 | | 25 | 90 | 0.23 | | Platy | Sg.Machang |
| 20 | Middle | 40 | | 180 | 30 | 0.54 | 70 | Line like | Sg.Temburong |
| Total | | | | | | 12.22 | | | |

The average area per landslide excluding this landslide was 0.4 ha, indicating that landslides of relatively large sizes were scattered. Nearly half of these landslides were line landslides which had narrow widths, but long slopes. These line landslides were believed to have been caused by very large falling trees, or by uprooting.

Table-29 tabulated landslides by catchment.

In the table, Tembourong comprises a small catchment facing the main stream catchment and catchments of several tributaries. the rate of landslide is the area ratio of landslides to the catchments. The figures in parentheses are the area ratios of the landslides excluding the No. 4 landslide.

According to the distribution map, landslides are concentrated in the catchments of Sg. Machang. The rate of landslides in these catchments was high. Landslides did not exist or were scattered in the other areas. Three landslides, No. 1, 2 and 20 totaling 0.83ha, were distributed in the downstream area from the confluence of Sg. Machang. Landslides could not be found in the catchments of three other tributaries including Sg. Apan. Of these landslides, Landslides No. 1 and 2 were line landslides occurring adjacent to the steep slopes near crest lines. Landslide No. 20 had a high vegetation covering ratio even in the aerial photographs taken in 1982. Vegetation has now recovered to such an extent that field confirmation is difficult.

Table-29 Landslides in each catchment

| Catchment | Catchment area (ha) | Number | Total area (ha) | Rate of Landslide(%) |
|---|---|---|---|---|
| Sg.Baki | 40.0 | | | |
| Sg.Apan | 144.1 | | | |
| Sg.Babi | 773.6 | | | |
| Sg.Machang | 5,645.0 | 15 | 6.21 | 0.11 |
| Sg.Sekurop | 736.3 | 1 | 0.48 | 0.07 |
| Sg.Temburong | 3,761.0 | 4 | 5.53 | 0.15(0.02) |
| Total | 11,100.0 | 20 | 12.22 | 0.11(0.07) |

Eleven of the 15 landslides in the Sg. Machang catchment, which had the next highest landslide ratio, occurred in the steep slopes of headwater zone.

These headwater zones were surrounded by crest lines branching from Bt. Belalong and could be devided roughly into two catchments. Both catchments showed topography which had high dissection and the valley density was high. The main stream meandered prominently and catchments showed complex topography. The geology in the area was frail and weak, but the landslides were distributed mainly near the crest lines surrounding the catchments. The headwater zones of these catchments including these crest lines and the Belalong catchment side were analysed as having high collapsing characteristic.

As mentioned earlier, a large number of line landslides could be found. These landslides started on a small scale and caused the falling of very large trees or were triggered by the falling of very large trees. This destroyed vegetation in the lower parts of long steep slopes and caused line landslides. (Landslides of this scale were very difficult to interpret by contact aerial photographs.) These landslides were believed to have expanded to nearby areas due to repeated heavy rains.

b. Bank landslides

As mentioned above, bank landslides could not be interpreted by aerial photos and the entire survey area could not be covered. Therefore, bank landslides were totalled separately from hillside landslides in this survey.

The survey range covered areas along rivers and small torrents inside the area to be used by ecotours. A total of 25 bank landslides 0.86 ha in area were observed. The average area per landslide was 0.03 ha and was considerably small in scale compared with landslides.

Table-31 summarizes bank landslides by catchment. The table shows river survey lengths, instead of catchment areas, and the number of bank landslides per km as a frequency of occurrence.

In terms of frequency, bank landslides occurred most frequently with small torrents, four to seven locations per km. In the main stream of the Temburong River, 1.4 landslides could be found per km. Fourteen landslides totaling 0.44 ha in area could be found before reaching Sg. Machang.

Many of bank slopes along the Temburong River had gentle slopes continuing above the lower steep slopes which have thin surface soil. Landslides occurred on these steep slopes, but the lengths of the slopes were not very long. In many cases, giant trees had fallen and many of these fallen trees remained inside collapsed land. Collapsed sediment was washed away by the main stream, whose water level increased freuently, and bedrocks were exposed at the foot of collapsed land.

Collapsed sediment was weathered and become fine grained in branch torrents which had small discharges, flowing down to, and depositing in, the downstream areas of the branch torrents. Many fallen trees could also be found in the branch torrents and an accumulation of them could be found in a large number of places.

Collapsed sediment was dammed up and accumulated where channels were blockaded by fallen trees. When this collapsed sediment was broken by heavy rains, the sediment would most probably become a debris flow and was carried into the main stream

Table-30 Results of bank landslide survey

| No. | Location | Slope (°) | Slope length (m) | Plane length (m) | Width (m) | Plane area (ha) | Vegetation (%) | Note | River (Catchment) |
|---|---|---|---|---|---|---|---|---|---|
| 31 | Bank | | | 15 | 8 | 0.01 | | | Sg.Temburong |
| 32 | Bank | | | 40 | 20 | 0.08 | | | Sg.Temburong |
| 33 | Bank | 45 | 25 | 17 | 10 | 0.02 | | Rock | Sg.Temburong |
| 34 | Bank | 35 | 30 | 24 | 15 | 0.04 | | | Sg.Temburong |
| 35 | Bank | 35 | 30 | 24 | 10 | 0.02 | | | Sg.Temburong |
| 36 | Bank | 45 | 20 | 14 | 8 | 0.01 | | | Sg.Temburong |
| 37 | Bank | 40 | 30 | 22 | 10 | 0.02 | | | Sg.Temburong |
| 38 | Bank | 34 | 50 | 41 | 8 | 0.03 | | | Sg.Temburong |
| 39 | Bank | 45 | 20 | 14 | 10 | 0.01 | | Rock | Sg.Temburong |
| 40 | Bank | 47 | 35 | 23 | 20 | 0.05 | | | Sg.Temburong |
| 41 | Bank | 48 | 25 | 16 | 8 | 0.01 | | Rock | Sg.Temburong |
| 42 | Bank | 40 | 15 | 11 | 15 | 0.02 | 60 | | Sg.Temburong |
| 43 | Bank | 42 | 55 | 40 | 25 | 0.10 | | New | Sg.Temburong |
| 44 | Bank | 38 | 25 | 19 | 10 | 0.02 | | | Sg.Temburong |
| 45 | Bank | | 15 | 15 | 20 | 0.03 | 80 | Restoration | Sg.Baki |
| 46 | Bank | | 30 | 30 | 30 | 0.09 | 80 | Restoration | Sg.Baki |
| 47 | Bank | 40 | 25 | 19 | 10 | 0.02 | | | Sg.Apan |
| 48 | Bank | 33 | 30 | 25 | 20 | 0.05 | 60 | | Sg.Apan |
| 49 | Bank | | | 30 | 8 | 0.02 | | | Sg.Machang |
| 50 | Bank | 38 | 30 | 23 | 10 | 0.02 | 80 | | Sg.Machang |
| 51 | Bank | 38 | 30 | 23 | 15 | 0.03 | 60 | | Sg.Machang |
| 52 | Bank | 38 | 20 | 15 | 10 | 0.02 | 80 | Restoration | Sg.Machang |
| 53 | Bank | 40 | 40 | 30 | 10 | 0.03 | 80 | | Sg.Machang |
| 54 | Bank | 40 | 100 | 76 | 10 | 0.08 | 80 | Restoration | Sg.Babi |
| 55 | Bank | 35 | 25 | 20 | 15 | 0.03 | | | Sg.Babi |
| Total | | | | | | 0.86 | | | |

Observing the degree of recovery of landslides, bush trees and herbs were growing over about half the number of collapsed land areas with exposed rocks, indicating that these areas were recovering naturally. Land where trees were dominant were mentioned specifically as naturally recovered land. (See Table-30 above.) As shown in the table, vegetation cover was progressing in four naturally recovered zones and in five other zones. Bank landslides expanding nearby and depositing sediment at a lower level could not be found. Thus, landslides tend to recover unexpectedly strongly due to the power of nature, even though the speed of recovery varies.

Table-31 Bank landslides in each catchment

| Catchment | Survey Length(Km) | Number | Total area (ha) | Rate of Landslide |
|---|---|---|---|---|
| Sg.Baki | 0.3 | 2 | 0.12 | 6.7 Num./Km |
| Sg.Apan | 0.5 | 2 | 0.07 | 4.0 |
| Sg.Babi | 0.5 | 2 | 0.11 | 4.0 |
| Sg.Machang | 1.2 | 5 | 0.12 | 4.2 |
| Sg.Temburong | 10.1 | 14 | 0.44 | 1.4 |
| Total | 12.6 | 25 | 0.86 | 2.0 |

(3) Impacts on park utilisation

Landslides result in devastation of forest land, and sediment runoff due to torrents can lead to disasters. Howerver, hillside landslides in the survey area were scattered deep inside the area and the possibility of sediment runoff to the downstream catchments seemed to be low.

Bank landslides along the banks were not large scale, and bedrocks were exposed at the foot of these bank landslides. This seems to have stopped further foot erosion, and expansions of landslides could not be found in most cases. Slopes which had recently collapsed damaged natural landscapes. This must be the general observation. However, the recovery power of nature can be observed on these slopes which are returning to forest land naturally and this is one way of arousing awareness of nature.

Regarding bank landslides, more attention must be paid to the impact made by fallen trees caused by landslides becoming driftwood and affecting the stability of torrents and safety of torrent utilisation, rather than to the amount of sediment. This will be discussed in the next paragraph. "Driftwood and fallen trees". However, the use of fallen trees remaining in bank landslides is also an effective method of stabilising the surface soil and accelerating natural restoration.

Several waterfalls set in striking landscapes could be found in branch torrents. A means of reaching them could be considered in the future as a torrent observaton route. In this case, it is also fun to go underneath or climb over fallen trees in a torrent course. If there are many fallen trees, this will present a problem in terms of pleasant walking conditions. Many areas near banks are steep and have unstable soil. If these areas are to be used as part of a hillside track, a route should be selected carefully and structures should be used on steep slopes of the banks so that these slopes would not become landslides.

### 4.4.2. Driftwood and fallen trees

(1) Survey method and results

Driftwood and fallen trees were observed from a boat along the main stream from Batang Duri to Sg. Machang. The present situation on the left and right banks of the Batang Dur~Kuala Belalong, Kuala Belalong~Sg. Apan and Sg. Apan~Sg. Machang blocks were interpreted. Tables-32 to 34 present the results of this survey.

a. Batang Duri~Kuala Belalong block

This was a channel 7.5km in length between Batang Duri and Kuala Belalong. Driftwood found was 103 pieces in 38 places on the right bank and 52 pieces in 28 places on the left bank. Specific examples of driftwood remaining ner the banks are: for example, in Place No. 1 on the right bank, one piece of driftwood was found. It measured 1m in length. Three pieces were found on the left bank, measuring about 15m each. In Place No. 10 on the left bank, two pieces of driftwood were 5m long three pieces were 3m long and three pieces were 2m long.

Fallen trees totalled 15 in seven places on the right bank. Nine fallen trees were found in six places on the left bank. These fallen trees were found in steep bank hillsides of the Temburong River forming a V-shaped valley and had fallen as a result of imbalance between crown weight and root swelling caused by strong rains or weathering of debris.

Table-32 Driftwood and fallen trees (Batang Duri ~Kuala Belalong)

| Survey No. | Driftwood (Number*Length) | | Fallen trees (Number*Length) | |
|---|---|---|---|---|
| | Right bank | Left bank | Right bank | Left bank |
| 1 | 1*1 | 3*15 | 1*10,1*5 | 2*10 |
| 2 | 4*5 | 1*10 | 1*10 | 1*10 |
| 3 | 1*15 | 5*10 | 1*15,1*10 | 2*20 |
| 4 | 1*10 | 1*10 | 2*10 | 1*20 |
| 5 | 1*15 | 1*15 | 1*10 | 2*15 |
| 6 | 7*10 | 1*15 | 5*15 | 1*10 |
| 7 | 3*7 | 2*7 | 2*10 | |
| 8 | 2*8 | 1*4 | | |
| 9 | 3*5 | 1*7 | | |
| 10 | 2*7 | 2*5,3*3,1*2 | | |
| 11 | 2*10 | 1*10 | | |
| 12 | 1*15 | 1*12,1*7 | | |
| 13 | 1*10 | 3*10,1*15 | | |
| 14 | 2*7 | 1*10 | | |
| 15 | 1*7,1*10.1*5 | 1*10 | | |
| 16 | 1*3,1*1 | 2*5 | | |
| 17 | 3*10,2*5 | 2*10 | | |
| 18 | 2*10 | 2*10 | | |
| 19 | 2*7,1*7 | 1*15 | | |
| 20 | 1*7 | 2*10 | | |
| 21 | 1*7 | 2*10,2*7 | | |
| 22 | 1*15 | 1*10 | | |
| 23 | 2*15 | 1*20 | | |
| 24 | 4*10 | 1*10 | | |
| 25 | 1*15 | 1*5 | | |
| 26 | 1*20,4*10 | 1*20 | | |
| 27 | 2*15 | 1*10 | | |
| 28 | 5*15,2*10 | 2*15 | | |
| 29 | 2*10 | | | |
| 30 | 1*15,1*10 | | | |
| 31 | 5*10,3*7 | | | |
| 32 | 4*7 | | | |
| 33 | 1*10 | | | |
| 34 | 6*20 | | | |
| 35 | 1*20 | | | |
| 36 | 1*20,2*10,2*7 | | | |
| 37 | 3*5 | | | |
| 38 | 1*20 | | | |
| Total | 103 Pieces | 52 Pieces | 15 Trees | 9 Trees |

Note : 1*15 1---Number of Pieces or Trees. 15---Length of Wood or Tree in meter.

b. Kuala Belalong~Sg. Apan block

Driftwood totalled 29 in 14 places on the right bank and 52 in 16 places on the left bank in a 2.6 km block between Kuala Belalong and Sg. Apan. Six fallen trees were found in four places on the right bank, and five trees in four places on the left bank.

c. Sg. Apan~Sg. Machang block

The channel between Sg. Apan and Sg. Machang totaled 5.7 km. Driftwood in this block totalled 86 in 25 places on the right bank and 105 in 32 places on the left bank. Eighteen fallen trees in 11 places on the right bank and 31 in 18 places on the left bank were counted.

Table-33 Driftwood and fallen trees (Kuala Belalong ~Sg.Apan)

| Survey | Driftwood (Number*Length) | | Fallen trees (Number*Length) | |
|---|---|---|---|---|
| No. | Right bank | Left bank | Right bank | Left bank |
| 1 | 2*10 | 5*20,2*7,3*7 | 1*20 | 2*20 |
| 2 | 3*20 | 2*20 | 1*10 | 1*20 |
| 3 | 2*15 | 1*10,2*5 | 2*10 | 1*10 |
| 4 | 1*7 | 1*20 | 2*15 | 1*15 |
| 5 | 2*10 | 2*7 | | |
| 6 | 2*10,1*7 | 1*5 | | |
| 7 | 3*10 | 3*10 | | |
| 8 | 3*15,1*7 | 4*10 | | |
| 9 | 1*10 | 5*10 | | |
| 10 | 1*10,1*5 | 1*5 | | |
| 11 | 1*15 | 2*7 | | |
| 12 | 2*5 | 1*5 | | |
| 13 | 2*10 | 3*5 | | |
| 14 | 1*20 | 10*15 | | |
| 15 | | 1*10 | | |
| 16 | | 3*7 | | |
| Total | 29 Pieces | 52 Pieces | 6 Trees | 5 Trees |

Note : 1*15 1---Number of Pieces or Trees. 15---Length of Wood or Tree in meter.

Table-34 Driftwood and fallen trees(Sg.Apan ~Sg.Machang)

| Survey | Driftwood (Number*Length) | | Fallen trees (Number*Length) | |
|---|---|---|---|---|
| No. | Right bank | Left bank | Right bank | Left bank |
| 1 | 7*5 | 5*10 | 1*15 | 1*15 |
| 2 | 1*15 | 1*5 | 1*15 | 1*10 |
| 3 | 5*5 | 2*15 | 2*10 | 1*10 |
| 4 | 2*10 | 5*10 | 1*10 | 3*15 |
| 5 | 1*10 | 2*10 | 1*10 | 2*20 |
| 6 | 2*10 | 3*5,5*5,2*10 | 1*10,1*5 | 1*10,1*15 |
| 7 | 1*10 | 1*5,1*7,3*3 | 3*10 | 5*15 |
| 8 | 1*15,1*10,1*7 | 1*10,3*5,1*7 | 1*10 | 1*20 |
| 9 | 1*10 | 1*5 | 1*10,1*7 | 1*7 |
| 10 | 5*5 | 2*15,1*10 | 1*10 | 1*10 |
| 11 | 2*15 | 1*15 | 3*10 | 1*7 |
| 12 | 1*15 | 2*10 | | 1*10 |
| 13 | 3*3,3*5,2*7 | 1*10,1*5 | | 2*10,1*20 |
| 14 | 1*15 | 5*10,5*3,3*3 | | 1*15 |
| 15 | 1*15 | 2*15 | | 2*20 |
| 16 | 1*10 | 2*20 | | 1*20 |
| 17 | 3*10 | 7*5 | | 1*10 |
| 18 | 2*15,1*10 | 1*10 | | 3*10 |
| 19 | 3*5,2*7 | 1*5 | | |
| 20 | 2*20 | 1*10 | | |
| 21 | 5*10,2*15,3*5 | 1*10,3*5,5*5 | | |
| 22 | 3*15,5*10,7*5,3*5 | 1*7 | | |
| 23 | 1*15 | 1*10 | | |
| 24 | 1*10 | 5*10 | | |
| 25 | 1*15 | 1*10 | | |
| 26 | | 1*15,1*10 | | |
| 27 | | 1*15,1*5 | | |
| 28 | | 3*10 | | |
| 29 | | 2*10,1*7 | | |
| 30 | | 5*5 | | |
| 31 | | 1*10 | | |
| 32 | | 1*10 | | |
| Total | 86 Pieces | 105 Pieces | 18 Trees | 31 Trees |

Note : 1*15 1---Number of Pieces or Trees. 15---Length of Wood or Tree in meter.

(2) Impacts on park utilisation

Driftwood and fallen trees are a product of the dynamics of nature and often form desolate landscapes in static natural parks. They not only lower the torrent stability, but also damage natural landscapes in the Ulu Temburong National Park, which uses river channels as a means of access. Furthermore, driftwood and fallen trees produce psychological impacts on ecotourists. It will be advisable to remove them by some method to avoid these impacts. The following three methods are proposed for removing driftwood and fallen trees:

1) Carrying driftwood and fallen trees to safe places.

2) Positive utilisation of driftwood and fallen trees by incorporating them in Park facilities, e.g., footpaths and other purposes.

3) Leave driftwood and fallen trees where they are now.

Some of the driftwood and fallen trees become weathered or covered by moss over a long period of time and have blended as one with nature. The method 3) is suggested for such cases by leaving driftwood and fallen trees safely where they are.

### 4.4.3. Gravel on stream beds and sedimentation conditions

The characteristics of the Ulu Temburong National Park are that the park offers opportunties not only for walking in jungles of tropical rain forests which are strictly conserved, but also in experiencing primeval river journeys using the Temburong River as a means of access to fully enjoy the rich waterside environment where green and water harmonise.

The gravel which forms river beds of the Temburong River and its tributaries, as well as the sedimentation condition of the gravel, wre surveyed to study the stability and safety of these water courses.

(1) Survey method

Information regarding the degree of devastation of the main stream and its principal tributaries, the positions and extent of large areas of sedimentation, the existence, or otherwise, of sources, together with other matters, was gathered by a field survey.

The distribution of areas of sedimentation from interpretation of the aerial photographs was compared with the results of the field survey.

(2) Survey results

The areas, channel lengths, elevation differences and slopes of stream beds in the catchments surveyed are shown below.

As in the previous paragraph, the catchment areas of the Temburong River includes catchments of the small branch torrents along the main stream, together with other tributaries.

Table-35 Outline of each catchment

| Catchment | Catchment area (ha) | Channel Length(m) | Elevation (m) | Slope of stream bed (%) |
|---|---|---|---|---|
| Sg.Baki | 40.0 | 420 | 60 | 14.3 |
| Sg.Apan | 144.1 | 1,420 | 165 | 11.6 |
| Sg.Babi | 773.6 | 5,400 | 200 | 3.7 |
| Sg.Machang | 5,645.0 | 19,200 | 445 | 2.3 |
| Sg.Sekurop | 736.3 | 3,600 | 165 | 4.6 |
| Sg.Temburong | 3,761.0 | 18,700 | 95 | 0.5 |
| Total | 11,100.0 | | | |

a. Stream beds of the Temburong River

The main stream of the Temburong River in the survey area, follows a meandering course, through steep hillside slopes formed by shale of the Tertiary stratum. The stream beds of the river are formed by a thick sedimentary layer of soft and fine-grained gravel produced in the survey area together with hard rocks of a sandstone type which differs from the lithology of the survey area.

Generally, when large-scale movement of soil occurs by a large flood or other reasons, areas of sedimentation containing large-diameter gravel are formed. These areas of sedimentation are scoured by subsequent small and medium floods or by annual runoff. Soil and gravel of grain size in accordance with the discharge are removed, resulting in the formation of various rapids and deep pools. Areas of sedimentation are then left as a terrace type of topography or as sandbars.

These sedimentary deposits were found distributed over six areas during the survey of the Kuala Belalong-Sg. Machang block. (See Figure-36.) App. Figure-12 typifies the centre transversal topography of these areas of sedimentation. Of these areas of sedimentation, Area No. 2 was the only area which clearly remained as a terrace type of topography. Shrubs which could be found frequently on banks were growing on areas of sedimentation. Similar trees grew on sandbars in Area No. 1, but could not be found in the other areas of sedimentation. This shows that the other areas were flooded frequently by freshets. Table-36 shows the extent of these areas of sedimentation by estimation. The lateral profiles and values shown, assume a use the water level of 2.8m (December 1).

Table-36 Area of sedimentation

| No. | Length (m) | Width (mean,m) | Area ($m^2$) | No. | Length (m) | Width (mean,m) | Area ($m^2$) |
|---|---|---|---|---|---|---|---|
| 1 | 200 | 25 | 5,000 | 4 | 170 | 35 | 5,950 |
| 2 | 160 | 30 | 4,800 | 5 | 100 | 40 | 4,000 |
| 3 | 250 | 20 | 5,000 | 6 | 130 | 30 | 3,900 |

This water level is about 30cm higher than the average water level for November and December. At this water level, entire stream beds approximately 30m in width become channels, while on stream beds more than 40m in width about 10m of slightly higher areas of deposition remain above the water surface. Seven floods registering more than 2m above this water level were recorded since measurement of the water level began. However, great variations were not reported in the deposition state.

Small-scale areas of sedimentation continued intermittently upstream to Sg. Machang, alternating with rapids. Stream beds with flat bottoms and narrow widths (20 to 30m) could be found in relatively straight blocks. Figure-36 illustrates these blocks considering them as "Equilibrium area" for the sake of convenience, and differentiating them from sedimentation blocks.

The table shown below presents the results of a survey of maximum, minimum and average grain diameters from the various areas of sedimentation. This table is intended to show the difference between sediment transported from branch torrents and river bed sediment of the main stream. The average grain diameters were obtained by selecteing typical areas of sedimentation and by measuring gravel diameters on three 2m lines. The differences in grain diameters were clear. The same sandstone gravel as could be found in the main stream was mixed in Sg. Machang and the average grain

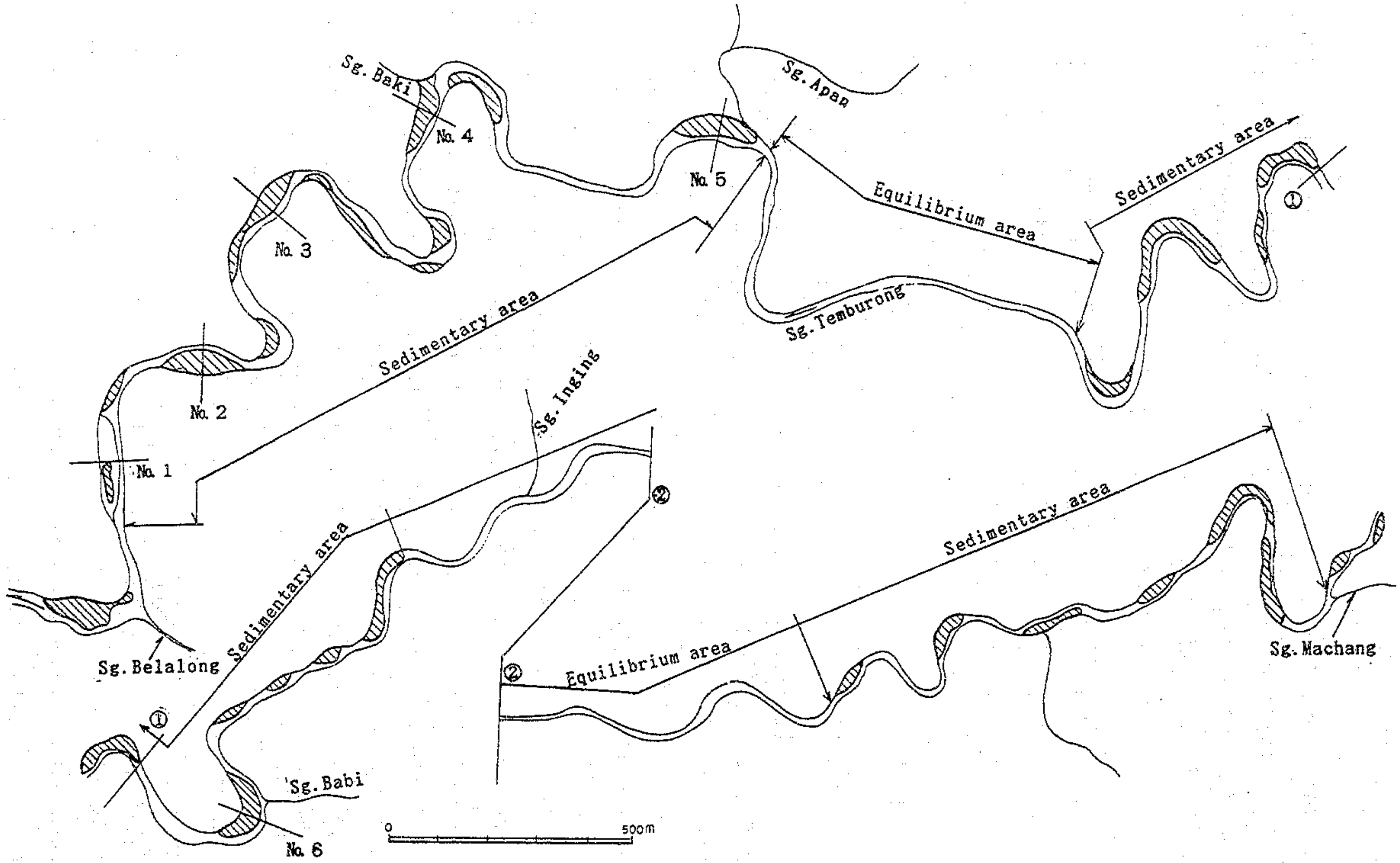



Figure-36 Distribution of sedimentary area diameter was generally intermediate.

Table-37 Grain diameter at each sedimentation site

| Place | Grain diameter | | | Place | Grain diameter | | |
|---|---|---|---|---|---|---|---|
| | Min. | Max. | Average | | Min. | Max. | Average |
| No.1 | 2 | 60 | 14.3 | No.6 | 2 | 60 | 15.2 |
| No.2 | 1 | 55 | 13.8 | Sg.Apan | 1 | 22 | 3.8 |
| No.3 | 2 | 50 | 16.8 | Sg.Babi | 1 | 20 | 3.5 |
| No.4 | 2 | 60 | 13.5 | Sg.Machang | 1 | 60 | 6.8 |
| No.5 | 2 | 70 | 14.5 | | | | |

b. Distribution of areas of sedimentation by aerial photograph interpretation

The contact photos on a scale of 1:25,000 taken in 1982 when the water level was low, enabled a relatively clear interpretation of the condition of the stream beds. Channels with river bed widths of about 50m could be identified. Channels below 50m in width could not be interpreted. Blocks in which dry riverbeds about 30m in width could be distinguised, but in which channels could not be found were classified as sedimentation zones where the sedimentation was thick and channels shifted to either the left or right bank.

App. Figure-13 was prepared as a distribution map classifying the area upstream from the confluence of Sg. Machang into sedimentation and flowing zones.

In the block between Kuala Belalong and Sg. Machang the distribution was collated by the field survey, and distribution by photo interpretation was used to verify whether or not large distribution variations existed. Large variations could not be found in the stretch of river containing sedimentation areas No. 1 to 6.

Interpretation of the aerial photographs showed that similar conditions continued for approx. 8km upstream of the survey area. In some areas, there were sedimentation sites more than 60m in width. Thus, the present river beds of the Temburong River are assumed to have been formed by repetitive sedimentation of gravel from upstream by bed load transport during freshets.

c. Condition of the tributaries

The results of a survey of the condition of the downstream areas of the principal tributaries between Kuala Belalong and Sg. Machang are described below.

(a) Sg. Baki and Sg. Apan catchment

These are two small torrents located on the right downstream bank of the Temburong River. Sediment (diameter 1 to 10cm) from hillsides upstream was transported and formed deposits 5 to 8m wide, over about 2% of the downstream area, extending about 200m from their entrances. The stream bed widths in the upstream of the two catchments became narrow and the stream bed gradient became steep, 5%. Stream beds with heads formed by an accumulation of generally flat rocks (maximum major axis 2m), produced by crushed and fallen bedrocks, continued here and there. Hard bedrocks formed waterfalls with a head of 10 to 20m in several places. One waterfall in Sg. Baki and four waterfalls in Sg. Apan could be found in the reconnaissance area.

Steep hillsides continued and many slopes had a thin layer of soil on their surfaces. Many cracks could be found, indicating these hillsides were made up of fragile rocks. Collapse and fall of these rocks was supplying sediment of fine grain size to stream beds and was the cause of many fallen trees. These were the characteristics of devastation.

(b) Sg. Babi catchment

This was a catchment located on the right bank of the Temburong River having a catchment area which was medium in size for the survey area. Dissection progressed in catchments of this scale and the average stream bed gradient would become gentle, 3.7%. Much sediment was transported. As in Sg. Apan, sediment of a fine grain size was deposited in 1 to 2% of the entire downstream areas. A bedrock zone assumed to have formed waterfalls a long time ago had been deeply eroded, producing narrow ravines here and there. Large numbers and fallen trees together with driftwood had accumulated. Several places could be found in downstream parts of bank landslides where sedimentation was dammed up. Clearing these places would further devastate the areas.

(c) Sg. Machang catchment

This catchment was located in an intermediate area of the catchment to be surveyed and was the tributary with the largest catchment area within it. The headwaters part of this catchmennt wad deep inside an area enclosed by creat lines leading from Bt. Belaong. The river continuously meandered prominently to near this headwaters part and the catchment had complex topography. The average stream bed gradient was gentle, 2.3%. Unlike other branch torrents, sediment forming stream beds contained a large amount of hard sandstone gravel 20 to 70cm in size as in dry riverbeds of the main stream of the Temburong River, together with weathered and fine-grained pebbles supplied from nearby hillsides. This gravel formed dry riverbeds containing driftwood. Bank landslides about 30m in slope length could be found scattered on bank hillsides. Vegetation covered many of these areas and extensive surface erosion could not be found.

(3) Impacts on Park utilisation

The stream beds of the Temburong River maintain their present state of equlibrium due to repeated transport and sedimentation of medium and large-diameter sandstone gravel continuing from areas further upstream. Inevitably, boat transportation is sometimes not possible for short periods of time due to movement of sediment, as long as the rivers remain in their natural state. Minimum dredging of stream beds must be studied in future in order to be assured of transportation even during low-water periods.

Driftwood is considered to cause great impacts to river beds and channels in normal floods. In this area, fallen trees which have become driftwood are long and large and remain in the upstream zones of the areas of sedimentation to form natural dams. There is a high possibility that these channels would be greatly changed by abnormal sedimentation of bed loads.

In order to prevent this, the utilisation and disposal of driftwood without greatly changing natural landscapes and river ecosystems, while paying attention to the accumlation of driftwood, should be studied as mentioned before.

## 5. Animals in the National Park

### 5.1. Objectives of the survey

Understanding the state of wildlife inhabitation, together with the vegetation, is essential when planning the forest management of the Ulu Temburong National Park, where the primitive natural ecosystem is well preserved.

The following surveys were conducted to fulfill the survey objectives, which were to collect the basic data.

It is desirable to prepare further substantial data through communication with UBD from now on, which will provide information beneficial for visitors.

The survey of wildlife inhabitation was mainly of mammals and birds, and was conducted by interviews and by referring to reference literature.

1) Reference literature and existing information

A check list of terrestrial mammals known to inhabit Borneo was prepared by studying reference literature. Species recorded as inhabiting Ulu Temburong and Brunei Darussalam were selected from the check list.

A list of birds recorded to inhabit Ulu Temburong was prepared using survey reports by University of Brunei Darussalam and other sources.

2) Field survey

"A Field Guide to the Mammals of Borneo," The Sabah Society, 1985, was shown to employees of the Forestry Department and to workers employed in the survey area totaling seven persons. They were asked if they had seen or captured any of these birds or mammals inside the National Park.

Maximum efforts were made during forest and other surveys to confirm the habitation of mammals and birds through field signs such as droppings, nibbles and footprints.

An entry was made in the check list as to whether or not they were rare species, precious species or preservation animals. The entries were made based on the following criteria.

Evaluation by the International Union for Conservation of Nature and Natural Resources (IUCN), designation in the appendices to the Washington Convention (Convention on International Trade in Endangered Species of Wild Fauna and Flora [CITES]), and the method of indicating the preservation-species designation for Brunei Darussalam. These are outlined below:

(1) Evaluation of danger degree by International Union for Conservation of Nature and Natural Resources (IUCN)

X (Extinct species) :

Animal species whose existence in the wilderness has not been confirmed in the past 50 years.

E (Endangered species) :

Animal species which are facing danger of extinction and have a high probability of extinction unless the factors causing their decreasing numbers are removed. Also animal species whose existence in the wilderness has been confirmed in the past 50 years, but are believed to have already become extinct by now.

V (Vulnerable species) :

Animal species which have a high probability of becoming endangered species unless the factors causing their decreasing numbers are removed in the near future. The species include those whose numbers are drastically decreasing by excessive seizure or large-scale destruction of their natural habitat, those whose numbers are decreasing rapidly and which may become extinct in future, and those whose numbers are large at present, but where there is an approching serious threat to their entire habitat.

R (Rare species) :

Animal species requiring special attention due to their small numbers, even though they are not classified as endangered or vulnerable species. Animals whose inhabiting areas are extremely limited or whose inhabiting densities are low.

I (Indeterminate species) :

Animal species which are classifie as endangered, vulnerable or rare species, but whose exact species cannot be determined because of lack of information.

K (Insufficiently Known species) :

Animal species which are suspected to belonging to one of the above-mentioned groups, even though a decision cannot be made due to lack of information.

T (Threatened species) :

Animal species including subspecies about which a different evaluation is made.

(2) Limits on international transactions by appendices to Washington Convention (CITES - Convention on International Trade in Endangered Species of Wild Fauna and Flora)

I (Appendix I)

Animal species which are facing danger of becoming extinct and are affected or may be affected by transactions. International transactions for commercial purposes are prohibited. Both export and import permits are needed for export and import for academic research purposes.

II (Appendix II)

Animal species which are not necessarily endangered, or in danger of becoming extinct at present, but which may become extinct unless transactions are limited. Export permits are needed for international transactions for commercial purposes.

(3) Conservation of animal species by Wild Life Protection Laws of Brunei Chapter 102

Animal species prohibited to be hunted, slaughtered orcaptured without receiving permits which are given only for scientific purposes.

7 mammal species, 23 bird and 4 reptile species are designated.

## 5.2. Survey Results

1) Preparation of check lists

As reference data, The Brunei Museum has been conducting surveys of animals from time to time and results of these surveys are reported in the Brunei Museum Journal issued every year. This was used as reference data. Additionally, many researchers were conducting surveys in an area of approximately 5,000ha as part of the tropical rain forest research project of the University of Brunei Darussalam and information on mammals and birds could be obtained from the UBD Biological Research Laboratory, which was the contact for the research project.

App. Table-17 and 18 annexed to this report list mammals and birds identified mainly by using this data appearing in the Appendix. In the past, 55 mammal species and 239 bird species had been reported in or near the

National Park area.

2) Field survey

Visual confirmation of mammals was not possible during field surveys such as a forest survey. The species could not be confirmed through voice or other forms. As traces, five traces of sun bear claws and footprints of bearded pigs and of several ungulate species could be confirmed in dry riverbeds and in forests. The only birds that could be found were little herons and several kingfishers (stork-billed, blue-banded and blue-eared kingfishers) spotted along the rivers while cruising by boat, as well as hornbills flying in the sky almost everyday.

The interview survey was conducted with six workers who were locally hired and one Forestry Department employee. A large number of mammal species could be confirmed. However, the information was obtained based on pictures in pictorial books and there were some uncertain elements. The checks were made by classifying the species into definite and slightly definite in accordance with the views of the seven persons interviewed. The results of the checks were listed in the check lists. A total of 44 mammals could be identified including 17 species which were not included in the report for the areas near the National Park.

The foregoing can be summarised as follows:

Forest mammals inhabit in large numbers and in large variety thanks to the rich growth environment, forest conservation policies of Brunei Darussalam, control on hunting and other factors. According to a survey by the UBD, Bornean gibbons and grey leaf monkeys, which were large arboreal primates, as well as longtailed macaque and pig tail macaque, were inhabiting in large numbers. A large variety of carnivores could also be found. If lucky, several species of otters, civets, mongooses, and sun bears could be viewed. Among the ungulates, bearded pigs, which are ranked V by IUCN, were inhabiting throughout the survey area. Footprints and roosts of barking deer, samber deer and other ungulates could be found.

According to the latest bird survey by the UBD, 184 bird species have been confirmed in the survey area of 5,000ha. Of those 124 species were found around waterside forests, 132 species on slopes up to 460m in altitude and 83 species at altitudes above 460m. One characteristic is that there are only 55 bird species inhabiting in lower-layer plant communities and that a large variety of birds inhabit canopies.

Among the avifauna, brown-eared bulbuls, robins, crested flycatchers, cuckoos and others are many. The number of hornbills is especially large. There are seven species: white-crowned hornbill, black hornbill, bushy crested hornbill, wreathed hornbill, wrinkled hornbill, rhinocerous hornbill, and helmeted bornhills. They can frequently be spotted from boats as they leisurely fly from one large crown to another high in the sky. Other report also confirmed pied hornbills. All the hornbill species listed as conservation species of Brunei Darussalam are inhabiting. Of these hornbill species, helmeted hornbills are a rare species in the world.

## 6. National Park Development Plan

### 6.1. Approach to the National Park Development Plan

The National Park area is covered by tropical rain forests. As a treasure-house of animals and plants and as a system of environmental conservation on a global scale, tropical rain forests are attracting great concern from all the people throughout the world. Recently, tropical forests, which account for about 50% of all forests on the earth, have been decreasing at an accelerated speed of more than 10 million ha per year, hence the existence of these great forests handed down from the primitive ages will increase in value at an accelerated pace.

National Park areas are areas regarded as "ones that include geological and topographical formations of special interest and which are reserved to maintain biologically diverse plant and animal communities for the benefit of the present and future generations." These areas are undisturbed forests for the "purpose of preserving in perpetuity the wilderness, flora and fauna, and other elements of the ecosystem for scientific, educational and other special uses." The goals set for the excellent tropical forests of Brunei Darussalam are to make them a "focal point of tropical forests, thereby endowing the country as having an outstanding reputation in respect of forest protection, management, research and education" as national goals. The forests in the National Parks are the core of those.

The National Park area does not have bare rock mountains standing high to surprise the eyes of the observer, great waterfalls or the other usual types of tourist attractions. Nevertheless, the expanse of great forests dating back to the primitive ages, and the various phases of forest landscapes formed by the forests, presents visitors to the National Park with the force and emotion of nature. The ecosystem of the area including simple and traditional lifestyle of the indigenous people living near the National Park teaches the richness of living together with nature. The basic policy of the development plan for the National Park, therefore, has been to avoid evils of tourism development of the conventional type, and the consequent great impacts not only to the forest ecosystem, but also to regional ecosystem. This basic policy has been implemented by selecting the ideal of ecotourism to commune with nature without destroying the forest or regional ecosystems.

The watersheds of the Belalong tributaries have already been considered as an arena for basic research. The Kuala Belalong Field Studies Centre has been opened there. The watersheds present possibilities of developing ecotourism in the National Parks based on the results of this research.

## 6.2. Utilisation Zone

### 6.2.1. Accessible range by boat and time required

Depending on the means of transportation used, access to the National Park starting from BSB can be divided into the following three stages:

1) BSB to Bangar (Brunei River to the downstream area of the the Temburong River, by speedboat)

2) Bangar to Batang Duri (paved road, by car)

3) Batang Duri to the National Park (midstream and upstream parts of Temburong River, by boat)

Stages 1) and 2) can be completed in a time of about 70 minutes in total. Access from Batang Duri to the National Park, stage (3) depends only on the Temburong River. Wooden boats mounted with an outboard engine with output of 15 to 30 horsepower called "temuai" by local residents are commonly used in the area.

The time required to navigate the Temburong River is greatly affected by the water level of the river. Other factors such as boat utilisation, safety and periods that the river cannot be used, should be taken into consideration when planning the National Park utilisation scope, with an emphasis on ecotours.

(1) Method of survey

The time required for a boat to reach the entrance to the National Park (Kuala Belalong) and five places inside the National Park from Batang Duri as the start point at various water levels was determined.

a. Check points were as follows

| Check Point | River Distance From Batang Duri (km) | |
|---|---|---|
| 1. Batang Duri | | |
| 2. Kuala Belalong | 7.5 | National Park entrance |
| 3. Sg. Baki confluence | 9.2 | Immediately downstream from the water gauge |

| | | | |
|---|---|---|---|
| 4. | Sg. Apan confluence | 10.1 | Entrance, Apan Viewing Platform |
| 5. | Sg. Babi confluence | 12.6 | |
| 6. | Sg. Machang confluence | 15.8 | |
| 7. | Sg. Babi_2 | 17.6 | |

(2) Survey results

At least two persons are needed for safe boat cruising. An outboard engine operator and skipper to direct and change the direction at the bow. If the water depth is sufficiently deep, the boats are operated only by the outboard engine. If the water depth is shallow, the engine is stopped, and both the operator and skipper operate poles to move the boat. They have to step out of the boat and push in some places. If the water depth becomes shallower or if it is dangerous, the passengers also move out of the boat and walk on dry river beds. During high water time, the course has to be selected carefully for safety, since the flow velocity increases, affecting the boat's cruising capability.

Data from the water gauge was used to calculate the daily average water level, and day time average water level (7 to 18:00), which was compared with the time required for each survey day, and used as a reference in analysis.

Four water level zones were set based on the journey times required for each daily average water level. The condition of each water level zone is outlined below.

| Water-gauge Level | General Condition |
|---|---|
| 1.7 - 1.9m | More than one hour was needed to reach Kuala Belalong and the passengers had to leave the boat and walk several times. At water level of about 1.7, more than two hours was needed. 3 to 4km of the 7.5km course had to be walked. One hour and 40 minutes to Sg. Apan in the National Park and 2 hours and 30 minutes to Sg. Babi. About one half of the course had to be walked through. Down: 50 minutes, 1 hour and 20 minutes at most, from Kuala Belalong. |
| 1.9 - 2.1m | Kuala Belalong could be reached in less than 1 hour and walking on dry river beds was almost unnecessary. However, the boat had to be pushed at several shoals. The Sg. Apan confluence in the National Park could be reached in less than 1 |

hour and 40 minutes. Walked about twice. Data from further upstream was not available, but aconsiderable portion to Sg. Machang had to be walked through. Down: Less than 40 minutes from Kuala Belalong.

2.1 - 2.3m Walking not required to Kuala Belalong and the time required was stable, 30 to 40 minutes. About 50 minutes to one hour to Sg. Apan upstream of Kuala Belalong. Had to walk twice or three times to Sg. Machang and more than 1 hour and 40 minutes was needed. Abandoning the boat and walking an additional once or twice was needed to reach Sg. Babi_2, and about 2 hours was needed. The channel further upstream was narrow due to gravel sedimentation and the boat had to be left more frequently. Cruising further upstream would not be suitable for safety reasons. Down: About 70 minutes from Sg. Machang and 30 minutes from Kuala Belalong.

2.3m - The time required to Kuala Belalong was stable, 30 to 40 minutes. 40 to 50 minutes to Sg. Apan. Sg. Machang could bereached using only the outboard engine. Time required 1 hour and 10 minutes to 1 hour and 30 minutes. Large areas of sedimentation were covered by water when the water level rose above 2.7m, when the channel would expand to the river bed width. The flow velocity was fast and the boat engine had to be operated at full power over the entire area to keep movinng up river. Travel times would not be shortened, but the danger in creases with further increase in the water level. Down: 1 hour from Sg. Machang, about 35 minutes from Sg. Apan and 20 minutes from Kuala Belalong.

The maximum day time water level during the survey period was 2.86m. At this water level, the entire river bed of the Temburong River becomes channels, and the flow velocity becomes considerably faster. The waves on the rapids were high, but the rapids were not difficult to navigate through. At this level, there was little danger. Nevertheless, highly specialised technology is needed to rescue people following accidents, such as overturning.

Should the water level increase further, the flow velocity would increase and the present outboard engines would not be powerful enough to navigate the rivers. The waves would become higher and boat operation would become more dangerous. The upper limit of the water level could not be decided during the survey.

(3) Accessible range and required time

a. Required time for each check point

The times required (minutes) from Batang Duri to the check points at the various water levels are summarised below. The accessible areas for each water level zone on a day trip based on the above results are shown on the right.

Table-38 Required time (each water level), min.

| Water level(m) | K.B | Sg.Apan | Sg.Machang | Sg.Babi_2 | Accessible area |
|---|---|---|---|---|---|
| 1.70<=WL<1.90 | 80~140 | 100~ | — | — | Kuala Belalong |
| 1.90<=WL<2.10 | 40~55 | 75~ | — | — | Sg.Apan |
| 2.10<=WL<2.30 | 35~40 | 55~60 | 100~ | 125~ | Sg.Machang |
| 2.30<=WL< | 25~35 | 40~55 | 70~95 | — | Sg.Machang |

If the water level was below 2.1m, the boat had to be pushed by hand over several shoals before reaching Kuala Belalong and time losses occurred. When the water level upstream of Kuala Belalong fell further, the boat had to be pushed over shoals or it was neccessary to get out, and walking on river beds was necessary. Sg. Apan could be reached by walking on river beds about twice. It was neccessary to get out of the boat on many shoals and a much longer time was needed upstream of Sg. Apan.

At a water level of 2.1m or more, the water depth was sufficient to reach Kuala Belalong by operating the outboard engine only. Entering the watershed of the Temburong River, Sg. Apan could be reached without getting out of the boat. Sg. Machang could be reached by getting out of the boat and walking on river beds two or three times.

Based on these observations, water levels below 2.1m at the water gauge point were classified as low water seasons and levels higher than 2.1m, as normal water level seasons. The time required for each block was summarised. In the table shown below, the numbers in parentheses are the times required in minutes. The top figures indicate the normal water level season and the bottom figures the low water season.

(40) (20) (50)

Batang Duri ----> K.Belalong ----> Sg.Apan ----> Sg.Machang

(40~140) (35~40) Not possible

b. Number of usable days

The water-level data for 365 days gathered during the survey period was classified into the above water level zones and the number of days corresponding to each water level zone was studied.

The water level data was studied for daily average (AVG) and for average during daytime (11 hours, 7:00 to 18:00, D_AVG). As supplementary information, maximum water level (MAX), minimum water level (MIN) and night average water level (19:00 to 6:00 on the following day, N_AVG) were also studied.

Table-39 Number of days (each water level)

| Water level(m) | MAX | MIN | AVG | D_AVG | N_AVG |
|---|---|---|---|---|---|
| 1.70<=WL<1.90 | 41 | 73 | 51 | 59 | 54 |
| 1.90<=WL<2.10 | 45 | 82 | 64 | 68 | 59 |
| 2.10<=WL<2.30 | 41 | 92 | 77 | 87 | 72 |
| 2.30<=WL | 238 | 118 | 173 | 151 | 180 |
| Total | 365 | 365 | 365 | 365 | 365 |

In the numbers of daily average water-level days and of daytime average water level days, the former showed 22 more days when the water level was more than 2.3 m. This indicates that there were more rainfalls from evening to night during the survey period and that the water level increased often during the night. There were 29 days more on night average than on day average when the water level was higher.

For daytime water level, on 238 days (65%), the water level was above 2.1m on average, and the boat could cruise to Sg. Machang. This number would increase to 306 days (84%) if the number of days with a water level above 1.9m was included, allowing cruising to Sg. Apan.

Figure-37 displays this as a monthly trend.

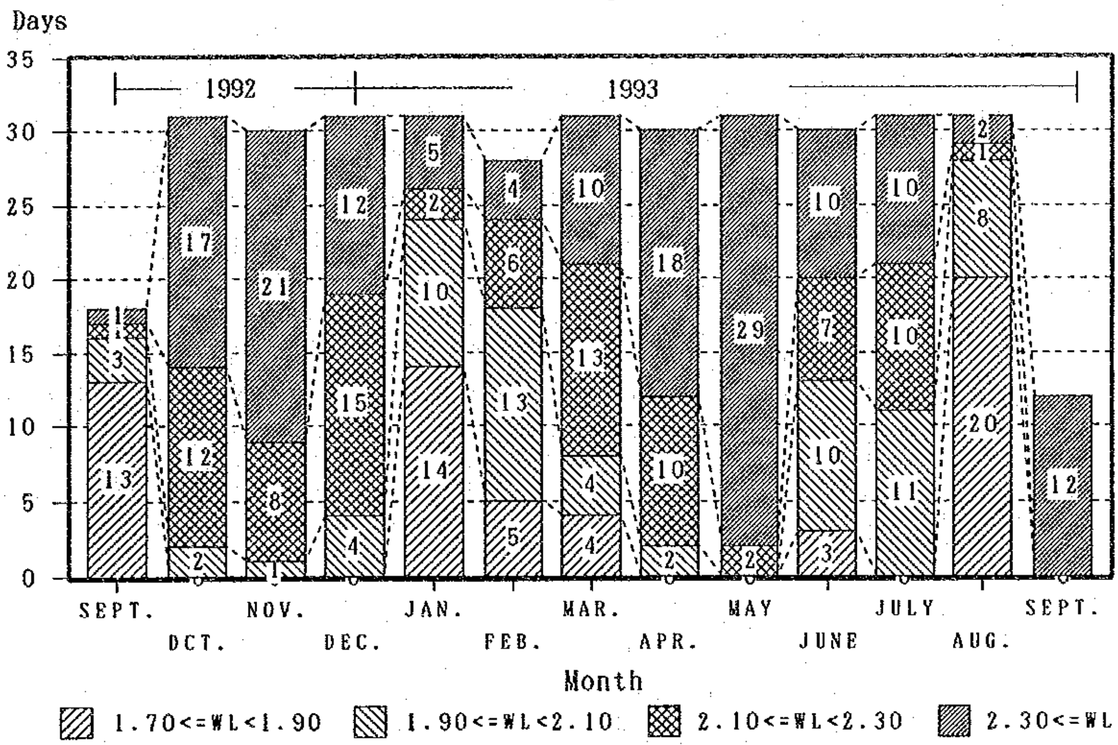



Figure-37 Number of days (monthly) for each water level

A dry season occurs twice a year, each lasting less than about two months. During these times, the water level falls below 2.1m and accessing Sg. Machang by boat is not possible. During the survey period, the water level was low in September, 1992 and in January, February and August, 1993. During these periods, low-water levels continued for about three weeks. At times, the water level was below 1.9m for more than two weeks, restricting accessing by boat to the vicinities of Kuala Belalong. For 20 days in August, the water level was below 1.9m.

The other eight months were the rainy seasons, and the water level allowing boats to be used to access Sg. Machang (2.1m or more) was maintained most of the time so that boats could be used to Sg. Apan.

### 6.2.2. Problems with existing forest trails and approach to nature observation paths

(1) Utilisation of existing forest trails and problems

The National Park area contains forest trails built by the Forestry Department for management of the National Park and trails built by the UBD for research and educational purposes.

In addition to those, work roads, which were built when National Park border beds (dotted line in the diagram), and helicopter landing spots were furnished, are available as forest trails, even though they are recognised as footpaths. These forest trails could be walked.

Figure-38 shows a sketch map of the forest trails built from near the confluence of Sg. Apan to the downstream area.

These trails were mainly built on ridges and follow the natural grades of the ridges. From the standpoint of land conservation, ridges were most stable places and were desirable in terms of maintenance and management. If trails were built in accordance with the natural grades, the trail construction distances could be shortened.

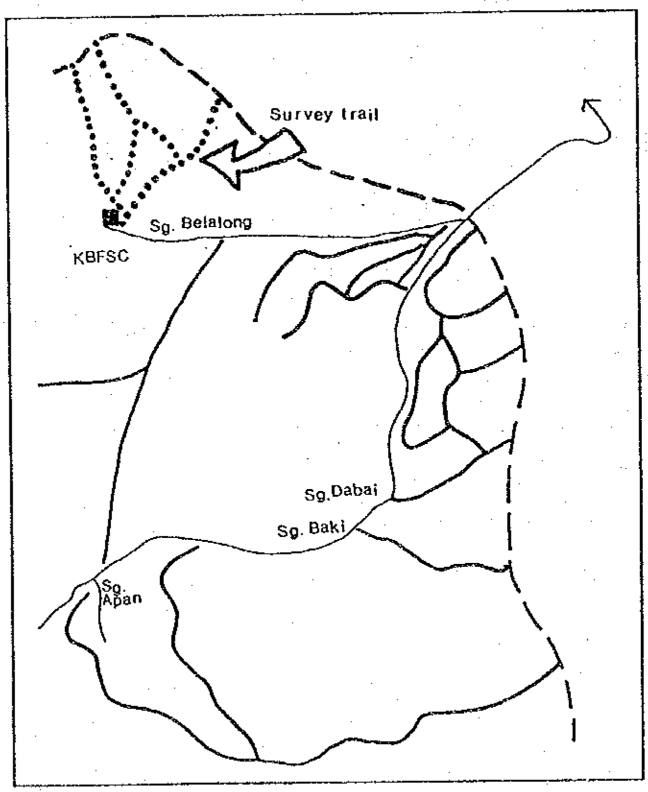



Figure-38 Forest trails in survey area

These trails could be used without difficulty by those who are accustomed to walking on graded land such as people specialised in managing National Parks.

Ecotours, on the other hand, will attract a wide range of people, from young to old. Furthermore, those who do not have much knowledge and experience of nature should preferably participate in them. Walking on these trails will be hard for them, where the natural grades are steep. Trails for ecotours should provide bypasses to reduce the trail grades where the grades are steep, or handrails installed for safety, log paths on slopes, while steps and other facilities must be provided where danger is expected.

(2) Case study of existing forest trails

The overall problems associated with the existing forest trails are described in (1). A study was made using a forest trail which is most frequently used at present, for use as a reference in setting ecotour routes.

The forest trail surveyed was a section of about 2km used by UBD as a nature observation trail. About 20 students were continuing nature observation in that area from Thursday to Sunday. In addition to these students, scientists from countries other than Brunei Darussalam also visit the area.

The first part of the forest trail is a steep hillside with a grade of more than 30°. Soon afterward, the bottom part of a ridge is reached and the ridge climbed. The distance to the spot which commands a good view is 800m. The path has many ascending and descending sections. The route reaches the middle part of the ridge passed earlier by traversing from halfway, and descends by the same route from there.

This forest trail gave the strong impression that it used a trail created by natural treading, minimising any artificial reform. Tree branches had been cut and put on steep parts to make steps (10 steps per slope of 6m). Steps were also made by small-scale cutting of earth (12 steps per slope of 7m), and rope was fixed on such steep places. The steepest stairs were near the entrance. Boards and small piles were used to prevent damage to the steps. The soil in that area was viscose, but there was no indication that the forest trail was causing impacts to the places around it as a source of erosion.

Nature trails for ecotours are required to have wide widths and gentle grades. The steps are required to use materials and designs that harmonise with the nature around them, and a structure that will allow ease of movement on them. A preferable trail environment would be through forests consisting of a variety of species, beautiful landscapes with an echo of the chirping of wild birds.

The survey trail was a path for students conducting experimental forest research, and amenity was not a major concern. However, high amenity will be required on nature trails for ecotourists who will come not only from Brunei Darussalam, but also from foreign countries. The near-nature construction techniques will have to be studied for cabins and benches for sheltering and resting, as well as for other park facilities, in addition to trail structures. Naturally, consideration will be needed to ensure that trails will not accelerate landslides.

### 6.2.3. Selection of sites for viewing wide forest landscapes

The entire survey area was covered by high trees and did not have many sites from which wide areas of forest type could be viewed.

Interviews with the staff members of the Forestry Department and locals who frequently entered the survey area indicated that such sites were only few. These sites were already used for aerial photo signals for aerial photography or for helicopter landings. This report also selected these sites for study in selecting points for viewing forest landscapes over a wide area.

The Apan aerial photo signal point commands 360° viewing, and it is possible to take in both close up and distant views. From this point, Bt. Belalong, the topography of the National Park area and the tropical rain forests can be observed.

The forests growing along the route from the confluence of Sg. Apan to this site were rich in substance and in variation. Forests of the 5 (5') H and 5 (4) H types appear in a balanced proportion. The dry riverbeds near the confluence, which would be the starting point of the route, were wide and this route was also suitable for observing typical forests in the National Park area.

Reaching this point produced a great sense of pleasure and satisfaction.

The grades of the section from the confluence of the Sg. Apan to the ridge line, which is divide between the Sg. Apan and the Temburong River, and of the upper section of the ridge line to the peaks of small hills are slightly steep. Bypasses to adjust the grades would be needed.

The Machang helicopter landing spot commands views of almost 300°. The scope for close-range views is not wide, but this site is suitable for observing forests in the middle distance, as well as proiding distant views.

Forests along the route to this point are poor in substance compared with those of the Apan aerial photo signal site. The proportion of occurrences of forests of the 5 (5') H and 5 (4) H types is not well balanced. This route is not suitable as a route to observe typical forests in the National Park area.

The grades of the route from the entrance are generally steeper than those for the route to the Apan aerial photo signal site. The ridges, which would become the main part of the course, are generally narrow. In some places, the ridges are so narrow that even walking is difficult. From a conservation standpoint also, this route could not be recommended as a forest observation route.

The viewing site on the left bank near Kuala Belalong is located close to the entrance to the National Park, which is advantageous. However, the viewing range is slightly less than 30° and the views are through trees. This point commands views of mainly production forests, rather than forests of the National Park area.

Comparing the three sites, the Apan aerial photo signal site was selected as the place which could commands view of the widest range of forest landscapes.

#### 6.2.4. Division of utilisation areas

The utilisation range of the National Park available to the ordinary user was assessed by conducting a utilisation range study of the National Park.

As mentioned earlier, the areas around the confluence of the Sg. Machang have the following features:

(1) Located within reach by boat even when the water level is high.

(2) Day trips are possible from BSB by boat even during the rainy season.

Taking these advantages into consideration, the confluence of Sg. Machang is the upper limit for day ecotours from BSB during the rainy season.

The areas around the confluence of the Sg. Apan have the following features:

(1) In the dry season, the area around the confluence of the Apan River is the limit that can be reached by boat.

(2) Footpaths are already built downstream from this point and the only work

required would be upgrade them to nature trails for ecotours.

The area around the confluence of Sg. Apan is the limit for day trips from BSB during the dry season. Creating new nature trails and other facilities downstream from this area, would avoid impacting on the natural environment.

The area around Kuala Belalong is the limit which can be reached by boat when the water level is extremely low.

Based on the above, the area downstream of the area near the confluence of Sg. Machang can be considered as an area that can be entered relatively easily even by ordinary users. The areas near the confluence of Sg. Apan and of Kuala Belalong would become limits that could be reached when the water level of the Temburong River is lower.

Large differences between forests upstream and downstream from the confluence of Sg. Machang could not be found in the survey.

A long time would be needed for rescue if an accident occurred upstream of the confluence of Sg. Machang.

Under the circumstance, the areas downstream of the confluence of Sg. Machang were designated utilisation areas of the National Park for ordinary users.

The distance is too far for ordinary users to walk from the confluence of Sg. Apan to the confluence of Sg. Machang and the use of boats would be appropriate. (A control footpath for rescue purposes in case of accidents would be needed for this section.)

## 6.3. Selection of Routes and Pathways

### 6.3.1. Approach to route selection

Routes to be selected vary considerably depending on who is to use the route, their interests, degree of knowledge, and their experience of nature. The information to be supplied will vary depending on how much analysis of nature in the tour area is required.

The following three policies were used in this report in selecting the routes because the National Park has been designated only recently and few people have visited the Park so far. Analysis of the ecosystem is actively being undertaken at present, centered on the Kuala Belalong Field Studies Centre.

The knowledge and conservation information which can be made available may change as the research advances.

(1) To select routes that will enable people visiting the National Park to observe the outline of views and structures of the forests representing the National Park area, as well as of the trees which make up the forests.

(2) To select routes that will utilise existing nature trails in order to avoid impacts on the environment that would occur if new nature trails were to be built. Routes to be selected should be such that they can be built only by making improvements such as reducing grades and providing simple safety measures.

3) To select routes that will enable learning about the importance of conserving the ecosystem, while enjoying the joy and thrill of experiencing the forests and rivers, and of resting near waterfalls and torrents.

### 6.3.2. Selecting rotues

The following three routes were selected in accordance with the route selection policies mentioned above:

Temburong Main Stream Route:

A route about 8 km in distance along the main stream of the Temburong River from Kuala Belalong at the entrance to the National Park to the confluence of Sg. Machang.

This route offers the joy and thrill of navigating the river upstream to view forest landscapes along the main stream of the Temburong River. The boat, mounted with an outboard engine, is overwhelmed by the size of forests.

Nineteen places were selected as viewing points along the route, such as typical forest communities of the National Park, riparian forests, riparian vegetation, giant trees, cliffs, waterfalls and torrent landscapes.

Apan Tropical Rainforest Viewing Route:

This is a 2,080m route on the southern slope of a ridge between the confluence of Sg. Apan and the aerial photo signal point.

This is a typical ecotour route commanding views of a wide area of tropical rain forests in the National Park over a full 360° range. It enables viewing of the topography of the National Park, distribution of forests, varying condition of forest types, forest structures and trees comprising features in the

National Park. It also commands views of the peak of Bt. Belalong and waterfalls on the Apan River. Landscapes can be viewed along the entire 2,080m length of this route.

Kuala Belalong Forest Viewing Route:

This is a 580m route at the entrance to the National Park. This route is located at the entrance to the National Park and can be used easily even when the water level is low in the dry season. This route enables visitors to observe forests in the National Park easily in a short period of time, such as the structures of bank forests, trees comprising these bank forests and trees growing on slopes.

The entire length of 580m provides good observation points.

### 6.3.3. Observation points along the Temburong River Main Stream Route

Names of the observation points listed below should be names that can be used with ease and familiarity by those who live in the area. The names given here were selected tentatively by the survey team for the purpose of reporting.

(1) Junction Forest: o.p. 1

This observation point is located at the entrance to the National Park at the confluence of the Temburong River and Sg. Belalong.

Visitors to the National Park arriving by boat from Batang Duri would rest a while in dry riverbeds or bank terraces which were always shaded by trees at this site.

They would be attracted by a community of forests covering the other side of the river having five giant trees as upper-storey trees. These five giant trees in the order of location from the inner side are: Meranti sarang punai bukit (45m high), Meranti sarang punai bukit (45m), Selangan batu (50m), Meranti sarang punai bukit (40m) and Meranti sarang punai bukit (35m). During the rainy season, tiny and quiet waterfalls appeared underneath. This is a very suitable observation point situated at the entrance to the National Park, which commands views access the river from a shaded rest area.

(2) Green Tunnel Entrance: o.p. 2

Cruising on up the Temburong River, a quiet stream is soon reached, which is covered by a deep-green riparian forest. A section 100m in length called the Green Tunnel Entrance was selected as the second observation point.

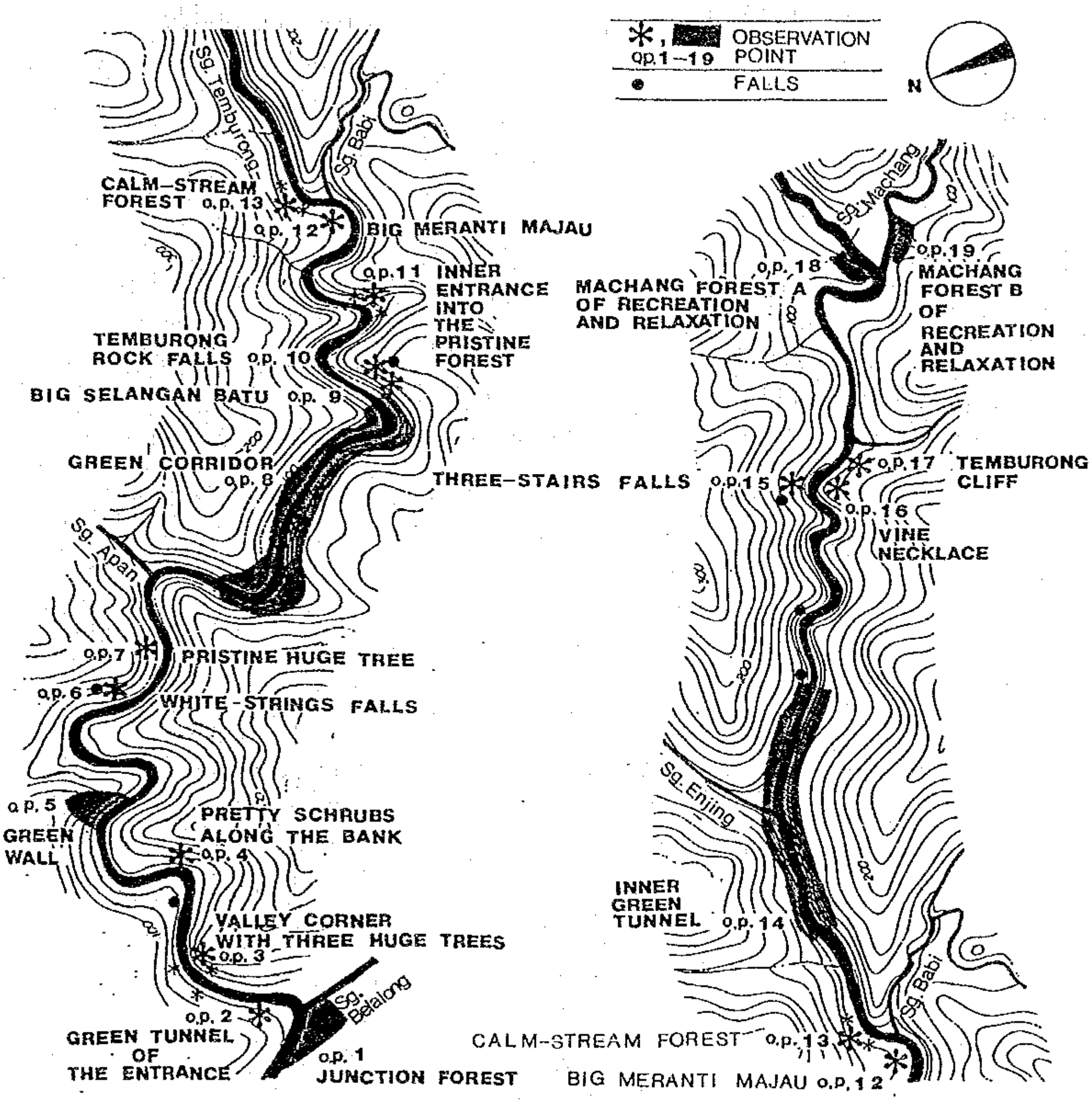



Figure-39 Observation points of Temburong main stream route

This place would impress on visitors the depth of the forests in the National Park, where soft sunbeams shine through branches of trees together with a gentle touch of cool winds even under the glittering sunlight in the dry season. The place would also impress on visitors the importance of the rich store of water within the forest.

Figures-40 and 41 show the front view, crown projection and forest profile diagrams of the stand structure on the right bank of the Temburong River totaling 100m in distance beginning with the confluence of the Belalong River, by the line-transect method.

Section 3.2 Forest Stand Structure explained the results of a survey of the Sample Plot No. 12, and explanations of the diagrams are omitted in this paragraph.

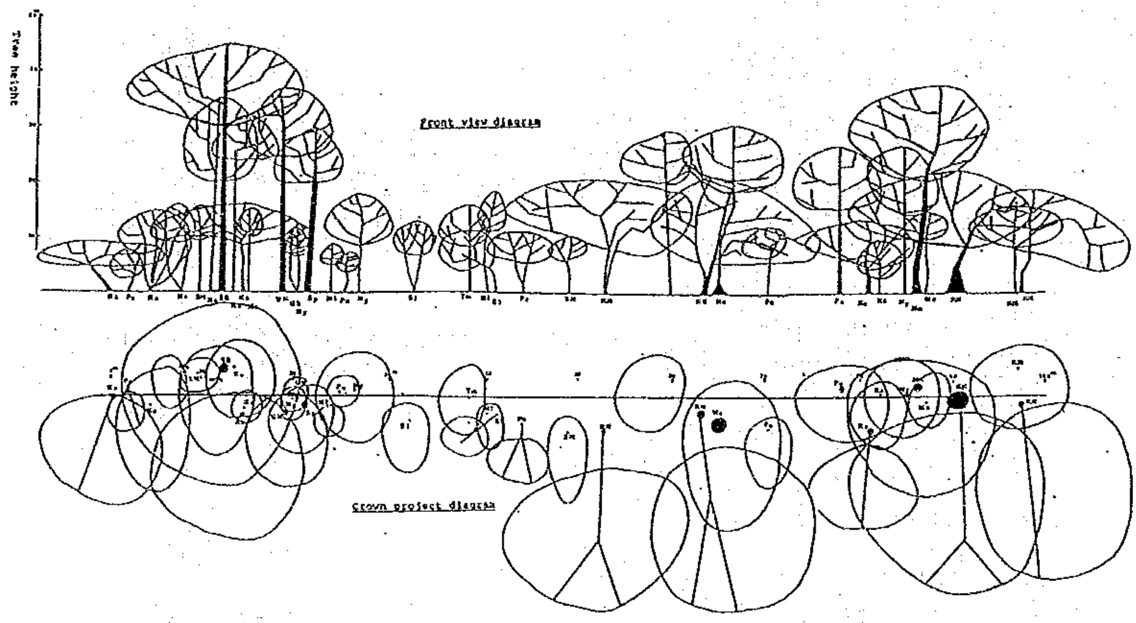


Figure-40 Front view and crown projection diagram at O.P.2

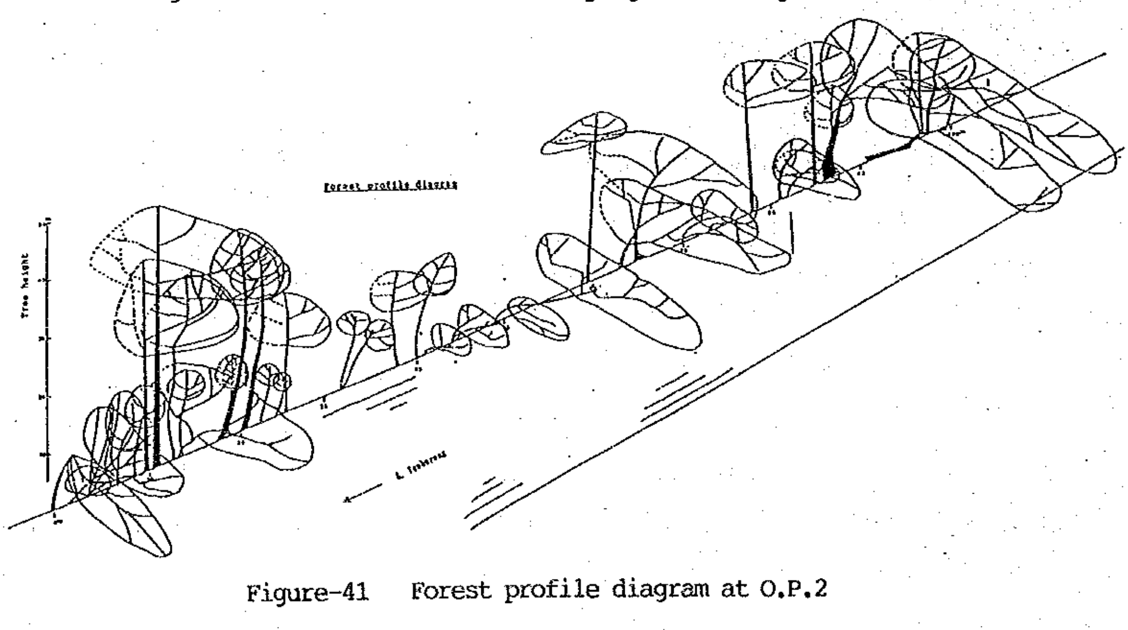


Figure-41 Forest profile diagram at O.P.2

(3) Valley Corner with Three Huge Trees: o.p. 3

Continuing on up the Temburong River, a point is reached where the river bends prominently to the right. Three huge trees stand there as if guarding the gate way to the National Park.

Benuang: H=40m standing on the left bank, is the tree furthest to the right. Menggaris: H=45m is seen on the left, making a pair with the tree on the right. Behind them, Menggaris: H=40m stands high, quietly reaching skywards as if welcoming the visitors to the primeval forests and praying for safe tours for them.

This point was selected as the third observation point.

(4) Pretty Shrubs along the Bank: o.p. 4

Many dwarf trees grow along the waterside of the Temburong River. At this point a community of Jambu ayar trees, 1.5 to 2.0m high is growing on a right angled bend to the left, the first such bend encountered on the boat trip. In many cases, Jambu ayar grow on clayey banks and in season, it has leaves that are slightly reddish or green.

(5) Green Wall: o.p. 5

All the slopes facing the Temburong River have forests that pride themselves on high trees. A forest community growing on the right bank on the third right hand bend, was selected as a typical point to observe these trees.

This is an area of forest that has two Selangan batu (H 35 and 50 m), Meranti (45m), Selangan batu (45m) and Meranti salang punai (45m) from left to right as upper-storey trees. It has Kedondong, Ranggu, Kasai, Sedaman, Jambu ayer and Menggaris as medium-storey trees 20 to 30m high.

(6) White Strings Falls: o.p. 6

This waterfall can be viewed during the rainy season. It is a small waterfall flowing into a rapid stream of the Temburong River, 5m high and 1.5m wide.

Shrubs grow on the bank leading to the falls and red peavy flowers of Ara hang down in many layers to comfort the feeling of the visitors.

(7) Pristine Huge Tree: o.p. 7

Further, a Menggaris tree appears on the left, growing on the right bank. As if to pride itself on its 60m height. Assigning to this tree the name "Pristine

Huge Tree", this was selected as an observation point.

(8) Green Corridor: o.p. 8

Upstream from the confluence of Sg. Apan, the boat rounds a sharp bend to the left. The 800m section upstream from this point, was called Green Corridor. The Temburong River gradually narrows and huge trees on both banks of the river appear as if they were falling upon the visitors. Huge Keruing neram trees are the most prominent in this landscape. These huge trees cover the water surface, bending in an arch shape from both banks of the river. Due to the humidity around the riverside and the light reflected from the water surface, the trunks of these trees were a place of symbiosis for various mosses, orchids, vines, ferns and other plants.

Waterfalls appear here and there in the Corridor and large forests appear through openings in the trees on the banks as if they were a high wall spreading all over the slopes. This area constitutes the main observation point in the intermediate part of the route.

(9) Big Selangan batu: o.p. 9

On the left bank immediately after passing through the Green Corridor, a big Selangan batu tree appears, stand 60m high. This tree is as high as the 60m Pristine Huge Tree (o.p. 7) mentioned earlier. This tree is outstanding, and its height dominates the area.

(10) Temburong Rock Fall: o.p. 10

This fall is the best along the route. A considerable volume of water falls 10m on to a slightly tilted rock. The fall features a calmness which harmonises with the quietness of the forests, and a magnanimity so appealing that one might wish to jump into it and play.

(11) Inner Entrance to the Pristine Forest: o.p. 11

As at the Green Wall o.p. 5, a wall of huge trees overwhelms the visitor. Huge trees making up the wall from left to right are Selangan batu (height 45 m), Menggaris (45m), Selangan batu (50m), Selangan batu (50m), Menggaris (50m), Menggaris (55m), Selangan batu (50m), Selangan batu (50m), Selangan batu (50m) and Menggaris (47m).

The Selangan batu and Menggaris trees at this point are the principal species that form the upper storey of the forests observed from the route together with Meranti salang punai, Meranti and Meranti majau.

(12) Big Meranti Majau: o.p. 12

This tree stands on the bank opposite the exit of Sg. Babi and is 55m high. Although high, it spreads its branches widely, to over 20m, securing its own territory to the maximum.

(13) Calm Stream Forest: o.p. 13

Here, the Temburong River always flows gently, although full of water in this upstream area towards the confluence of Sg. Babi. Together with the forests around it, it transmits the calmness of the forests.

The upper- and middle-storeys of the forests forming the right bank comprise the following trees: Kedondong (height 40m), Selangan batu (45), Damar hitam (40), Terantang (40), Selangan batu (40), Selangan batu (40), Meranti salang punai bukit (35), Selangan batu (50) and Kasai (35).

(14) Inner Green Tunnel: o.p. 14

This observation point about 1 km long extending on either side of the Sg. Enjing confluence. As in the Green Corridor o.p. 8 and Calm Stream Forest o.p. 13, pleasant observation from the boat can be enjoyed at this point.

Superb buttresses grow on the bank and forests on both banks of the river were also splendid. For example, Meranti majau (height 45m), Kapur paji (45), Menggaris (50), Meranti salang punai bukit (50), Meranti salang punai bukit (40) and Kasai (35) stand in this order as upper-storey trees. Middle-storey trees are Dabai (10) and others.

(15) Three-Stairs Falls: o.p. 15

The route has eight falls. Some of them disappeared during the dry season or become thin and appear again in the rainy season.

Even though not listed as a route observation point, four falls on Sg. Apan are spectacular, specially the second innermost, falling 26m in three stages. The Three-Stairs Falls listed here falls 15m in three stages. The amount of water increases further during the rainy season and doubles the beauty of the falls.

(16) Vine Necklace: o.p. 16

Vines hanging from Keruing neram trees jutting out onto the surface of the river cross the Temburong River as beautiful necklaces highlighting the nearby landscapes.

(17) Temburong Cliff: o.p. 17

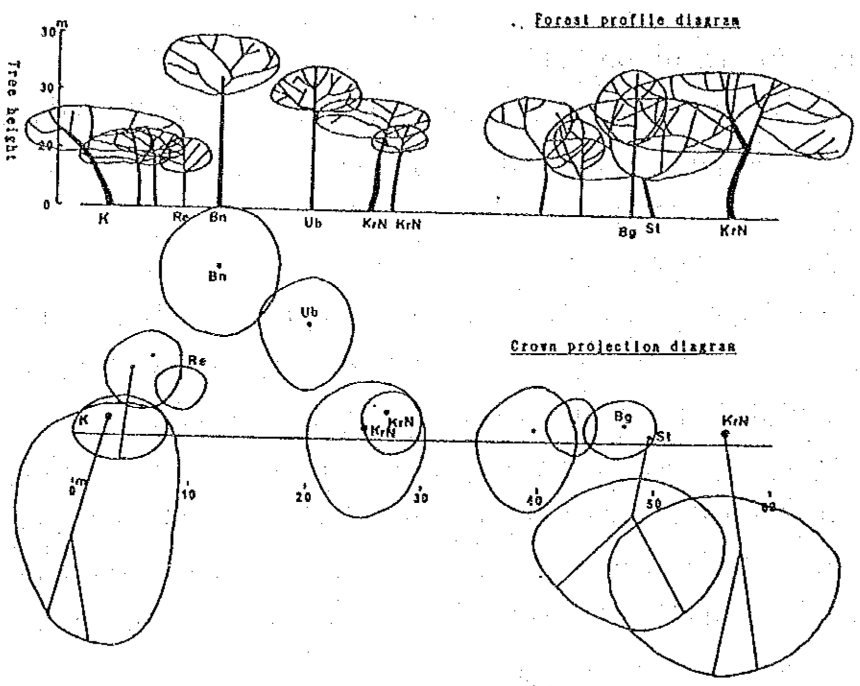



Figure-42 Forest profile and crown projection diagram at O.P.18

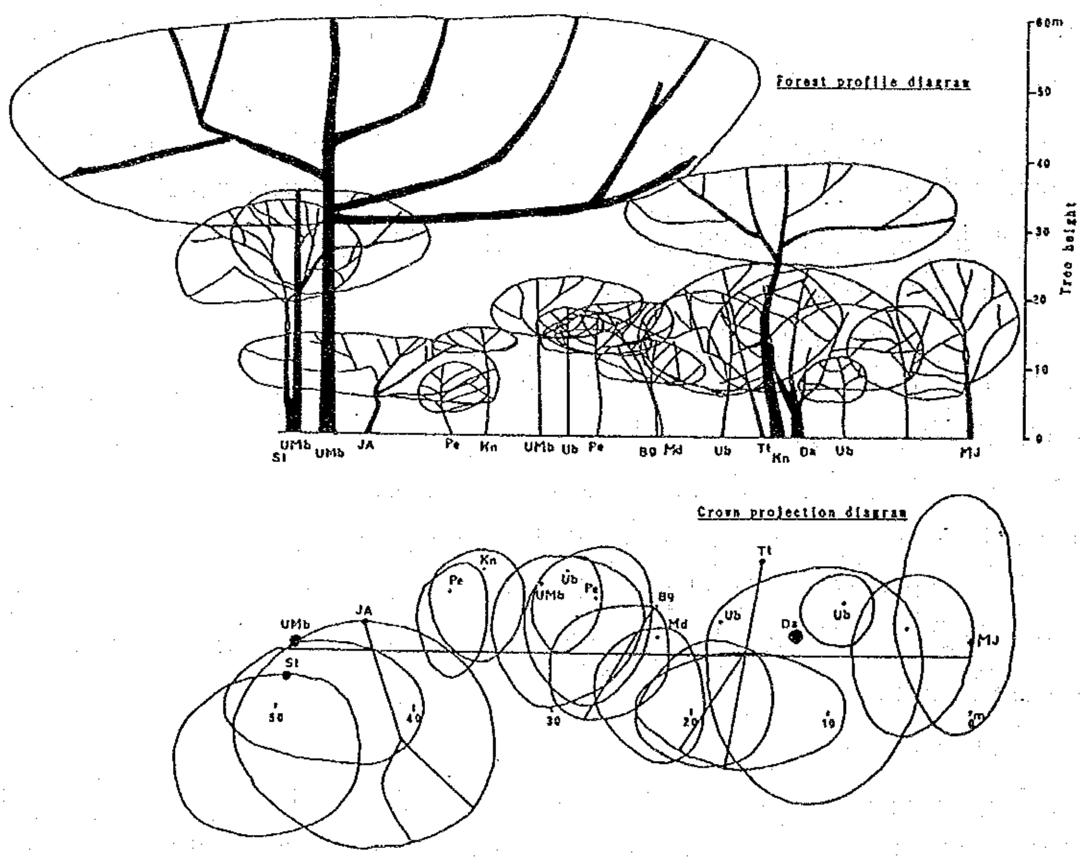



Figure-43 Forest profile and crown projection diagram at O.P.19

Many rock walls formed by sedimentary rocks of the Palaeogene can be found on both banks of the Temburong River. Selangan batu (height 30m), Meranti salang punai (20) and other trees grow on rock walls at this point to provide them with a degree of elegance.

(18, 19) Machang Forests of Recreation and Relaxation A and B:
o.p.s. 18 and 19

These observation points are the last along the route at the confluence of the Temburong River and Sg. Machang. The edge of the ridge dividing the two rivers is relatively flat and would be a good place for visitors to rest.

The forest viewed on the opposite side of the Temburong River by visitors resting here, was called the Recreation and Relaxation Forest A. The forest viewed on the opposite side of Sg. Machang was called the Recreation and Relaxation Forest B. These two forests form the landscapes of the banks.

These forests are described in the descriptions for the Plots No. 15 and 16 in section 3.2. Forest Stand Structure and are not described here again. A front view and crown projection diagram of the forests are given below.

Figure-42 shows the structure of the forest from the confluence of Sg. Machang to the right bank of the Temburong River.

Figure-43 shows the structure of the forest on the left bank at the exit of Sg. Machang.

On the left side of Figure-43, a large Urat mata bukit tree identified by the symbol "UMb" is shown. Since this was close to a line-transect survey area it was shown in the diagram as additional information illustrating the condition of the forest close by.

Machang Forests of Recreation and Relaxation A and B have lengths of 60 and 50m, respectively, along the banks.

This report selected a total of 19 places as observation points as described above. As more ecotours are conducted, these observation points themselves are likely to be further developed.

6.3.4. Observation points along the Apan Tropical Rainforest Viewing Route:

This route is a track 2,080.7m long in total diagonal length from the confluence of Sg. Apan and the Temburong River to the viewing point.

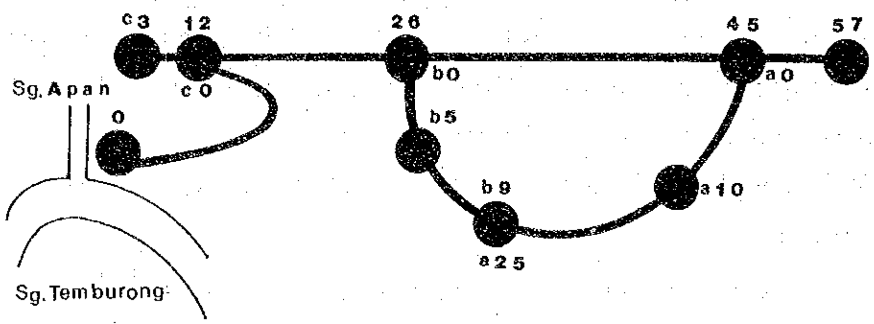



Figure-44 Apan tropical rainforest viewing route

The route can be divided into the following sections:

1) From the confluence to the ridge (IP.0 to 12, length 201.5m, a bypass to ease the grade),

2) A section from which splendid forests can be observed near IP.12 (IP.c0 to c3, length 53.0m),

3) A section from which forests of the 5 (5') type can be observed while climbing the ridge line gradually (IP.12 to 26, length 362.6m),

4) A Section from which forests of the 5 (4) H type can be observed while growing on slopes, while walking along gentle gradients (IP.b0 to b9 and a25 to a0, length 613.3m, bypass),

5) Section which reach the ridge again, and which provides clear views of tropical rain forests over 360° (IP.45 to 57, length 304.6m),

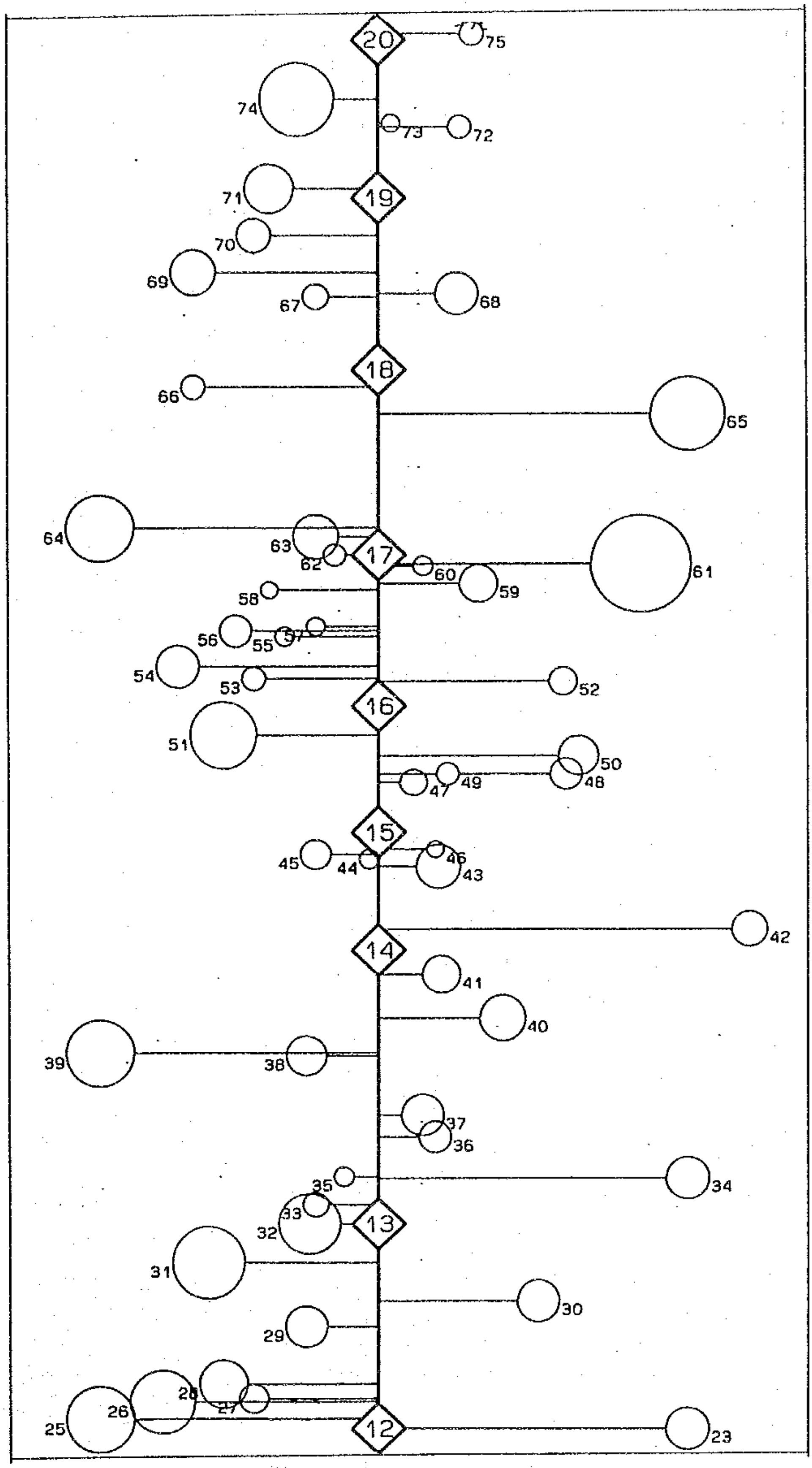
6) Section from which forests of the 5 (5') type can be observed while descending the ridge on the return journey (IP.26 to 45, length 545.7m).

The entire length of this route was surveyed simply, and selected taking ease of walking into consideration. Consideration was given to walking near specially large trees or buttresses, splendid forest communities or forests where typical forest type of the National Park could be viewed.

An offset survey was conducted to determine the principal trees growing on either side of the route, and a Tree Map to enable the trees making up forests to be identified was prepared.

More specifically, the positions of standing trees were measured with an accuracy of the order of 10cm to survey species names, tree heights, buttress heights and diameter breast heights. A total of 375 trees were surveyed, mainly those which formed the upper- and middle-storeys.

Figure-45 Tree map of Apan tropical rainforest viewing route



Two places along the route were surveyed by the belt-transect method to obtain data for observation of the forest structure.

Figure-45 shows a Tree Map of the block between IP.12 and 20 (length 227.5m) as an example. The distance between IPs is shown in a scale of 1:1,000, the distance from the route (survey line) to the trees is shown by 1:200, the diameter breast height is shown by a circle, in a scale of 1:100.

Table-40 presents the results of the tree survey in the area.

Table-40 Details of trees near Apan tropical rainforest viewing route

| No. | Mark | Local Name | DN | Botanical Name | SC | DBH | TH | BT |
|---|---|---|---|---|---|---|---|---|
| 23 | DH | Damar hitam | D | Shorea richetioides Heim | | 70.0 | 42.0 | 2.0 |
| 24 | SlI | Selangan batu lobang idong | D | Shorea domatiosa Ashton | E | 86.0 | 50.0 | 3.0 |
| 25 | MSb | Meranti sarang punai bukit | D | Shorea ovata Dyer ex Brandis | E | 110.0 | 43.0 | 3.0 |
| 26 | MSb | Meranti sarang punai bukit | D | Shorea ovata Dyer ex Brandis | E | 105.0 | 55.0 | 4.5 |
| 27 | MSb | Meranti sarang punai bukit | D | Shorea ovata Dyer ex Brandis | E | 48.0 | 38.0 | 2.0 |
| 28 | MSb | Meranti sarang punai bukit | D | Shorea ovata Dyer ex Brandis | E | 80.0 | 42.0 | |
| 29 | DH | Damar hitam | D | Shorea richetioides Heim | | 68.0 | 30.0 | 1.0 |
| 30 | d | Kedongdong | N | | | 70.0 | 28.0 | 2.0 |
| 31 | d | Urat mata | D | | | 120.0 | 43.0 | 4.0 |
| 32 | KP | Kapur paji | D | Dryobalanops lanceolata Burck | E | 100.0 | 50.0 | 2.0 |
| 33 | Mp | Merpauh | N | Swintonia glauca Engler | M | 41.0 | 28.0 | 1.0 |
| 34 | d | Kapur paji | D | | | 70.0 | 38.0 | |
| 35 | Bt | Bintawak | N | Artocarpus anisophyllus Miq. | M | 32.0 | 34.0 | |
| 36 | Mp | Merpauh | N | Swintonia glauca Engler | M | 52.0 | 42.0 | 4.0 |
| 37 | Rs | Resak | D | Vatica | M | 68.0 | 43.0 | |
| 38 | UMb | Urat mata bukit | D | Parashorea parvifolia Wyatt Smith ex Ashton | E | 65.0 | 47.0 | 7.0 |
| 39 | MM | Meranti majau | D | Shorea leptoclados Sym | E | 110.0 | 55.0 | 5.0 |
| 40 | Mp | Merpauh | N | Swintonia glauca Engler | M | 76.0 | 47.0 | |
| 41 | Mp | Merpauh | N | Swintonia glauca Engler | M | 62.0 | 22.0 | 2.0 |
| 42 | Slb | Selangan batu | D | Shorea Spp. | M | 58.0 | 45.0 | |
| 43 | KS | Kembang semangkok(Br.) | N | Scaphium macropodum(Miq)Beumee | ME | 72.0 | 42.0 | 3.0 |
| 44 | Pt | Putat | N | Barringtonia fusiformis King | M | 32.0 | 25.0 | |
| 45 | SBd | Selangan batu daun nipis | D | Shorea glaucescens Meijer | M | 49.0 | 25.0 | |
| 46 | Spt | Sepetir(Br.) | N | Sindora corriacea Maing.ex Prain | ME | 28.0 | 35.0 | |
| 47 | Ub | Ubah | N | Eugenia spp. | UM | 43.0 | 30.0 | 2.0 |
| 48 | KrT | Keruing ternek | D | Dipterocarpus palembanicus V.Sl. | E | 52.0 | 32.0 | |
| 49 | Pe | Pendarahan | N | Myristica SP. | UM | 37.0 | 28.0 | |
| 50 | Mnk | Melunak(Br.) | N | Pentace floribunda King | ME | 65.0 | 35.0 | 3.0 |
| 51 | MM | Meranti majau | D | Shorea leptoclados Sym | E | 110.0 | 41.0 | 4.0 |
| 52 | KrT | Keruing ternek | D | Dipterocarpus palembanicus V.Sl. | E | 46.0 | 44.0 | 1.0 |
| 53 | MPB | Meranti paya Bersisek | D | Shorea scaberrima Burck | M | 39.0 | 40.0 | 1.5 |
| 54 | Bt | Bintawak | N | Artocarpus anisophyllus Miq. | M | 70.0 | 45.0 | |
| 55 | Ub | Ubah | N | Eugenia spp. | UM | 32.0 | 40.0 | 1.5 |
| 56 | Ub | Ubah | N | Eugenia spp. | UM | 53.0 | 44.0 | 1.8 |
| 57 | | — | | | | 30.0 | 36.0 | |
| 58 | Ub | Ubah | N | Eugenia spp. | UM | 28.0 | 38.0 | |
| 59 | KrP | Keruing puteh | D | Dipterocarpus caudiferus | E | 62.0 | 49.0 | 0.5 |
| 60 | Pe | Pendarahan | N | Myristica spp. | UM | 32.0 | 35.0 | |
| 61 | d | Meranti sarang punai bukit | D | | | 160.0 | 45.0 | 4.0 |
| 62 | Md | Medang | N | Actinodaphne spp. | UM | 36.0 | 40.0 | |
| 63 | KrT | Keruing ternek | D | Dipterocarpus palembanicus V.Sl. | E | 73.0 | 56.0 | 0.5 |
| 64 | MeL | Meranti lapis | D | Shorea lamellata Foxw. | E | 110.0 | 55.0 | |
| 65 | Ms | Mampisang(Br.) | N | Disepalum anomalum Hook.f. | U | 120.0 | 52.0 | 4.0 |
| 66 | | — | | | | 40.0 | 35.0 | |
| 67 | Ub | Ubah | N | Eugenia spp. | UM | 42.0 | 31.0 | |
| 68 | UMb | Urat mata bukit | D | Parashorea parvifolia Wyatt Smith ex Ashton | E | 70.0 | 48.0 | 4.0 |
| 69 | UMb | Urat mata bukit | D | Parashorea parvifolia Wyatt Smith ex Ashton | E | 75.0 | 38.0 | 2.5 |
| 70 | Kr | Keruing | D | Dipterocarpus sp | E | 56.0 | 32.0 | |
| 71 | SBT | Selangan batu daun tebal | D | Shorea crassa Ashton | E | 80.0 | 55.0 | 3.0 |
| 72 | Ub | Ubah | N | Eugenia spp. | UM | 38.0 | 30.0 | 2.0 |
| 73 | DH | Damar hitam | D | Shorea richetioides Heim | | 29.0 | 20.0 | |
| 74 | d | ** | | | | 120.0 | 38.0 | 3.0 |
| 75 | DH | Damar hitam | D | Shorea richetioides Heim | | 39.0 | 38.0 | 1.0 |
| 76 | | — | | | | 35.0 | 34.0 | |

Note : d(Mark):Dead Tree D_N:Dipterocarpaceae or Not SC:Story Class
DBH: Diameter at Breast Height TH:Tree Height BT:Buttress Height

Table-41 shows the positions of the IPs and trees.

Using Tree No. 65, these diagrams and tables can be explained as follows:

"Tree No. 65, local name: Mempisang, non-Dipterocarp family, botanical name: Disepalum anomalus Hook.f. Has a diameter breast height of 120.0cm, tree height of 52m and buttress 4.0m high. Stands 368.0 (345.0 + 23.0)m from the route start point IP.0 or 10.0m on the right 23.0m past IP.17"

Table-41 Position of IP. and trees

| NUMBER | | DISTANCE from | | | D B H |
|---|---|---|---|---|---|
| IP. | TREE | IP. m | STARTING POINT (IP.0) m | SURVEY LINE (COURSE LINE) | |
| 12 | | 0.0 | 201.5 | 0.0m | cm |
| | 23 | 0.0 | | R 10.0 | 70 |
| | 25 | 1.7 | | L 9.0 | 110 |
| | 26 | 4.5 | | L 7.0 | 105 |
| | 27 | 5.0 | | L 4.0 | 48 |
| | 28 | 7.4 | | L 5.0 | 80 |
| | 29 | 16.8 | | L 2.3 | 68 |
| | 30 | 21.0 | | R 5.2 | 70 |
| | 31 | 27.4 | | L 5.5 | 120 |
| 13 | | 0.0 | 235.8 | 0.0 | |
| | 32 | 0.0 | | L 2.2 | 100 |
| | 33 | 3.2 | | L 2.0 | 41 |
| | 34 | 7.5 | | R 10.0 | 70 |
| | 35 | 7.8 | | L 1.1 | 32 |
| | 36 | 14.3 | | R 1.8 | 52 |
| | 37 | 17.9 | | R 1.4 | 68 |
| | 38 | 27.7 | | L 2.3 | 65 |
| | 39 | 28.2 | | L 9.0 | 110 |
| | 40 | 33.8 | | R 4.0 | 76 |
| | 41 | 41.0 | | R 2.0 | 62 |
| 14 | | 0.0 | 280.3 | 0.0 | |
| | 42 | 3.4 | | R 12.0 | 58 |
| | 43 | 13.7 | | R 1.9 | 72 |
| | 44 | 14.9 | | L 0.3 | 32 |
| | 45 | 15.7 | | L 2.0 | 49 |
| | 46 | 16.5 | | R 1.8 | 28 |
| 15 | | 0.0 | 299.6 | 0.0 | |
| | 47 | 8.2 | | R 1.1 | 43 |
| | 48 | 9.6 | | R 6.1 | 52 |
| | 49 | 9.6 | | R 2.2 | 37 |
| | 50 | 12.6 | | R 6.5 | 65 |
| | 51 | 16.0 | | L 5.0 | 110 |
| 16 | | 0.0 | 320.3 | 0.0 | |
| | 52 | 4.0 | | R 6.0 | 46 |
| | 53 | 4.5 | | L 4.0 | 39 |
| | 54 | 6.5 | | L 6.5 | 70 |
| | 55 | 11.4 | | L 3.0 | 32 |
| | 56 | 12.3 | | L 4.6 | 53 |
| | 57 | 13.0 | | L 2.0 | 30 |
| | 58 | 19.0 | | L 3.5 | 28 |
| | 59 | 20.0 | | R 3.2 | 62 |
| | 60 | 22.9 | | R 1.4 | 32 |
| | 61 | 23.2 | | R 8.5 | 160 |
| 17 | | 0.0 | 345.0 | 0.0 | |
| | 62 | 0.0 | | L 1.4 | 36 |
| | 63 | 3.0 | | L 2.0 | 73 |
| | 64 | 4.5 | | L 9.0 | 110 |
| | 65 | 23.0 | | R 10.0 | 120 |
| | 66 | 27.4 | | L 6.0 | 40 |
| 18 | | 0.0 | 375.8 | 0.0 | |
| | 67 | 12.0 | | L 2.0 | 42 |
| | 68 | 12.5 | | R 2.5 | 70 |
| | 69 | 16.0 | | L 6.0 | 75 |
| | 70 | 22.0 | | L 4.0 | 56 |
| 19 | | 0.0 | 403.3 | 0.0 | |
| | 71 | 1.5 | | L 3.5 | 80 |
| | 72 | 11.5 | | R 2.6 | 38 |
| | 73 | 12.1 | | R 0.4 | 29 |
| | 74 | 16.0 | | L 2.6 | 120 |
| 20 | | 0.0 | 429.0 | 0.0 | |

Walking along this 2,080m route, the names and sizes of the trees visible nearby can be determined at any position on the route and everybody can easily memorise them by using the Tree Map.

Reaching IP.57, which is the end point of the route, the ambience becomes limitless in every respect and mountains of primeval tropical rain forests expand indefinitely from one's
feet.

A belt-transect survey was conducted in two places to observe the structures of the forests on this route. Figures-46 and 47 show part of the results of this survey. These forests are already described as Sample Plots No. 17 and 18 in section 4.2. Forest Stand Structure. Only diagrams are shown below and descriptions of them have been omitted.

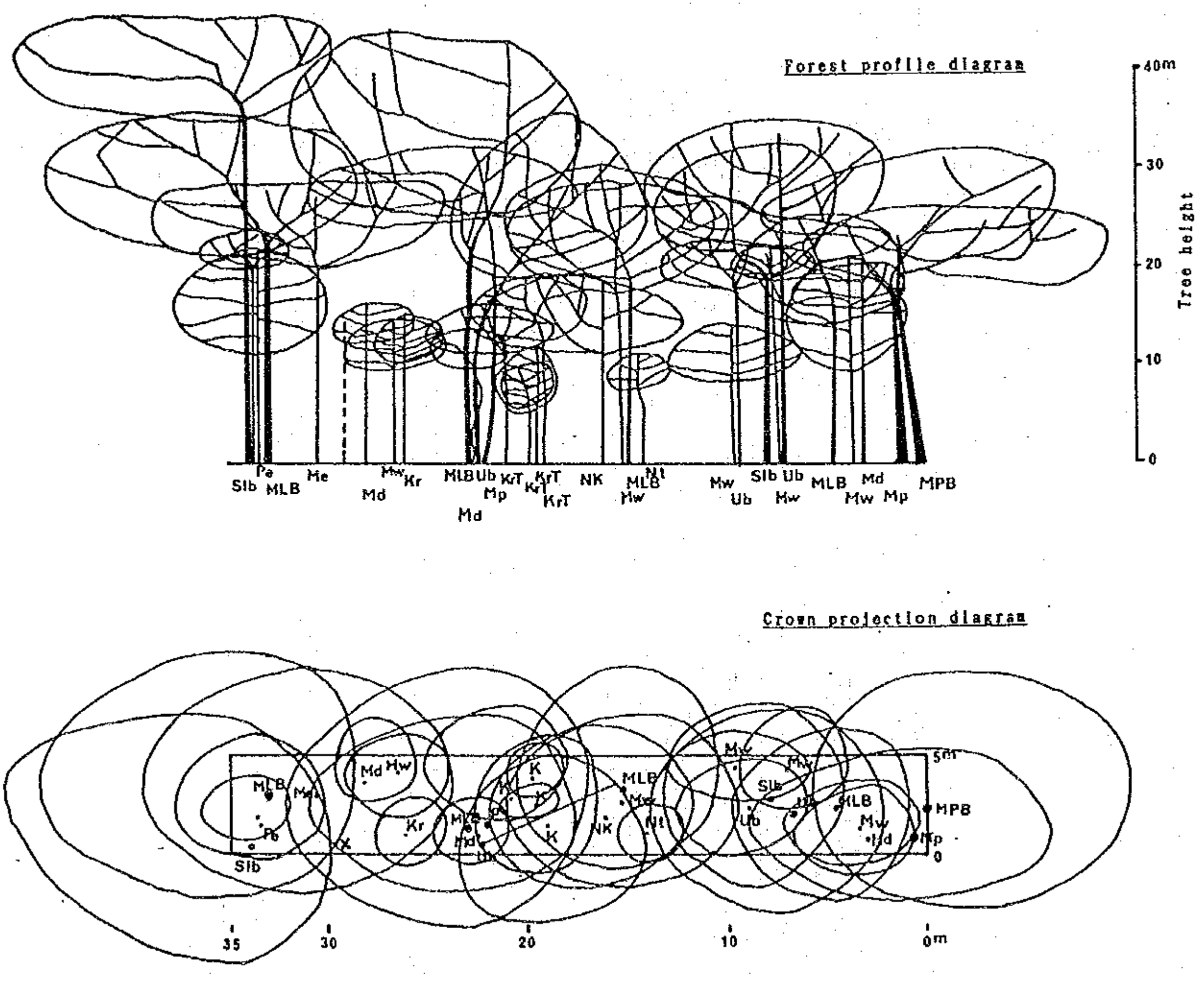



Figure-46 Forest profile and crown projection diagram at plot No.17

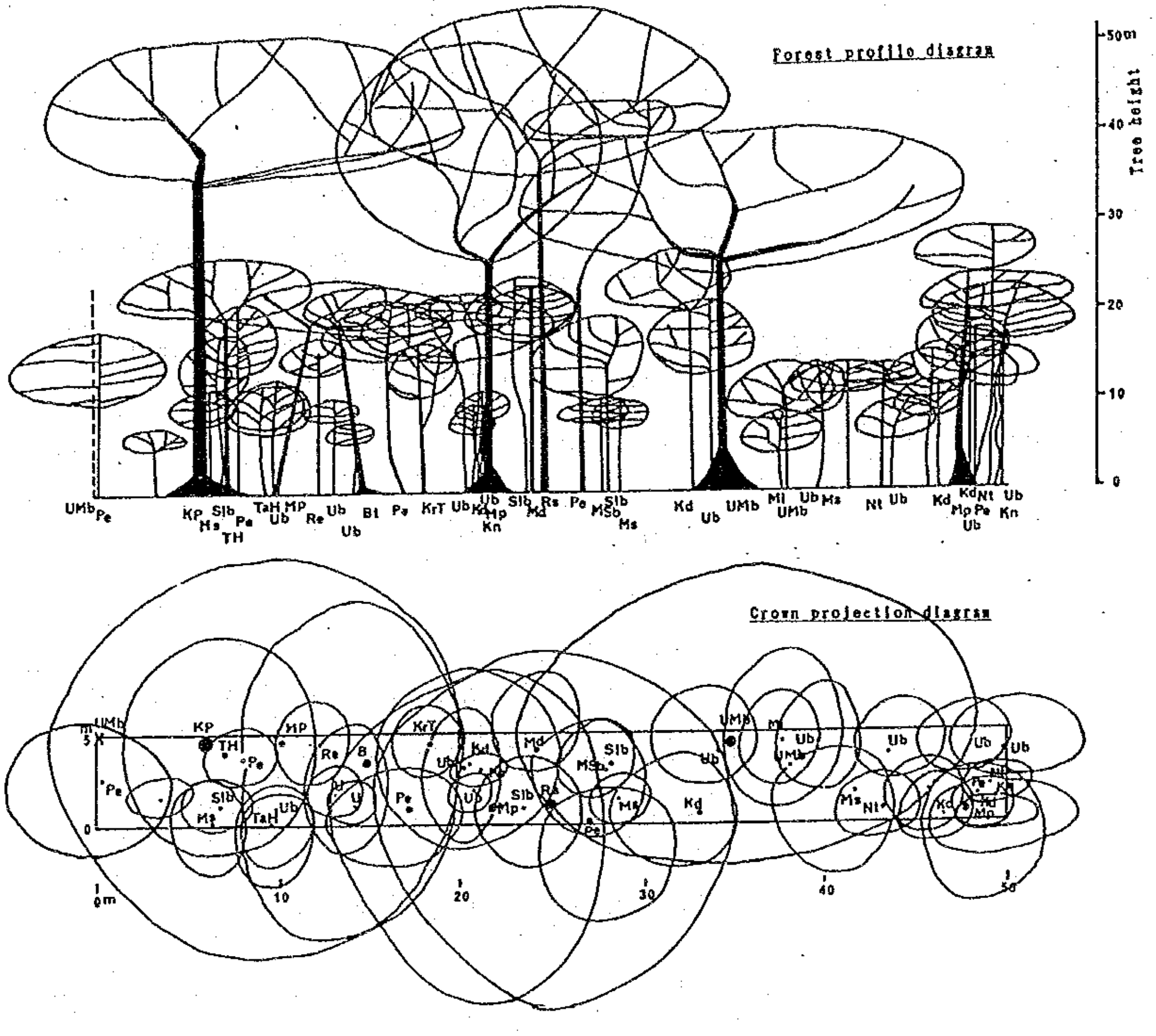



Figure-47 Forest profile and crown projection diagram at plot No.18

Both of these two plots were set on ridges. Plots No. 17 and 18 correspond to blocks IP. 40 to 42 and to IP. 13 to 15, respectively.

These two places were selected to show how the trees shown in the Tree Map live by forming types of plant societies with other trees.

### 6.3.5. Observation points along the Kuala Belalong Forest Observation Route

This was a 580m route set on the right bank of the Temburong River immediately upstream from the confluence of the Belalong and Temburong Rivers.

The entire route provides a continuous series of observation places. As in the Apan Tropical Rainforest Viewing Route, a Tree Map was prepared comprising 46 trees.

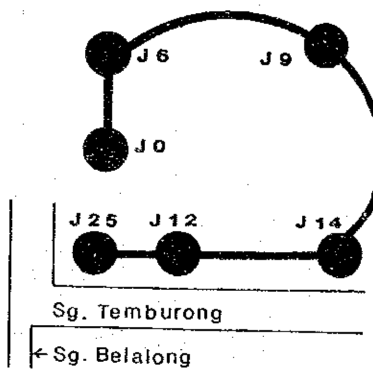



Figure-48 Kuala Belalong forest observation route

The section between IP.J17 and IP.J25 is the Green Tunnel Entrance op.2 in the Tembulong Main Stream Route. This route enables easy observation of forests in the National Park.

Figure-49 shows a Tree Map of the section between IP.J0 and J6 of the route.

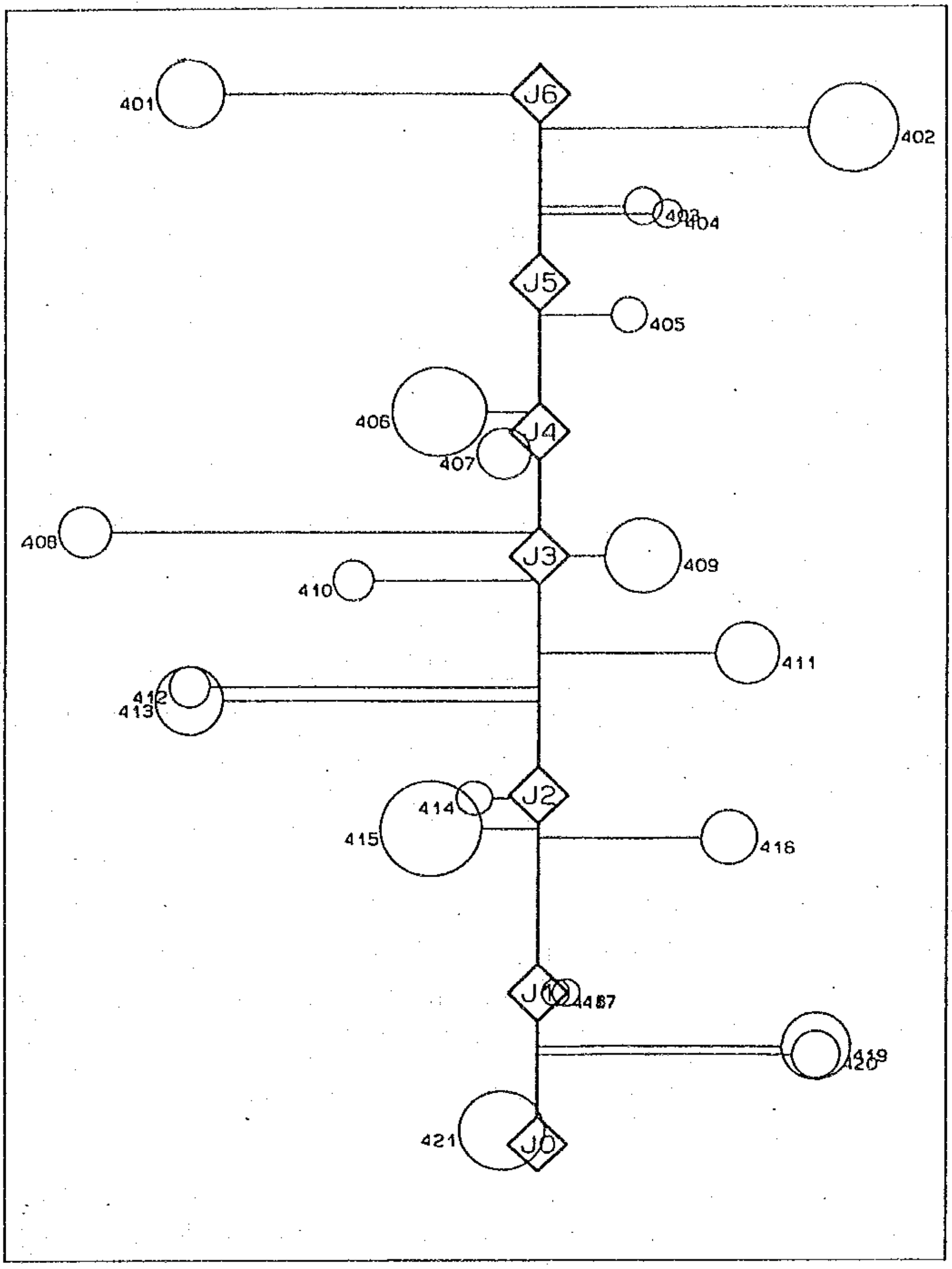



Figure-49 Tree map of the Kuala Belalong forest observation route, IP.JO ~J6

### 6.3.6 Forest landscapes downstream from the National Park

(1) Ecotours in the National Park area and forest landscapes in the downstream area.

Travelling along the Temburong River by boat, views of natural landscapes which are mutually interrelated and continuously varied can be enjoyed.

As mentioned in section 2.3. the National Park Viewed from the Watershed Forests, cruising upstream from the rivermouth, "mangrove forests grown by the sea and river" and "palm forests spreading from the riverside" appear. "Housing forests" appear near Bangar and "forests of shifting cultivation farmers" expand.

The forests in the National Park assure a stable flow of water, the source of these downstream forests. The forests downstream from the National Park are indispensable "primeval tropical rain forests" and an integnal part of ecotour observation.

(2) Observation points from the rivermouth to the National Park entrance

Characteristic forests that can be viewed by boat from the rivermouth to Bangar are listed sequentially below:

1) The rivermouth of the Temburong River has excellent forests in two storeys. The banks are covered by Nipah trees. Behind the Nipah trees were Bakau minyak trees growing as an upper storey producing a flat, horizontal canopy.

2) Pure forests of Bakau minyak spread root systems characteristic of Mangrove trees to heights of 1 to 2m, forming communities about 15m high.

3) Bakau minyak trees form an upper storey 20m in tree height and Nipah forms a lower storey 5m in height. Burut burut trees displayed brown shiny stems along the shore. Yellow fruits about 15cm in diameter hanging from tree branches are impressive.

4) Bakau kurap trees in uniform forests 15m in tree height, different from Bakau minyak of the Mangrove family near the rivermouth appear. Soon, the Mangrove growth marginal land was reached.

5) Forests change back to two storeys. Dungung (tree height 10 to 13m) and Nipah (7m). Ara (15m) and Nibong (15m) mix in some places.

6) Vegetation chang to uniform forests of Nibong (tree height 15m). Nibong trees have splinters on their stems, and the fruit is edible. Nibong is a palm with a beautiful tree form.

7) Close to the confluence of the Batu Apoi Rivers, Nipah trees spread as one storey 8 to 10m in tree height. In the distance Dungung trees (tree height 20 m) and Ara trees (15m) could be seen above them.

8) Nipah trees still continue but forests mixed with Gurah trees appear. Trees of both species are about 10m high.

9) Standing above the Gurah trees which form a lower storey 10m in tree height, Binjai trees (tree height 25m) appear. The distribution of Nipah trees becomes sparse in this area, and are about 5m high. Rengas trees (10m) increase in this area and some Kayu arang (20m) can also be viewed.

10) Near Bangar town, Getahpara (tree height 15 to 20m), Binjai (25 to 30m), Ara (15m) and planted Buah kelapa (15 to 20m) become upper-storey trees. White flowers of Merbadak trees (3m) and purple flowers of Kudok kudok (2m) adorn the river banks.

Figure-50 summarises the changes in tree composition forming the forest landscapes viewed from the boat.

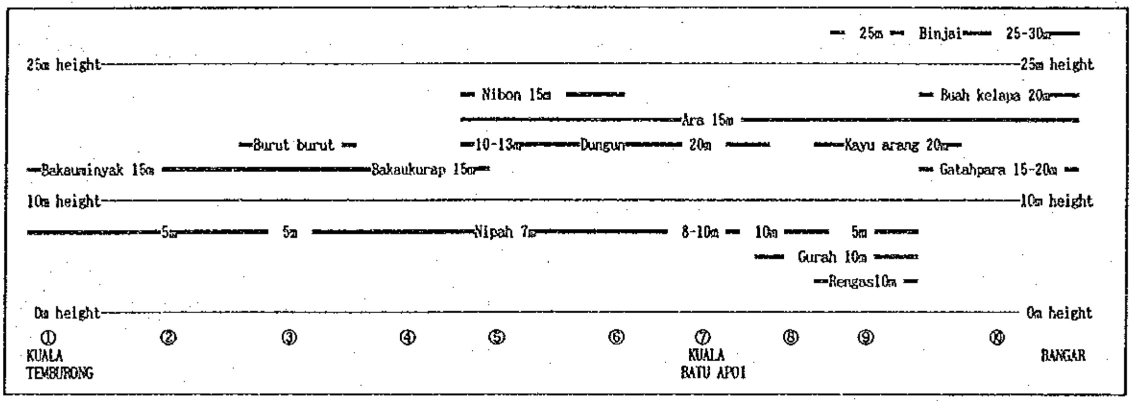



Figure-50 Forest landscape from Kuala Temburong to Bangar

From Bangar to Batang Duri, the boat was abandoned and the journey continued by car on a paved road. On the road, houses around Bangar and housing shelter forests of Kg. Amo and Batang Duri can be viewed.

Many of the trees forming these housing shelter forests were planted by the residents. Some of the trees have grown naturally without being cut.

These trees are closely related to the lifestyle of the residents, protecting rooms in their houses against intense sunshine, providing fruits and edible oil, and providing green trees as landscapes, among other purposes.

The results of a survey of housing shelter forest trees along the roads near Bangar are given below:

Membangan (fruits), Durian salat (fruits), Terap (fruits), Kapayas (fruits), Rambutan (fruits), Mempelam (fruits), Kandis (fruits), Pinang (fruits), Durian (fruits), Buluh (handiworks), Ubikayu (starch making), Jambu (fruits), Nangka