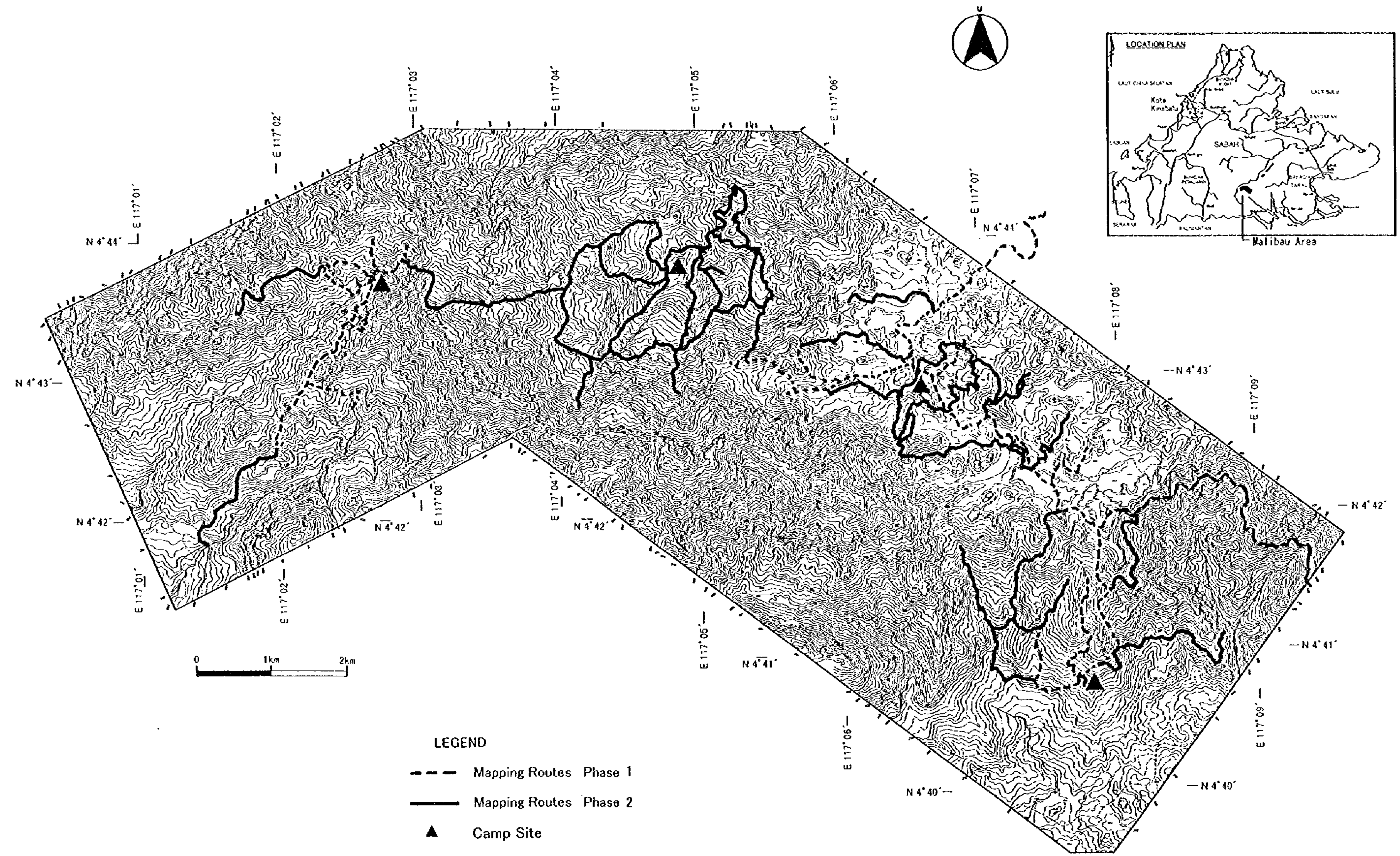


Figure 3-3-1 Mapping Routes - Malibau

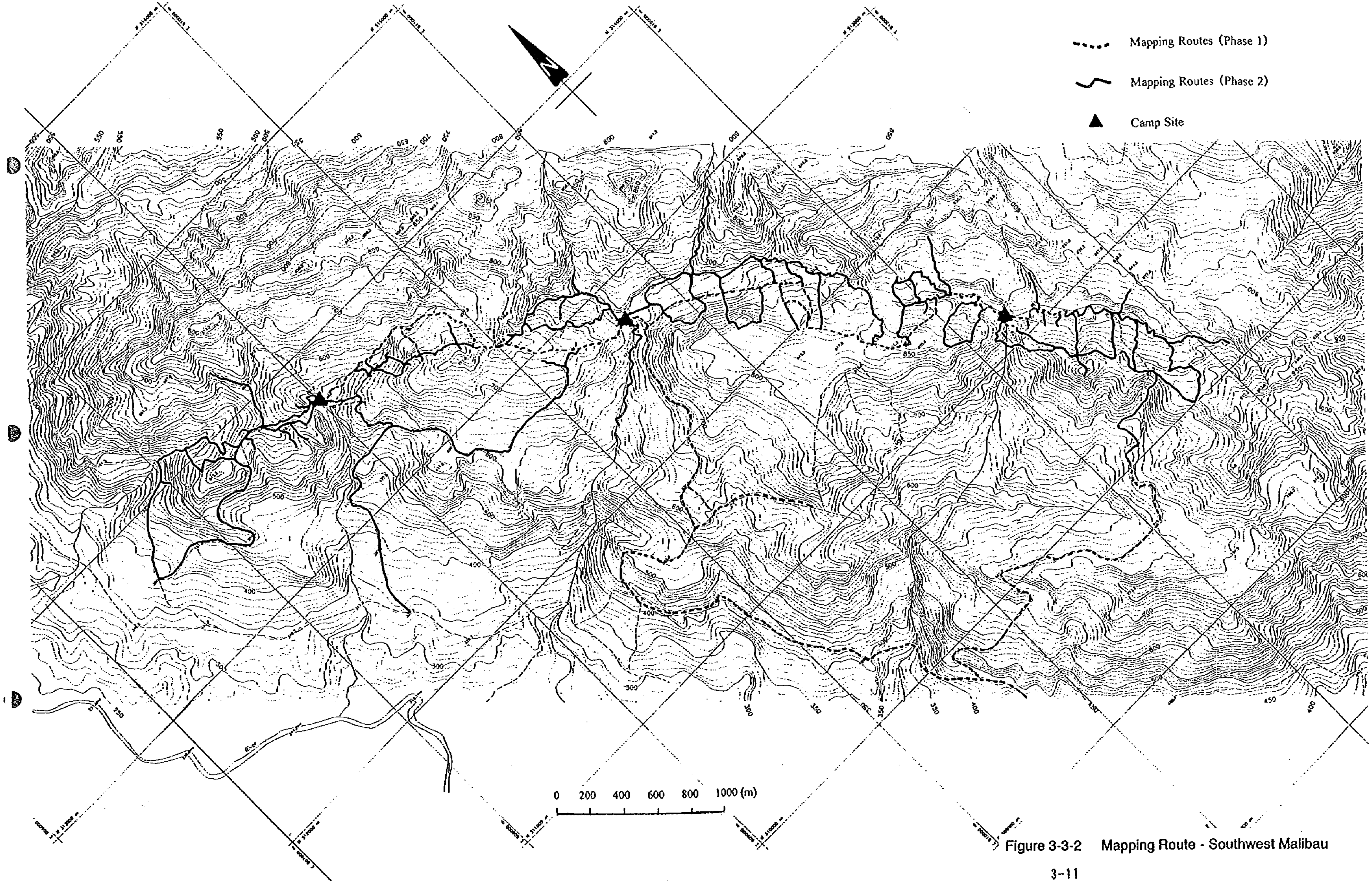


Figure 3-3-2 Mapping Route - Southwest Malibau

Table 3-1-2 List of Coal Outcrops - Soutwest Malibau Area

Outcrop No.	Location	Seam	Strike	Dip	Thickness Coal / Seam	Remarks
Phase 2						
NK101	JD14-15	SA lower	N 50 W	80 S	0.48 / 0.61	
NK102	JD15	SA	N 45 W	70 S	0.35 / 0.35	
NK103	JD17-18	SA	N 40 W	90	0.55 / 0.55	
NK104	JD022	SB1	N 50 W	50 S	3.15 / 3.40	
NK105	JF004	SA lower	N 50 W	90	0.30 / 0.30	north of JF004
NK106	JF004	SA	N 40 W	85 S	0.30 / 0.30	
NK107	JF007	SA	N 50 W	90	0.35 / 0.35	
NK108	JF018	SB1	N 45 W	90	0.70+ / 0.70+	
NK109	JF027	SC1	N 50 W	90	1.37 / 1.45	
NK110	JF028	SC2	N 40 W	85 S	0.97+ / 0.97+	
NK111	JG009	SC1	N 40 W	70 S	1.45+ / 1.45+	relogging in 1998 old SW62
NK112	JG018	SE1	N 40 W	65 S	0.50 / 0.60	
NK113	JG036-37	SD upper	N 40 W	25 S	0.25+ / 0.60+	
NK114	JG037	SD	N 40 W	40 S	Upper 0.55/0.55 Lower 0.30/0.30	
NK115	JG039	SC1	N 40 W	60 S	0.50+ / 0.50+	
NK116	BH27	SC2	N 40 W	65 S	1.20 / 1.23	relogging in 1998 old SW61
NK117	BH28	SC1	N 40 W	50 S	0.92 / 0.92	relogging in 1998 old SW60
NK118	JJ004	SE1	N 60 W	45 S	0.75 / 0.75	
NK119	JJ005	SE2	N 60 W	40 S		csh (5.05m) w/coal bands
NK120	JJ008	SF	N 75 W	65 S		csh-shale carbonaceous (1m)
NK121	JJ049		N 10 E	45 E	0.60+ / 0.60+	
NK122	JJ052		N 10 E	65 E		csh w/coal layer (1.55m) 柱状図なし
NK123	JJ057	SE1	N 85 W	50 S	0.33 / 0.33	
NK124	JJ058	SD	N 60 E	50 S	0.71 / 1.72	
NK125	JJ056-1	SE2	N 55 W	65 S	0.85+ / 0.98+	
NK126	JJ056-2	SE2 upper	N 80 E	45 S	0.20 / 2.15	csh-shale carbonaceous (2.15m)
NK127	JK002	SE1 lower	N 30 W	70 S		csh-shale carbonaceous (1.05m)
NK128	JM003	SC1	N 40 W	80 S	0.80 / 1.30	
NK129	JM007	SC1	N 45 W	70 NE	1.01 / 1.25	
NK130	JM010	SC2	N 50 W	85 NE	0.85 / 0.85	
NK131	JM012	SC1	N 35 W	80 NE	1.00+ / 1.00+	
NK132	JM019	SB1	N 50 W	90	1.30+ / 1.40+	
NK133	JN002-003	SB2	N 35 W	75 NE	0.30 / 0.30	csh w/coal layer(0.35m) coal (0.30m) = YK017
NK134	JP005	SB2	N 35 W	70 NE	1.60+ / 1.60+	
NK135	JQ001	SC3	N 55 W	80 S	0.93+ / 0.95+	
NK136	JQ004	SD	N 45 W	75 S	Upper 0.40/0.40 Middle 0.55/0.55 Lower 0.41/0.43	
NK137	JQ020	SE2	N 60 W	50 S	0.75 / 0.75	one coal seam(0.70+/1.35+) above this seam
NK138	JQ022	SE1	N 60 W	60 S	0.60 / 0.60	
NK139	JQ035	SC1	N 65 W	85 S	0.60 / 0.60	
NK140	JR001	SC3	N 50 W	80 N	0.90 / 0.90	
NK141	JV004	SB1	N 50 W	80 S	Upper 3.05/3.05 Lower 1.50/1.88	
NK142	JV011	SE1	N 45 W	70 S	0.82 / 0.82	
NK143	JV024	SD	N 45 W	50 S	Upper 0.16/0.16 Lower 0.35/0.35	
NK144	JW9-2	SB1	N 50 W	75 S	2.25+ / 2.45+	
SK001	JZ23		N 70 W	80 N	0.25 / 0.25	
SK002	JZ25-26	SD	N 50 W	90	1.40 / 1.40	
SK003	JZ55-55-1	SB(L)	N 60 W	50 S	0.30 / 0.30	

Table 3-1-2 List of Coal Outcrops - Soutwest Malibau Area

Outcrop No.	Location	Seam	Strike	Dip	Thickness Coal / Seam	Remarks
SK004	JZ55-1	SB1	N 62 W	48 S	0.60 / 0.60	
SK005	JZ60	SD	N 60 W	65 S	0.20 / 0.20	
SK006	JZ46-5	SB1	N 70 W	74 S	0.57 / 0.59	
SK007	JZ46-7	SD	N 50 W	83 S	0.25 / 0.25	
SK008	JZ66	SE1	--	--	1.45 / 1.45	moved block
SK009	JZ75	SE1	N 60 W	60 S	0.75+ / 0.75+	
SK010	JZ95	SE1	N 50 W	65 S	0.90 / 0.90	
SK011	JY06-2	SE2	N 58 W	72 S	1.29 / 1.29	
SK012	JY06	SE1	N 50 W	70 S	0.60+ / 0.60+	under big tree
SK013	JY17	SE1	N 56 W	60 S	1.19 / 1.20	
SK014	JY18	SE1	--	--	0.80+ / 0.80+	
SK015	JY19	SE2	N 40 W	70 S	2.00 / 2.00	
SK016	JY21	SE1	N 70 W	55 S	1.05 / 1.05	
SK017	JY22	SE2	N 60 W	61 S	1.69 / 2.07	
SK018	JY29	SE(L)	N 55 W	60 S	0.65 / 0.65	
SK019	JY34-1	SE2	N 80 W	75 S	2.49 / 2.54	
SK020	JY36	SE1	N 65 W	65 S	1.47 / 1.54	
SK021	BK03	SD	N 60 W	80 S	1.20 / 1.20	
SK022	JX07	SE2	EW	65 S	1.08 / 1.23	
SK023	JX28	SE2	--	--	1.10+ / 1.10+	moved large coal seam block
SK024	JY60-2	SB1	N 72 W	85 S	0.40 / 0.45	
SK025	JW05-06	SE1	N 60 W	60 S	3.47 / 4.45	upper 2.07/2.07 lower 1.40/1.40
SK026	JW07-08	SE1	N 70 W	80 S	3.05 / 4.75	Btm 0.75/0.75 0.75/0.75 0.80/0.85 0.75/0.75 Tc
SK027	JW10-1	SE2	N 70 W	60 S	0.30 / 0.30	
SK028	JW13	SE2	N 55 W	75 S	0.25 / 0.25	
SK029	JW25	SE2-SE1	N 60 W	85 S		coal-csh
SK030	JW39	SE1	N 80 W	90 S	0.99 / 1.79	upper 0.57/0.62 lower 0.42/0.42
SK031	JW40-1	SE1	N 55 W	85 N	0.42 / 1.25	
SK032	JW41	SE2	N 60 W	80 S	0.18 / 0.31	
SK033	JW61	SD	N 80 W	85 S	0.25 / 0.25	
SK034	JV06		N 50 W	52 S	0.25 / 0.25	
SK035	JV10		N 45 W	55 SW	0.23 / 0.23	
SK036	JU24-25	SC2	N 40 W	80 E	0.32 / 0.35	
SK037	JU44	SD	N 20 W	70 W	0.40 / 0.46	
SK038	JU45	SD	N 20 W	75 W	0.57 / 0.63	
SK039	JU67	SC4	N 25 W	70 S	0.95 / 0.95	
SK040	JU68	SD	N 25 W	75 S	1.60 / 1.80	Bottom? due to big tree roots
SK041	JU73-1	SE1	N 45 W	60 SW	0.73 / 0.78	2 csh beds above SK041
SK042	JU74	SE2	N 45 W	55 SW	0.86 / 1.01	1.08/1.71 including lower parts
SK043	JU76	SF	N 50 W	85 SW	1.75 / 1.93	
SK044	JT41	SD	N 20 W	45 W	1.57 / 2.35	one coal seam(0.5m) below this seam
SK045	JT44	SC4	N 20 W	80 W	0.63 / 0.63	thinning out toward the depths
SK046	JT41-2	SD	N 30 W	50 W	Upper 0.90/1.60, Lower 0.90/0.90	
SK047	JT48	SC4	--	--		in a muddy stream
SK048	JT53	SC1	--	--		moved block (50cm)
SK049	JT74	SC4	--	--		moved block (85cm)
SK050	JT95	SD	N 40 W	75 w	2.05 / 2.23	
SK051	JS45	SF	--	--		moved block (50cm)

Table 3-1-2 List of Coal Outcrops - Soutwest Malibau Area

Outcrop No.	Location	Seam	Strike	Dip	Thickness Coal / Seam	Remarks
SK052	JU03	SC2	N 35 W	70 W	1.47+ / 1.47+	relogging in 1998, old SW15 (1.70/1.70)
SK053	JS82	SE2	N 45 W	85 SW	0.50 / 0.50	
Phase I						
SW13	JU27	SC2	N 40 W	50 NW	0.35 / 0.35	
SW14	JU19	SC2	N 35 W	90	0.55 / 0.62	relogging in1998
SW15	JU03	SC2	N 35 W	70 W	1.70+ / 1.70+	relogging in 1998 SK052 (1.47+/1.47+)
SW16	BH107	SC3	--	--	0.80+ / 0.80+	
SW17	BH104-1	SC2	N 45 W	80 N	0.70 / 0.70	relogging in1998
SW18	BH104-BH104-1	SC3	N 45 W	80 N	1.12 / 1.20	relogging in1998
SW19	BH90	SC2	N 38 W	72 N	1.20 / 1.20	relogging in1998
SW20	BH85	SC2	N 45 W	77 S	1.05 / 1.05	relogging in1998
SW21	BH78	SC1	N 45 W	90	0.60 / 0.60	
SW22	BH77	SB2	N 40 W	90	0.42 / 0.49	
SW23	JP26	SB2	N 40 W	80 S	2.86 / 2.90	relogging in1998
SW24	BH93	SD	N 40 W	85 N	Top 0.52/0.55	Middle 0.45/0.45 Bottom 0.37/0.37 relogging in 199[illegible]
SW25	JT12	SF	N 39 W	70 NE	1.55 / 1.60	relogging in1998
SW33	BK72	SB lower	N 70 W	68 S	0.68 / 0.68	
SW34	BK73	SB1	N 65 W	68 S	0.40 / 0.40	
SW35	BK78	SE2	N 60 W	45 S	1.70 / 1.91	
SW36	JX15	SE1	N 85 W	70 S	2.40 / 2.75	
SW37	BK111	SE1	N 75 W	[illegible]0-90 S	4.09 / 4.86	relogging in1998
SW59	BH22	SB1	N 40 W	42 S	1.10 / 1.50	
YK015	BH0-BH1	SE1	N 35 W	70 S	1.05 / 1.07	
YK016	BH19	SB1	N 30 W	35 W	1.10 / 1.10	thin out toward SW59
YK018	BH71	SB2	N 40 W	75 S	0.25 / 0.25	
YK019	BH32-4	SC1	?	?	1.00 / 1.00	approximately
YK020	BH86	SC1	N 50 W	65 N	0.50 / 0.50	
YK021	BH93	SE1	N 40 W	80 N	0.75 / 0.75	relogging in1998
YK022	BH100	SE1	N 40 W	80 N	0.90+ / 0.90+	
YK023	BH108-JU01	SC1	N 35 W	70 N	0.70 / 0.70	
YK024	JU02-JU03	SC1	N 60 W	65 N	0.60 / 0.60	
YK025	JT90	SC3	N 45 W	75 N	0.95 / 0.95	relogging in1998
YK026	JT91	SC4	N 30 W	70 N	0.90 / 0.90	relogging in1998
YK027	BK45	SE2	N 50 W	80 S	1.20 / 1.20	
YK028	BK46	SE1	N 50 W	80 S	1.30+ / 1.30+	
YK029	BK77	SE1	N 55 W	60 S	2.00 / 2.00	
YK030	BK94	SE1	N 70 W	54 S	1.90 / 1.90	
YK031	JY53-JY54	SE2	N 50 W	60 S	1.40 / 1.45	
YK032	BK124	SF	N 85 W	65 S	0.50 / 0.50	

Based on the result of quality evaluation in Phase 1, some kinds of analyses to evaluate the suitability as steaming coal were carried out on selected samples, in addition to general analytical items in Phase 1 as shown below :

① All samples : Proximate analysis, Calorific value, Total sulfur, Ultimate analysis, Free swelling index (FSI)

② Selected samples : Hardgrove grindability index (HGI), Ash fusion temperature, Ash analysis (SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O, SO_3, P_2O_5, TiO_2, MnO)

The number of samples in each area is as follows :

	Malibau	SW-Malibau	Silimpopon	Total
Sample ①	15	25	1	41
Sample ②	7	7	1	15

Analysis of sample ① was done at coal laboratory in GSD Sarawak, while analysis of sample ② was done in Japan. Selected samples were homogeneously divided into halves, sample ① and ②, and each of them were sent to Sarawak and Japan respectively.

4. Coal Seams in the Study Area

4. Coal Seams in The Study Area

4.1. Malibau Area

4.1.1. Mode of Occurrence

The coal zone in the area was confirmed to extend for about 16 km in the strike direction with the thickness of 600 m to 1,000 m. A large number of coal seams are contained in the coal zone. A total of 130 coal outcrops were observed through geological mapping in Phase 1 and Phase 2 as listed in Table 3-1-1.

Figure 4-1-1 shows the location of coal outcrops in the area. By comparing relative position and elevation of neighboring outcrops, continuity of each outcrops has been inferred, and then correlation of coal seams has been established throughout the area, taking their stratigraphic position into account. Continuity of each outcrop is indicated by connecting with broken lines in the figure. Figure 4-2-1 illustrates the correlation of coal seams with representative stratigraphic columns of coal zone, which were produced from geological cross sections at corresponding positions.

As shown in the above-mentioned figures, relatively long continuity is recognized in six coal seams, which have been named MA to MF from the bottom to the top. Other coal seams that exist between these six seams are less continuous or show sporadic mode of occurrence.

Figures 4-3-1 and 4-3-2 exhibit coal seam profiles measured at outcrops in both Phase 1 and Phase 2 and they are arranged at corresponding levels according to the correlation shown in Figure 4-2-1. The following is a brief explanation of the condition of main coal seams :

<u>MA Seam</u>

The seam lies near the bottom of the coal zone and exists in the middle-eastern part of the area. Only three outcrops were observed and their average thickness is 0.87 m with 1.09 m at the maximum. Confirmed distance of seam continuity is about 0.6 km with possible extension of 1 km toward the west where the seam is deteriorated to carbonaceous shale.

MB Seam

The seam exists in the middle part of the area extending for about 2.6 km along the strike. Seven outcrops were observed and four of them are more than 1 m in seam thickness. However, the seam thins to 0.3 m at both eastern and western ends of the outcrop line. In general, the seam contains some partings as seen in the profile of SK230 which has the maximum seam thickness of 1.52 m including 0.46 m parting.

MC Seam

The seam exists in the eastern part of the area with a continuous extent of about 2 km. It seems to continue farther 2 km to the east and 0.5 km to the west, but outcrops there are very thin or deteriorated to carbonaceous shale. The average thickness of eight outcrops in 2 km extent is 0.92 m with the maximum thickness of 1.51 m including partings.

MD Seam

The seam exists in the middle to eastern part of the area and shows the longest continuity of about 5.7 km. Although all the outcrops are less than 1 m, nine outcrops observed in the main part of its extent have no parting and are less variable in thickness, ranging from 0.57 m to 0.85 m averaging 0.7 m. It is thinning to the west but eastern limit of its extent has not been confirmed.

ME and MF Seams

Both seams exist only in southeastern part of the area with confirmed extent of 1.2 km for ME seam and 0.9 km for MF seam. Three outcrops were observed in each seam and the average thickness is 0.4 m for ME seam and 0.7 m for MF seam. Thinning trend toward the east was observed in both seams but western limit is unknown.

Coal Seams in western part

In the westernmost part of the area, there are four coal seams in the lower half of the coal zone, which have been unnamed because of their uncertainty of correlation with coal seams in other parts. Their thickness is invariable ranging from 0.6 m to 0.7 m without any parting. In the upper half of the coal zone, only a few thin coal seams or carbonaceous shales are present.

The coal seam condition of Malibau area is summarized as follows :

(1) There are a large number of coal seams in a widely extended coal zone. Among them, six coal seams which have been named MA to MF Seams keep their continuity in relatively long distance ranging from 5.7 km in MD seam to 0.6 km in MA seam. Other coal seams are less continuous or occur sporadically.

(2) The coal seams are generally thin. Among 130 coal outcrops observed in Phase 1 and Phase 2, only 12 outcrops exceed 1 m in seam thickness. The thickest outcrop is 1.52 m of MB seam including partings. It seems that thicker seams contain more partings like MB seam which is more than 1 m thick at four outcrops but their average coal thickness excluding partings is 0.89 m. Regarding coal thickness, only six outcrops exceed 1 m in the area.

4.1.2. Geological Structure

Geological structure of the area is relatively stable. The coal seams extend in the shape of crescent, changing their strikes from NW-SE at the eastern part to WSW-ENE at the western part. The dip of the coal seams range from 30 to 55 degrees toward the south, 40 degrees on the average as shown in Figure 4-4-1. Any structural disturbance was not observed in the field except at the southeastern corner where a faulting was inferred accompanied by a synclinal structure, but it does not extend to the main part of the coal zone.

4.2. Southwest Malibau Area

4.2.1. Mode of Occurrence

The coal zone in the area was confirmed to extend for about 6.5 km in NW-SE direction. In addition to 4.5 km of coal zone confirmed in Phase 1, farther 1 km each to both eastern and western sides was traced and some coal outcrops were observed. However, the coal seams in the extension zone are mostly thin and deteriorated. Therefore, the main part of the coal zone containing relatively thick coal seams is 5 km in distance.

A total of 133 coal outcrops were observed during field work in Phase 1 and Phase 2 as listed in Table 3-1-2. The location of coal outcrops and their correlation are shown in Figure 4-1-2 and Figure 4-2-2 respectively.

As seen in Figure 4-2-2, both the thickness of coal zone and the number of coal seams increase toward the east. Coal zone in the eastern part is 350 m in thickness and contains more than eight coal seams. On the contrary, only a few coal seams are present in the coal zone of 100 m thick in the western part.

Based on the correlation in Figure 4-2-2, coal seams in the area were divided into six seams (groups) and they were named SA to SF Seams (groups) from the bottom to the top. Among them, SA, SB, SC and SE groups are composed of a few separate coal seams and SD and SF are of a single coal seam.

As shown in these figures, all the coal seams do not exist continuously throughout the area. It is presumed that in those parts indicated as discontinuity, deposition of peat was not taken place originally or peat was washed out at early stage of deposition, judging from sandstone dominated lithology in those parts.

Figure 4-3-3 exhibits coal seam profiles measured at outcrops in both Phase 1 and Phase 2 and they are arranged at corresponding levels according to the correlation shown in Figure 4-2-2. The following is a brief explanation of each coal seam (group).

SA Seam Group

This group exists at the bottom of coal zone in a limited extent. It contains two coal seams and both of them are very thin. The maximum thickness among six outcrops is 0.61 m including partings.

SB Seam Group

This group has two coal seams, namely, SB1 and SB2 Seams.
SB1 Seam extends for 1.5 km in the middle part of the area. It is generally thick but shows a great variation in thickness, ranging from 5.1 m to 1.1 m among seven observed outcrops, although roof and floor were indefinite at three outcrops.

SB2 Seam appears near the eastern limit of SB1 Seam, extending 0.5 km to the east. It has a thickness of 2.9 m at an outcrop of the middle part but quickly thins within a distance of 30 m. In the western part of the area, there are two separate outcrops at the stratigraphic position of SB Seam, but their extent is very limited and the thickness is very thin.

SC Seam Group

This group exists only in the eastern half of the area and consists of four coal seams, named SC1 to SC4 Seams from the bottom to the top. At the easternmost part, all of the four seams are present, but they gradually disappear toward the west in order from the top seam to the bottom and finally only SC1 Seam is present at the middle part of the area. The confirmed extent of individual seams ranges from 0.2 km in SC4 Seam to 2.2 km in SC1 Seam. The coal seam in this group contains few parting and thickness is relatively invariable compared with other seams, ranging from 0.92 m of SC1 to 1.00 m of SC3 seams on the average of individual seams.

SD Seam

The seam occurs in two separate places, namely, for 1.4 km in the middle part and for 0.8 km in the eastern part at a 2 km interval of absence of the seam. It exceeds 1 m thick at four outcrops out of ten observed with the maximum thickness of 2.23 m. However, the thickness varies widely and the greater thickness does not continue for long distance. Splitting features into a few plies are observed to the central part near the interval of the seam absence.

SE Seam Group

This group consists of two seams, SE1 and SE2, and they are regarded as the most promising seams in the area in terms of thickness and continuity.

SE1 Seam is present over 3.5 km in the middle-western part and 1.3 km in the eastern part with a discontinuous interval of 1 km in between. In the western part, it has the maximum thickness of 4.86 m and keeps the thickness of more than 1 m for 1.5 km to the east, while it splits and thins quickly to the west. The average coal / seam thickness of 20 outcrops in this part is 1.52 m / 1.81 m except thin seams at the both ends. In the eastern part, it is less than 1 m thick ranging from 0.6 to 0.9 m.

SE2 Seam also occurs separately for 1.7 km in the west and for 0.9 km in the east with an interval of 2.7 km in the middle. In the west, nine outcrops excluding three at the westernmost extension exceed 1 m thick, with 2.54 m at maximum and 1.64 m on the average. In the eastern part, there are only two outcrops both of which are thin or splitting.

SF Seam

The seam occurs at the easternmost part of the area. Although the thickness of two outcrops is 1.77 m on the average, it extends only for 0.5 km. At the western part, a coal outcrop was found at the corresponding horizon to SF Seam but it is only 0.5 m thick.

The coal seam condition of Southwest Malibau area is summarized as follows :

(1) A total of 11 coal seams exist in the area and they are divided into six seam groups, namely, SA to SF from the bottom to the top. Both the number of coal seams and the thickness of coal zone increase to the east. The longest continuous extent is 3.5 km in SE1 Seam at the western part.

(2) Compared with Malibau area, the extent and the thickness of the coal zone in the area is much smaller, while the thickness of coal seams contained in the coal zone is much greater. The average thickness of individual coal seams are mostly more than 1 m and great thickness of more than 4 m are found in SB1 and SE1 Seams. However, the coal seams in the area are considerably variable in their thickness. Although SC Group shows relatively constant thickness, they are as thin as about 1 m.

4.2.2. Geological Structure

The coal seams extend in NW-SE direction with very steep dip to the southwest, nearly vertical or dipping in the opposite direction at some places in the eastern part. Representative geological cross sections are shown in Figure 4-4-2.

At the immediate south of the coal zone in the central part, there appears to be a synclinal structure. Because of poor coal seam occurrence on the southwestern side of the apparent synclinal axis, a question has been left after Phase 1 whether the steeply dipping coal seams are in a synclinal structure or overturned.

During the field work of Phase 2, some sedimentary structures were observed such as "load cast" and "ripple mark", which are believed to be the evidence to determine the upper and lower sides of a bed of sedimentary rock. Based on these observation, it was concluded that all the coal seams incline to the southwest originally and a synclinal axis must exist at the southwestern side of and in parallel to the coal zone.

Concerning the reason why only a few thin coal seams exist on the southwestern side of the synclinal axis, it is presumed that, judging from the great thickness variation of coal seams in the main part, they did not extend as far as this side originally, in other words, the sedimentary environment in this part was not suitable for peat deposition.

4.3. Silimpopon Area

4.3.1. Mode of Occurrence

Out of several coal seams in Silimpopon area, only the Queen Seam has mineable thickness. Almost all data of the Queen Seam is based on the report by P. Collenette (1954), because no additional exploration was done since then except for observation and sampling of one outcrop of the Queen Seam during the present study.

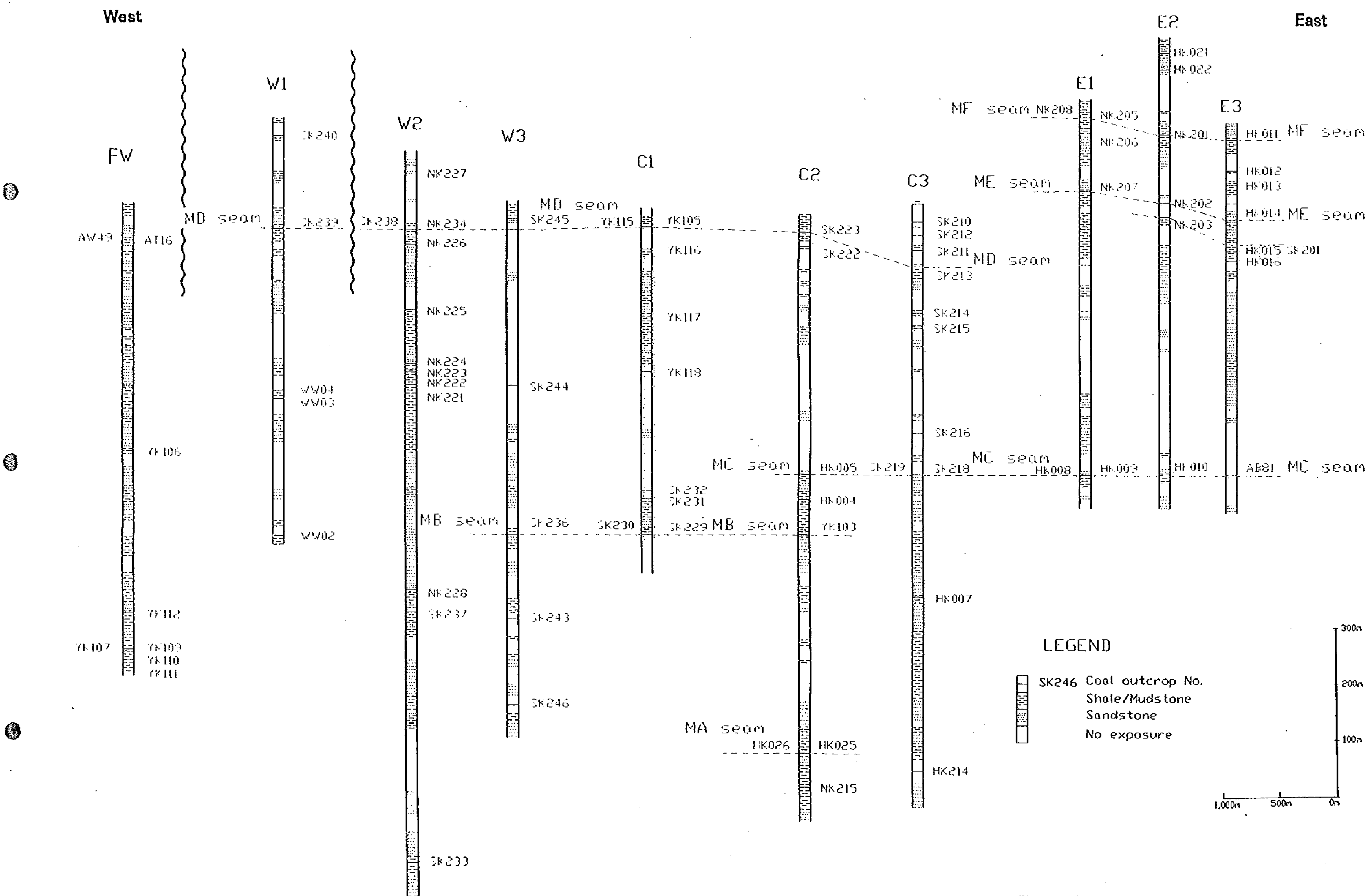
The coal seam data included in the report is based on the following activities :

- Nine boreholes drilled in early 1900's
- Geological mapping by Collenette around 1950
- Record of an old coal mine operated between 1906 and 1932

The outcrops of the Queen Seam have been traced from the north to the southeast for a distance of about 7 km. The outcrops near the old mine mouth are more than 1.7 m thick. However, it seems that a parting at the lower part is thickening and coal above the parting is thinning and deteriorating toward the southeast and finally, the seam deteriorates to coaly shale at the outcrop PC331.

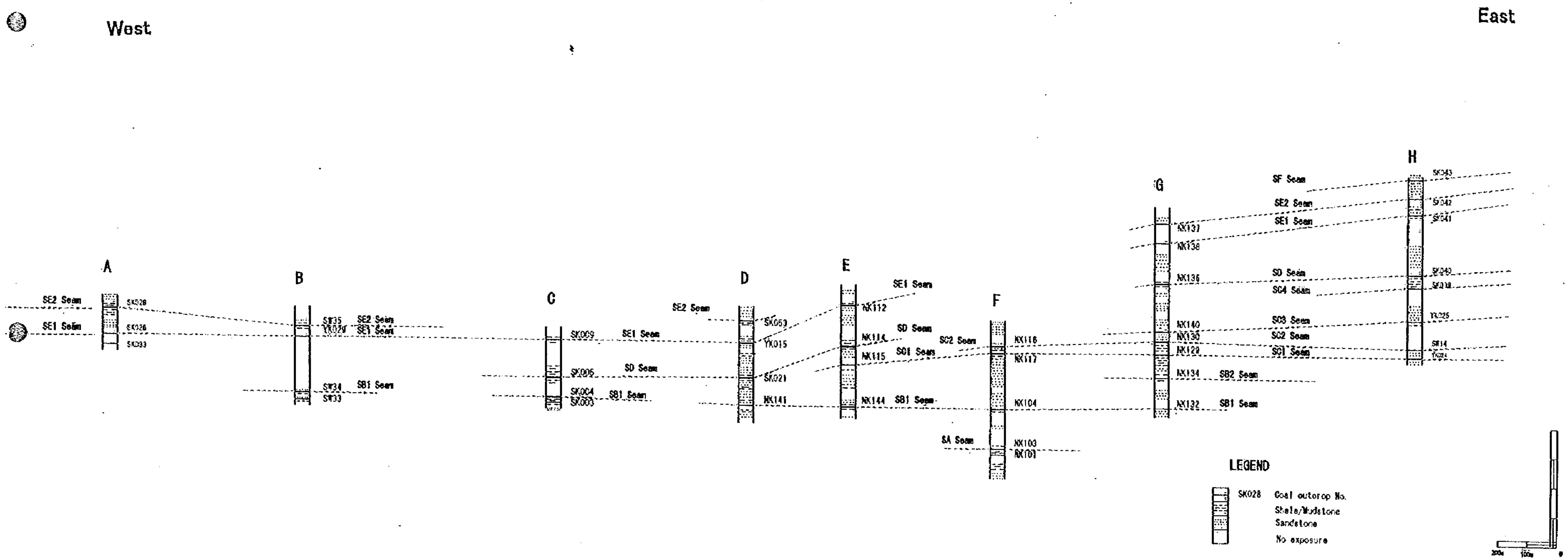
In the western part, the Queen Seam was not exposed ~~and~~ for a distance of 3 km. There are three thin coal outcrops at the southwestern part and they have been provisionally correlated to the Queen Seam. If the correlation is correct, they indicate the same thinning trend as in eastern part.

In seven boreholes out of nine, the Queen Seam was encountered and their records have been given as shown in Table 4-1.



Positions of columnar sections are shown in Figure 4-1-1.

Figure 4-2-1 Coal Seam Correlation - Malibau



Positions of columnar sections are shown in Figure 4-1-2.

Figure 4-2-2 Coal Seam Correlation – Southwest Malibau

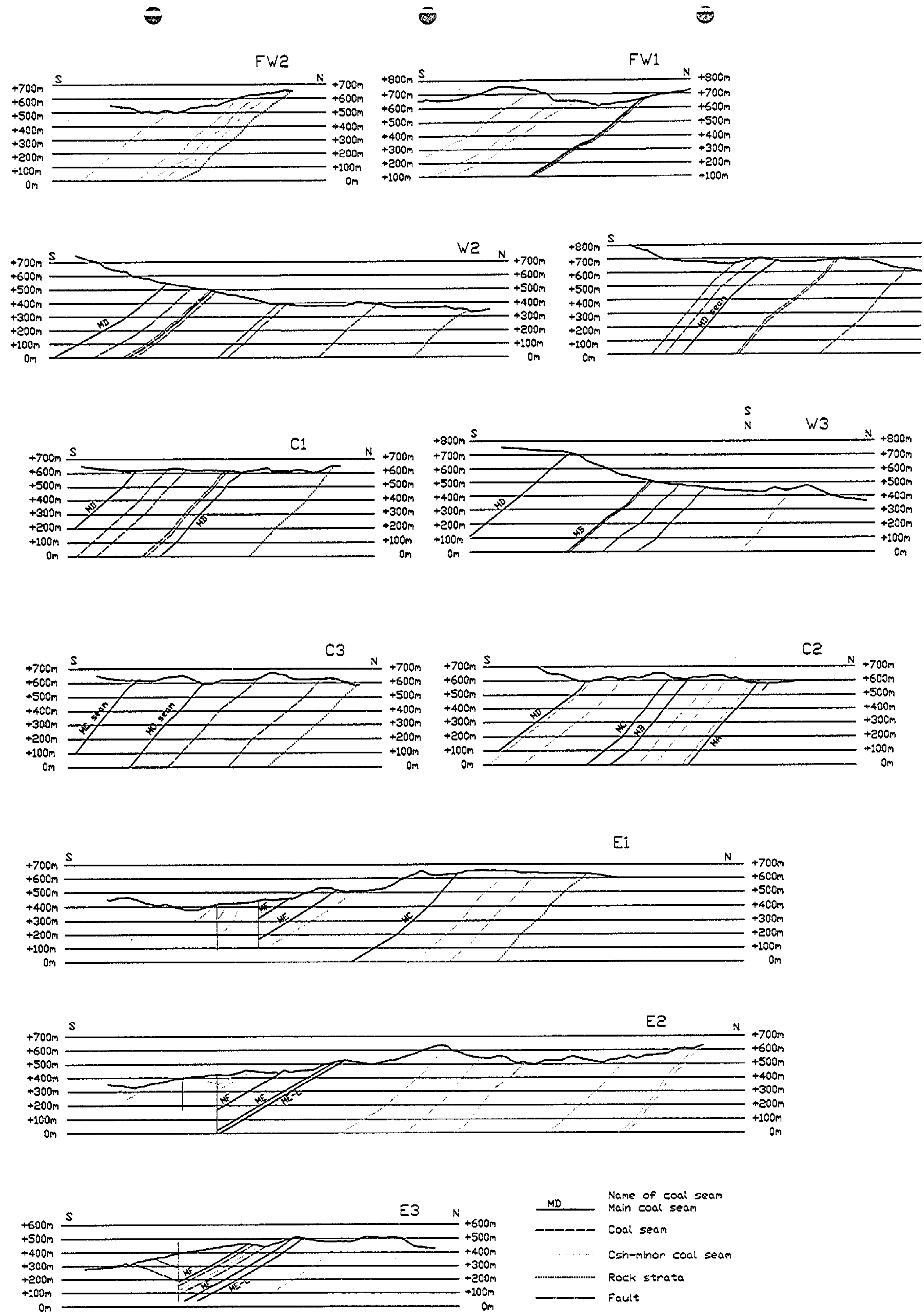


Figure 4-4-1 Geological Cross Sections - Malibau

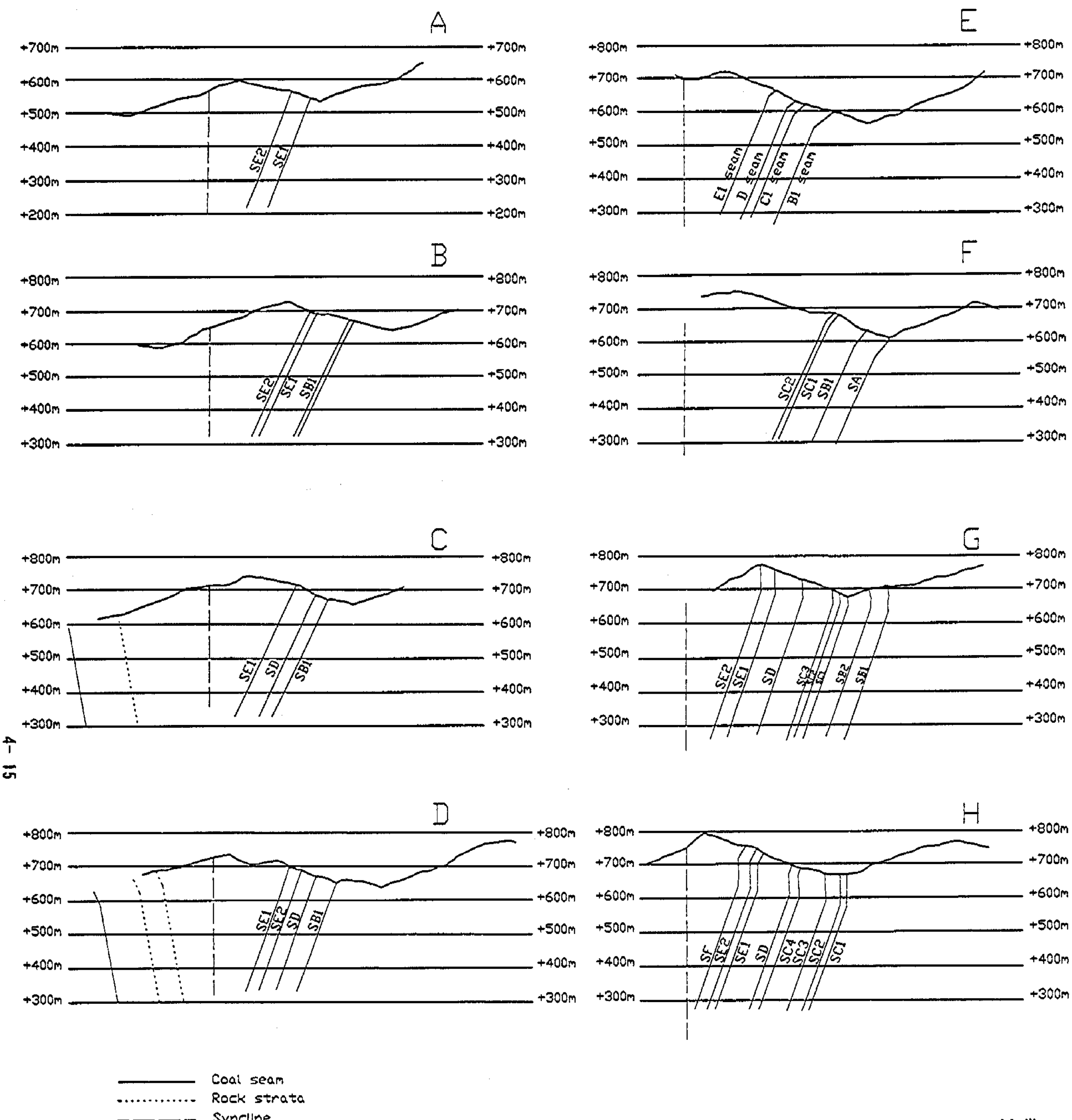


Figure 4-4-2 Geological Cross Sections - Southwest Malibau

Table 4-1 Drilling Record in Silimpopon (feet. inches)

Hole No.	Depth to Coal	Thickness of Coal
No.1 Diamond	261	no record
No.2 Diamond	149	6.0
No.3 Diamond	237	6.0
No.4 Diamond	181	6.0
No.2 Isler	365	5.11
No.3 Isler	492	6.0
No.5 Isler	585	5.5

In two boreholes, No.1 and No.4 Isler, the Queen Seam was not encountered, although they were sunk to a depth considerably greater than that at which the Queen Seam was expected. Drilling record shows as follows :

Expected depth of coal (feet) - No.1 : 420, No.4 : 660

Total depth drilled (feet) - No.1 : 1,209, No.4 : 1,111

The cause for absence of the Queen Seam is not clear, but the following suggestion has been given in the report, "The presence of thin coal, coaly rock, and dark shale where the Queen Seam is missing suggests that the discontinuity may be due to deterioration of the seam."

It should be noted that the accuracy of drilling information in the above report is uncertain partly. For instance, the borehole positions are shown in the map attached to the report without coordinates and ground elevation and further, river system in the map is different from that in the existing topographic sheet No.4/117/10. These matters are related to the accuracy of the positions of the Queen Seam. Regarding the coal seam data in the boreholes, the presence of parting and their thickness is unknown owing to the lack of detailed log of the seam.

Figure 4-5 shows the profiles of the Queen Seam formerly observed at outcrops, boreholes and an adit as well as one outcrop investigated during this study. The seam normally contains some partings of mudstone and carbonaceous shale which appears to be thicker to the south. A thin coal band is present at 0.6 to 0.8 m above the Queen Seam around the mined out area. The roof of the seam is weak shale, occasionally carbonaceous, and the floor is hard sandstone in general. The isopachs of the seam thickness are also drawn in the Figure 4-5.

4.3.2. Geological Structure

The structure contours of the Queen Seam are shown in Figure 4-6 together with the representative cross sections of the area.

The geological structure in the area is dominated by a broad syncline, of which axis plunges to the southeast. The Queen Seam in the eastern limb of the syncline lies with an average dip of 10 degrees to the south. The dip in the western limb seems to be steeper than in the eastern limb.

A fault is inferred based on the discontinuity of the Waterfall Sandstone bed on the surface with an estimated horizontal displacement of about 300 m. If this is so, the underlying Queen Seam may also be affected as shown in Figure 4-6. A fault is recorded in the old mine plan at the southwestern corner of the mined area. However, it is more likely that this discontinuity of the coal seam was not caused by a fault but by deterioration of the coal seam.

As mentioned before, it was suggested that the missing of the Queen Seam in two boreholes is due to deterioration of coal seam. However, it is still possible that a minor normal fault may have caused the missing, because any deterioration trend is not found in the surrounding boreholes.

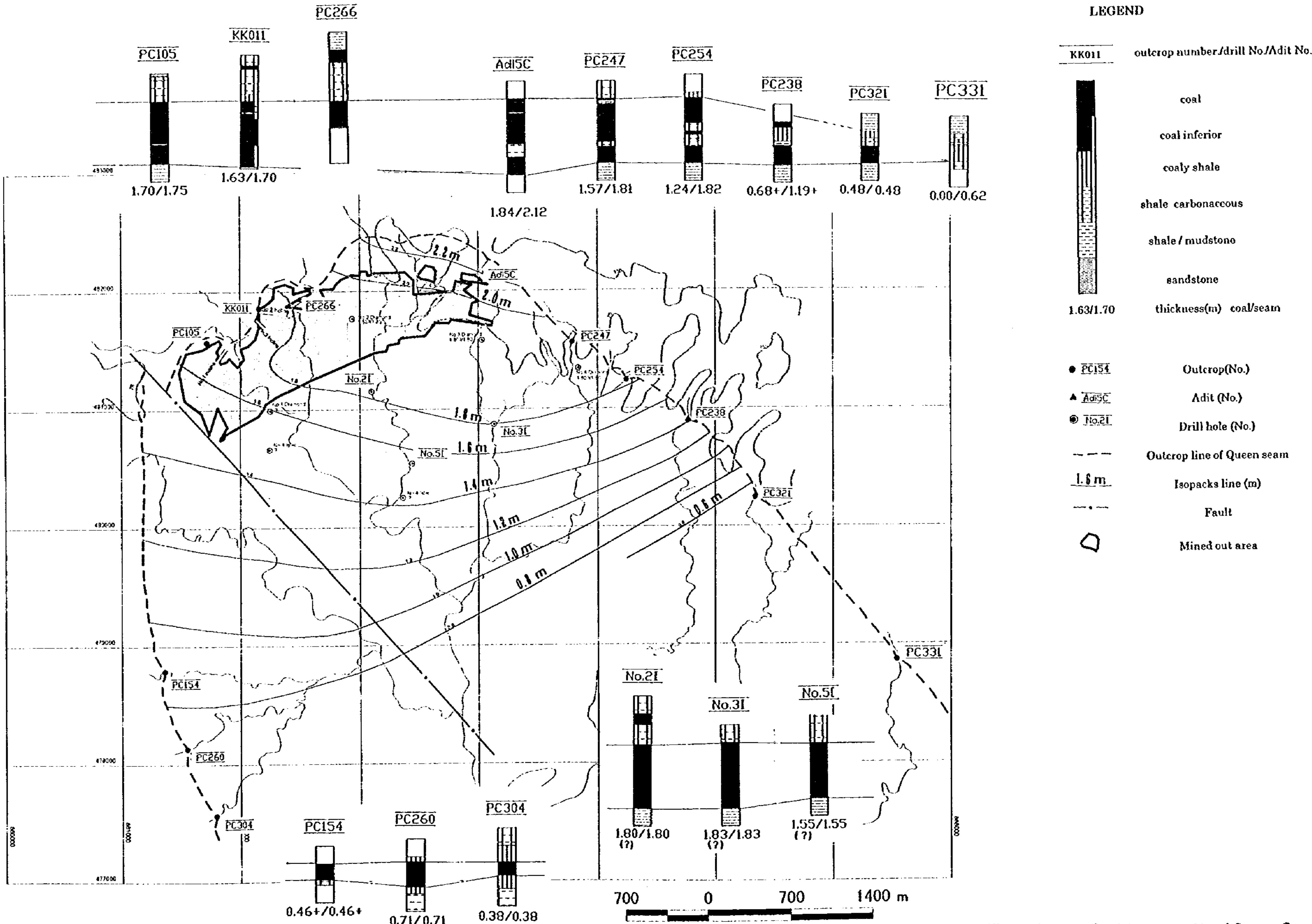


Figure 4-5 Coal Seam Profile of Queen Seam

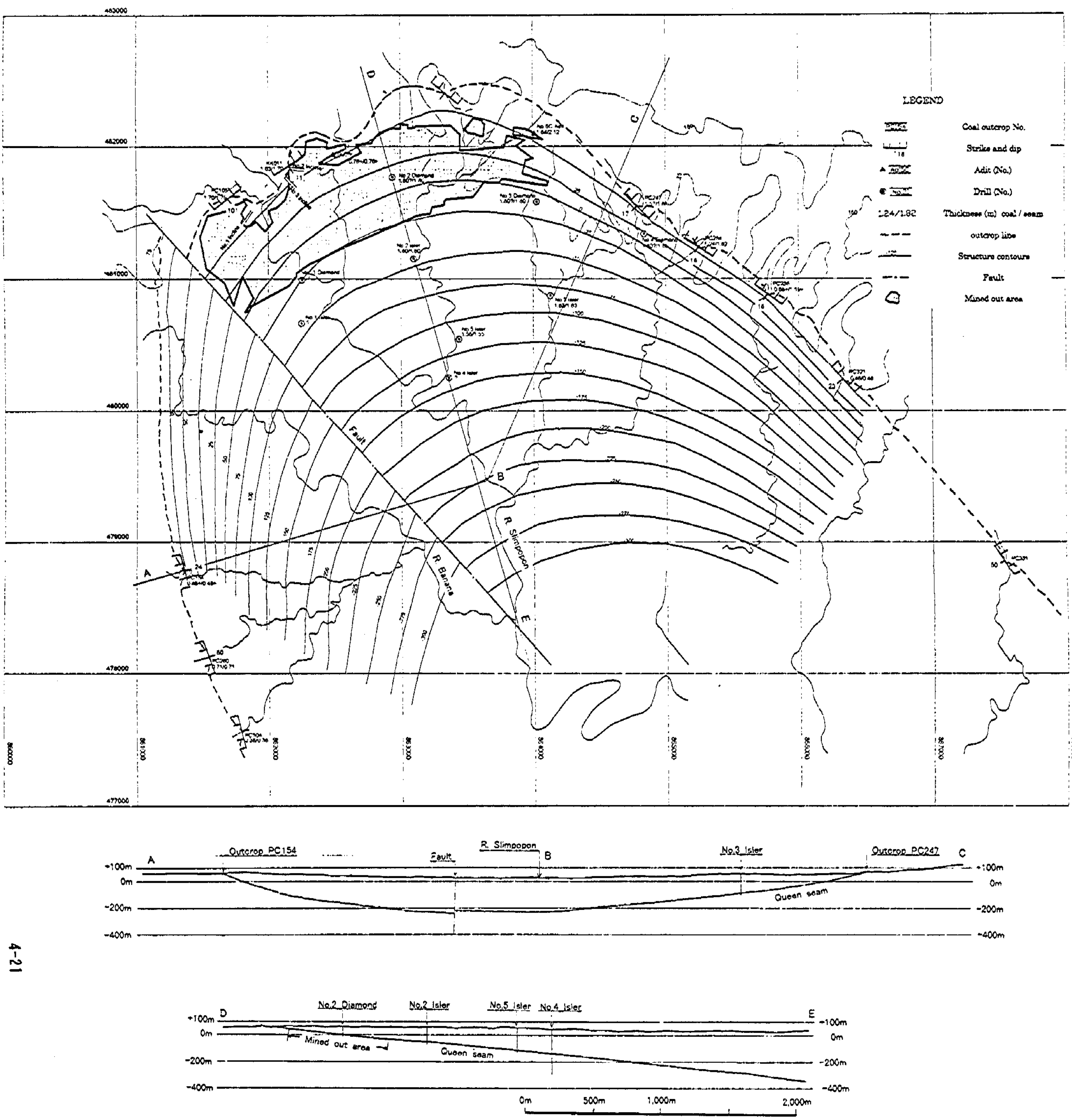


Figure 4-6 Geological Structure of Queen Seam

5. Estimate of Coal Resources

5. Estimate of Coal Resources

5.1. Criteria for Coal Resource Estimate

In-situ coal resources have been estimated in Malibau and Southwest Malibau areas. Coal resources in Silmpopon area have not been estimated in the present study, because the estimated reserves have been given in the previous report (P.Collenette, 1954) and no additional exploration has been done since then.

The estimate was made basically in accordance with the GSD's Reserve/Resource Classification System, an extract from which is attached in Appendix 1. The criteria adopted for resource estimate in this study are as follows :

(1) Resource class

In Phase 1 study, all of the estimated resources were classified as "Inferred Resources" in the stage of Prospecting. Since the Phase 2 study is regarded as "General Exploration Stage of Geological Study" according to the definitions of GSD's system and the reliability of geological data has been improved by detailed mapping, the estimated resources are upgraded to "Indicated" in resource class.

(2) Coal seam

In Phase 2 study, correlation of coal seams has been established for the most part except thin and sporadically occurring coal seams. Therefore, coal resources are estimated for individual coal seams separately according to the correlation.

(3) Limiting factors

(a) Coal thickness

More than 0.6 m (excluding parting)

Average coal thickness of all outcrops is used for estimate of each block.

(b) Maximum distance of estimate

In strike direction from observation points : 1,000 m

In dip direction from the surface : 500 m

The distance in dip direction was limited to half of that in strike direction because of no exploration for underground part of resources.

(c) If the next outcrop is less than 0.6 m, estimate area is limited to the distance divided proportionally by the thickness of two outcrops.

(d) Specific gravity of coal : 1.3

5.2. Coal Resources

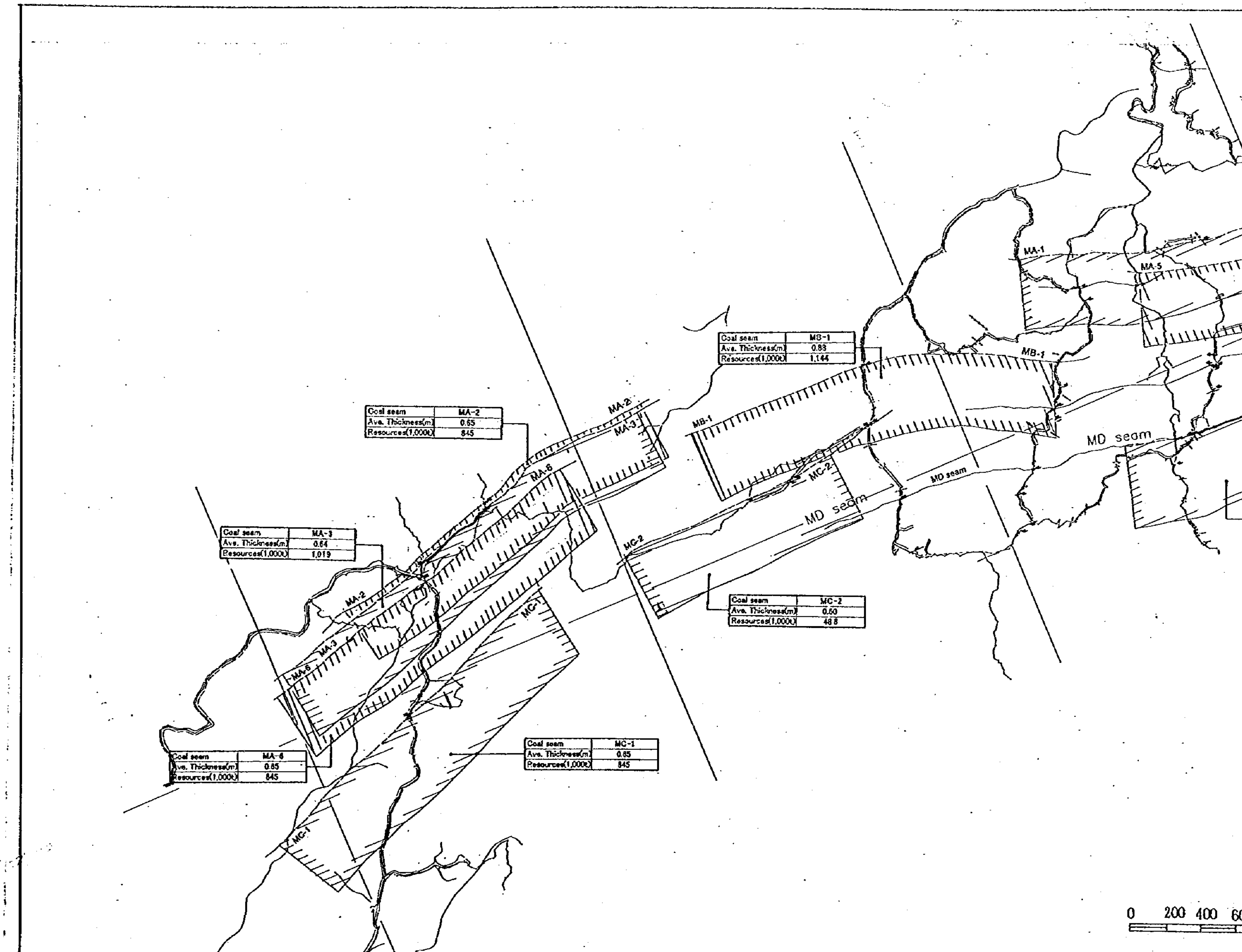
On the basis of above mentioned criteria, resource tonnage of each coal seam block is obtained with the following formula :

Coal resources (t) = length of block (m) x 500 (m) x average thickness (m) x 1.3

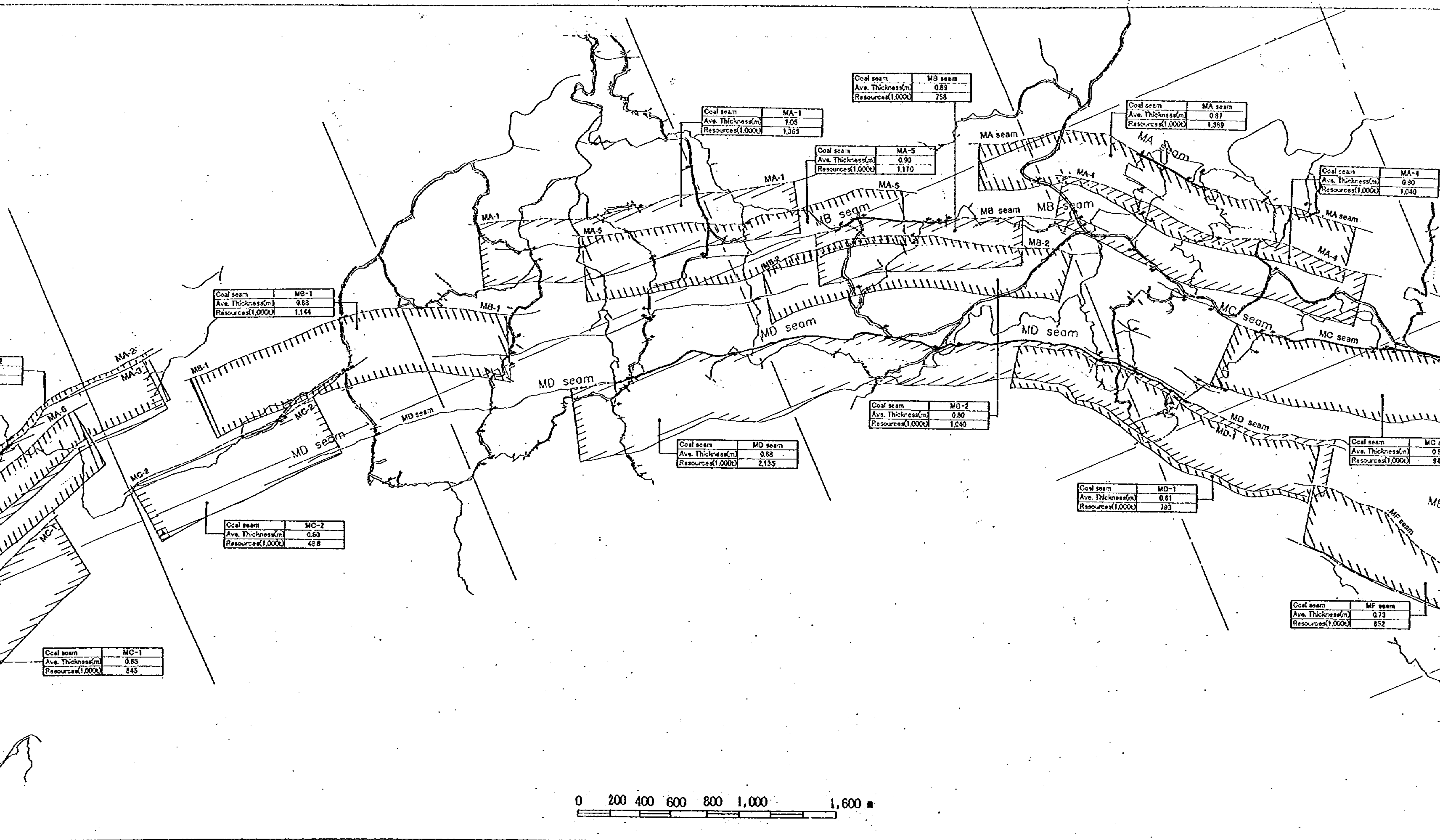
Figure 5-1-1 and 5-1-2 illustrate the area and the thickness of each coal seam used in the resource estimate and the estimated coal resources are summarized in Table 5-1. Total "Indicated" coal resources are about 18 million tonnes in Malibau area and 26 million tonnes in Southwest Malibau area.

The following characteristics of coal resources in each area are recognized from the above figures and the table:

(1) In Malibau area, most of the other coal seams than main seams, which have been named MA to MF, were observed at only one outcrops. They were numbered temporally by adding a numeral after the name of main seam, for example, MA-1 and MB-2, according to their relative stratigraphic positions. This proves the sporadic mode of occurrence of coal seams in Malibau area. In Southwest Malibau area, on the other hand, all coal seams were observed at more than one place and consequently, their continuity were confirmed to some extent.



Coal seam MB-1
Ave. Thickness(m) 0.83
Resources(1,000t) 1,144
Coal seam MA-2
Ave. Thickness(m) 0.65
Resources(1,000t) 845
Coal seam MA-3
Ave. Thickness(m) 0.64
Resources(1,000t) 1,019
Coal seam MC-2
Ave. Thickness(m) 0.60
Resources(1,000t) 48 8
Coal seam MA-6
Ave. Thickness(m) 0.65
Resources(1,000t) 845
Coal seam MC-1
Ave. Thickness(m) 0.65
Resources(1,000t) 845
MA-1
MA-5
MB-1
MA-2
MA-3
MA-6
MC-2
MC-1
MD seam
0 200 400


Coal seam | MB seam
Ave. Thickness(m) | 0.89
Resources(1,000t) | 758
Coal seam | MA-1
Ave. Thickness(m) | 1.05
Resources(1,000t) | 1,365
Coal seam | MA seam
Ave. Thickness(m) | 0.87
Resources(1,000t) | 1,369
Coal seam | MA-5
Ave. Thickness(m) | 0.90
Resources(1,000t) | 1,170
Coal seam | MA-4
Ave. Thickness(m) | 0.80
Resources(1,000t) | 1,040
Coal seam | MB-1
Ave. Thickness(m) | 0.88
Resources(1,000t) | 1,144
Coal seam | MB-2
Ave. Thickness(m) | 0.80
Resources(1,000t) | 1,040
Coal seam | MD seam
Ave. Thickness(m) | 0.68
Resources(1,000t) | 2,135
Coal seam | MD-1
Ave. Thickness(m) | 0.61
Resources(1,000t) | 793
Coal seam | MC-2
Ave. Thickness(m) | 0.60
Resources(1,000t) | 488
Coal seam | MC-1
Ave. Thickness(m) | 0.65
Resources(1,000t) | 845
Coal seam | MF seam
Ave. Thickness(m) | 0.73
Resources(1,000t) | 852
MA seam
MB seam
MC seam
MD seam
MF seam
MA-1
MA-2
MA-3
MA-4
MA-5
MA-6
MB-1
MB-2
MC-1
MC-2
MD-1
0 200 400 600 800 1,000 1,600 m

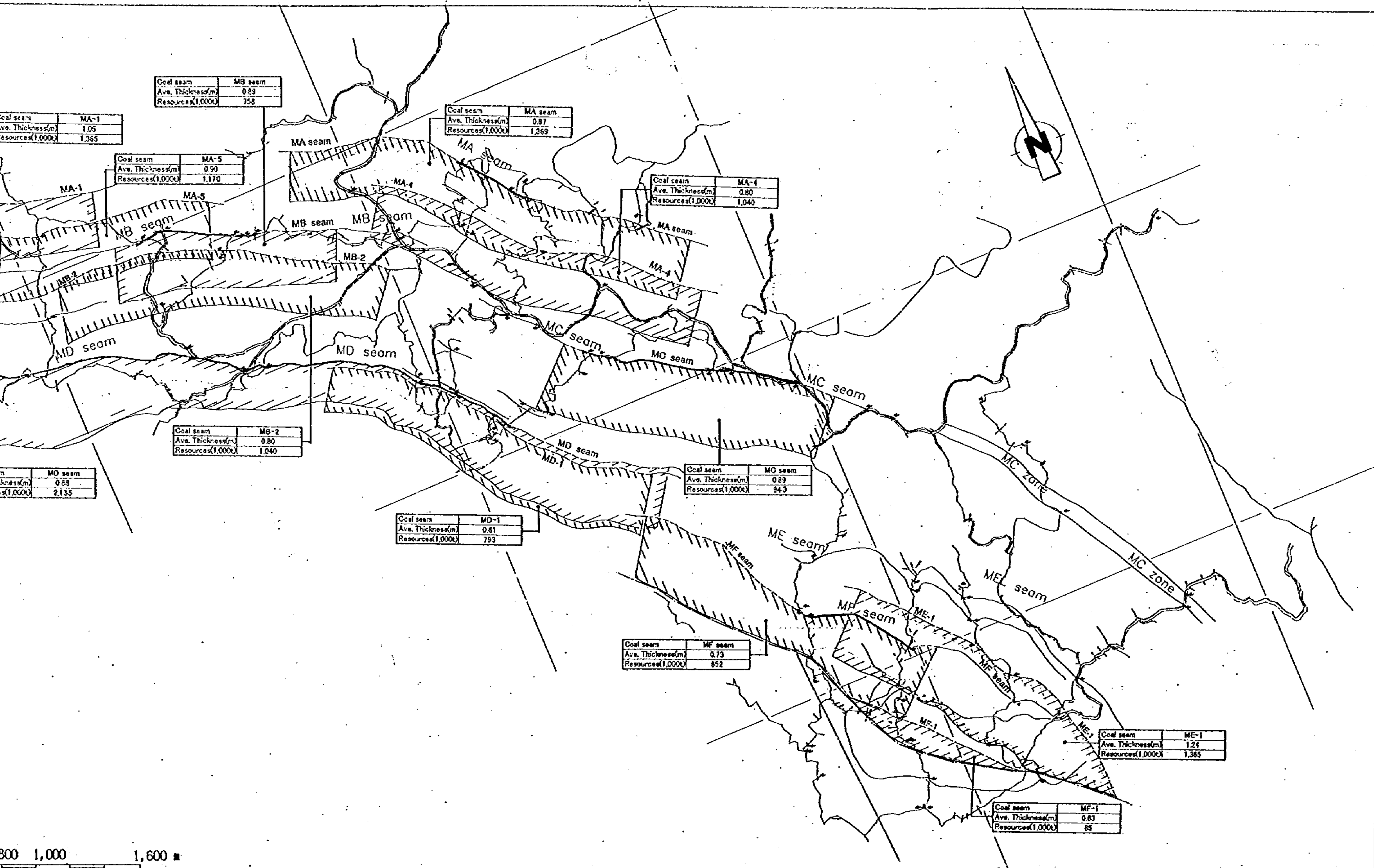


Figure 5-1-1 Estimate of Coal Resources - Malibau

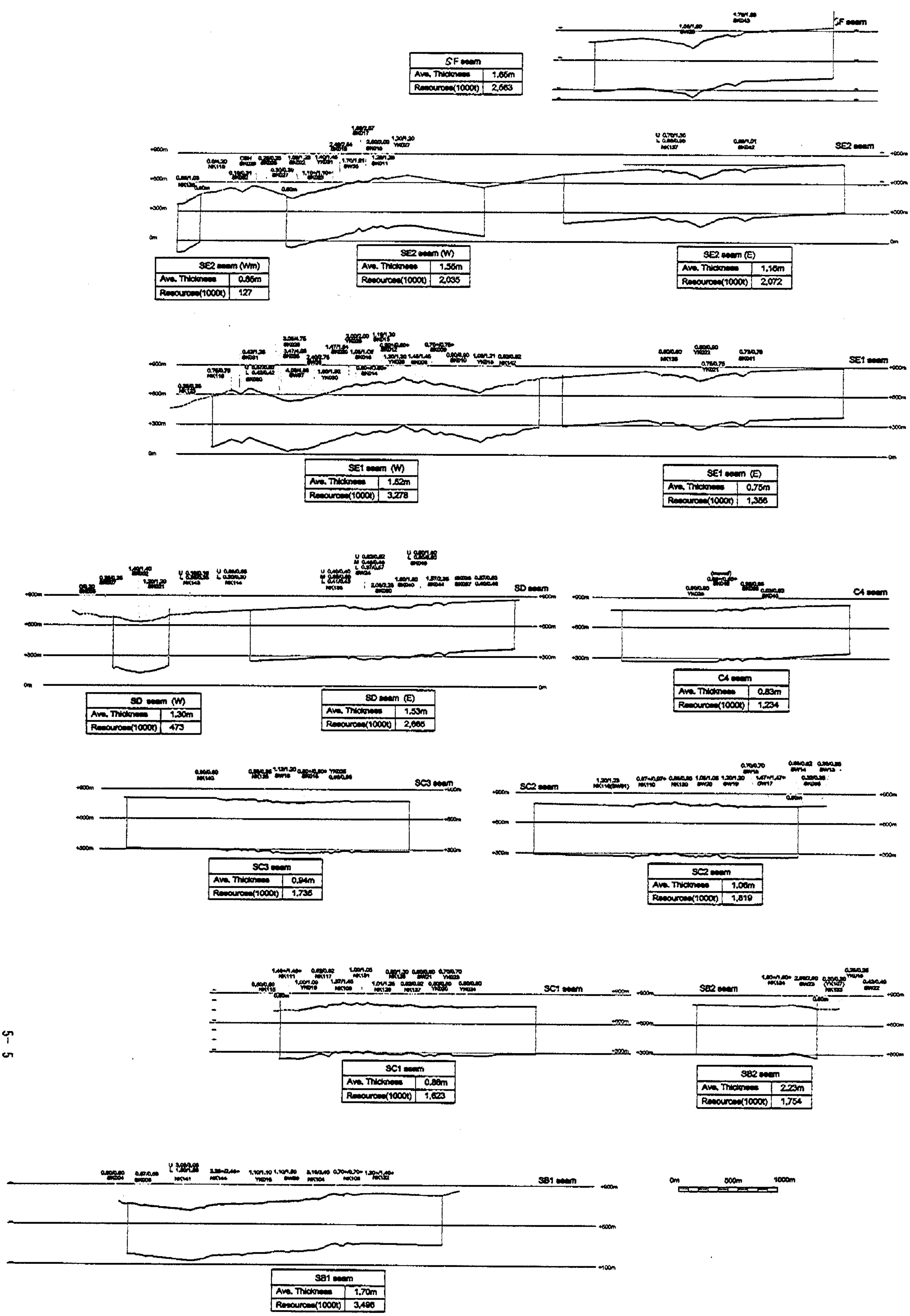


Figure 5-1-2 Estimate of Coal Resources - Southwest Malibau

Table 5-1 Coal Resources

Malibau Area

Seam	Observ. points (>0.6m)	Ave. Thickness (m)	Strike Distance (m)	Distance along dip (m)	Coal Resources (1,000t)
MF-1	1	0.63	1,100	500	85
MF Seam	3	0.73	1,800	500	652
ME-1	1	1.24	1,900	500	1,365
ME Seam	0	—	0		0
MD-1	1	0.61	2,000	500	793
MD Seam	9	0.68	4,830	500	2,135
MC-2	1	0.60	1,250	500	488
MC-1	1	0.65	2,000	500	845
MC Seam	6	0.89	1,630	500	943
MB-2	1	0.80	2,000	500	1,040
MB-1	1	0.88	2,000	500	1,144
MB Seam	5	0.89	1,310	500	758
MA-6	1	0.65	2,000	500	845
MA-5	1	0.90	2,000	500	1,170
MA-4	1	0.80	2,000	500	1,040
MA-3	2	0.64	2,450	500	1,019
MA-2	1	0.65	2,000	500	845
MA-1	1	1.05	2,000	500	1,365
MA Seam	3	0.87	2,420	500	1,369
Total					17,901

S.W. Malibau Area

Seam	Observ. points (>0.6m)	Ave. Thickness (m)	Strike Distance (m)		Coal Resources (1,000t)
SF Seam	2	1.65	2,390	500	2,563
SE2 Seam (Wm)	1	0.85	230	500	127
SE2 Seam (W)	9	1.55	2,020	500	2,035
SE2 Seam (E)	2	1.16	2,760	500	2,072
SE1 Seam (W)	20	1.52	3,310	500	3,278
SE1 Seam (E)	4	0.75	2,800	500	1,356
SD Seam (W)	2	1.30	560	500	473
SD Seam (E)	7	1.53	2,680	500	2,665
SC4 Seam	4	0.83	2,280	500	1,234
SC3 Seam	5	0.94	2,840	500	1,735
SC2 Seam	7	1.06	2,640	500	1,819
SC1 Seam	12	0.88	2,840	500	1,623
SB2 Seam	2	2.23	1,210	500	1,754
SB1 Seam	9	1.70	3,160	500	3,496
Total					26,230

(2) With regard to the coal thickness, the weighted average by tonnage is 0.76 m in Malibau area and 1.27 m in Southwest Malibau area. Furthermore, all the coal seams in Malibau area except two isolated seams are less than 1 m in coal thickness.

(3) It is concluded from these data that the coal resources in Malibau area are unfavorable compared with those in Southwest Malibau with respect to thickness, continuity, and resource quantity.

6. Evaluation of Coal Quality

6. Evaluation of Coal Quality

6.1. General Comments on Analytical Result

During the study of Phase 1 and Phase 2, a total of 56 samples were collected from the outcrops in Malibau, Southwest Malibau and Silimpopon areas. They were analyzed at laboratories in GSD Sarawak and in Japan. The analytical results of all samples collected in both Phase 1 and Phase 2 are shown in Table 6-1-1 and 6-1-2.

In the above tables, the following conversion and addition was made to the original report from the laboratory :

(a) Fixed carbon content in proximate analysis was added by subtracting the sum of the other components (M, A, VM) from 100%.
(b) The unit of gross calorific value was converted from kj/kg to kcal/kg.
(c) Oxygen content (daf) in ultimate analysis was added by subtracting the sum of the other components (C, H, N, S) from 100%, where total sulphur content was used in this calculation after converted to dry ash-free basis.

Table 6-2 is a summary of main quality parameters extracted from Table 6-1-1 and 6-1-2. Since only one sample was taken from full seam section of the Queen Seam during the study, the previous analytical results have been shown in Table 6-3 in order to supplement the quality data of the Queen Seam.

The followings are the general comments on the result of each analytical item :

(1) Moisture

The average moisture content on air dried basis (inherent moisture) is higher in the order of Southwest Malibau, Malibau, and Silimpopon. Inherent moisture varies depending on the degrees of weathering and coalification. Since the all samples were taken from outcrops, it is difficult to determine the correct moisture content of unweathered coal.

It is presumed, however, that the moisture content of unweathered coal in each area is roughly estimated at 3 % in Southwest Malibau, 2 % in Malibau, and 1.5 % in Silimpopon, judging from its relationship with other parameters such as calorific value and oxygen content.

(2) Ash

Ash content of raw coal sample varies widely in general. High ash value is due to the presence of many non-coal partings in the sampling section as seen in coal seam profiles of HK105 in Malibau and NK141-M in southwest Malibau. Ash content of coal without any visible parting is estimated to be less than 15 % in Malibau and 10 % in Southwest Malibau. Higher ash in Malibau coal is probably due to the presence of larger amount of very thinly banded partings or invisible mineral matter in coal structure.

(3) Volatile Matter

Although volatile matter content on air dried basis varies widely, it is in a similar range on dry ash-free basis in Malibau and Southwest Malibau as shown in Table 6-2. Consequently, fuel ratio, which is given by the ratio of fixed carbon to volatile matter, is similar in both areas. The Queen Seam in Silimpopon area has slightly higher volatile matter (daf) and lower fuel ratio than those of other two areas. In the previous data, volatile matter content of the Queen Seam is more than fixed carbon in every analysis as shown in Table 6-3.

(4) Calorific Value

Although the calorific value of Malibau coal is lower on air dried basis, it is higher on dry ash-free basis compared with Southwest Malibau coal. This is the effect of higher ash content and lower moisture content of Malibau coal than those of Southwest Malibau.

Figure 6-1 illustrates the relationship between calorific value and ash content of each area. Calorific value is directly proportional to ash content. The points below the average line in the figures show the samples with higher moisture content.

Table 6-1-1

COAL ANALYSIS - MALIBAU AERA

Sample No.	(HK021)	(HK022)	NK201	SK208	(HK012)	(HK013)	(HK014)	(HK015)	SK211	NK227	SK224	SK227	(YK115)
Coal Seam No.	MF1		MF	MF	ME1		ME		MD1		MD	MD	MD
Sample Thickness (m)	0.63	0.45	0.75	0.75	1.50	0.51	0.38	0.81	0.73	0.40	0.77	0.70	0.57
Total Moisture (ar. %)*	7.8	10.4	9.9	7.0	14.0	9.4	6.4	11.9	7.0	4.0	5.1	5.6	8.0
Proximate Analysis (ad. %)*													
Moisture	1.8	2.2	6.2	4.3	3.9	2.0	0.6	2.5	4.1	2.8	3.2	3.2	2.6
Ash	15.5	27.6	29.5	12.4	44.5	32.0	31.3	48.2	26.2	14.6	20.7	15.2	12.9
Volatile Matter	39.3	33.6	28.9	36.6	24.0	30.4	34.9	24.3	31.2	38.1	33.7	37.3	39.6
Fixed Carbon	43.4	36.6	35.4	46.7	27.6	35.6	33.2	25.0	38.5	44.5	42.4	44.3	44.9
Calorific Value (ad. Kcal/kg)*	6,699	5,542	4,369	6,264	3,633	5,198	5,442	3,759	5,031	6,399	5,824	6,249	6,688
Total Sulfur (ad. %)*	2.56	1.46	1.58	1.85	0.85	3.79	3.12	0.70	0.73	2.29	2.15	1.14	0.90
Ultimate Analysis (daf. %)*													
Carbon	81.4	78.8	72.3	77.8	73.6	77.9	79.3	79.1	76.6	79.3	78.7	78.8	79.6
Hydrogen	5.78	5.63	5.02	5.39	5.39	5.67	6.15	6.25	5.58	5.67	5.69	5.70	5.81
Nitrogen	1.27	1.33	1.80	1.61	0.85	1.08	1.26	1.95	1.62	2.08	1.70	1.78	1.40
Oxygen	8.45	12.16	18.43	12.98	18.51	9.61	8.71	11.28	15.15	10.17	11.09	12.32	12.12
Free Swelling Index (FSI)*	1.5	1	0	1	0	1	1.5	0	0	1.5	1	2	1
Hardgrove Grindability I (HGI)**				70.1							51.9		
Ash Fusibility** (Reducing Atmosphere, deg. C)													
Deformation				1,300							1,385		
Sphere				1,330							1,420		
Hemisphere				1,340							1,425		
Fluid				1,370							1,450		
Ash Analysis (dry, %)**													
SiO_2				43.9							54.8		
Al_2O_3				28.83							26.28		
Fe_2O_3				11.41							7.90		
CaO				2.79							1.43		
MgO				1.76							2.00		
Na_2O				0.55							0.53		
K_2O				1.94							2.97		
SO_3				1.72							1.32		
P_2O_5				4.21							0.15		
TiO_2				1.38							1.08		
MnO				0.05							0.02		

Sample No.	SK238	SK219	SK217	SK230B	(YK120)	SK237	SK243	SK246	NK216	(HK025)	HK026	(HK018)	(HK017)
Coal Seam No.	MD	MC	MC	MB	MB		MA5	MA1	MA	MA	MA		
Sample Thickness (m)	0.85	0.95	1.03	1.58	0.80	0.57	0.90	1.14	0.70	0.85	1.09	1.00	0.45
Total Moisture (ar. %)*	5.7	3.9	4.9	4.0	5.4	3.6	3.9	4.4	4.1	5.1	4.1	6.6	5.8
Proximate Analysis (ad. %)*													
Moisture	4.0	2.0	2.6	2.0	1.8	2.2	2.8	3.1	2.8	1.6	2.9	1.7	1.3
Ash	10.1	30.1	25.9	35.3	19.3	7.3	3.4	13.5	5.2	10.6	10.7	17.8	41.0
Volatile Matter	40.4	32.2	32.4	31.2	38.6	43.3	43.2	37.7	40.6	40.5	38.2	38.2	28.4
Fixed Carbon	45.5	35.7	39.1	31.5	40.3	47.2	50.6	45.7	51.4	47.3	48.2	42.3	29.3
Calorific Value (ad. Kcal/kg)*	6,604	5,382	5,534	4,866	6,388	7,312	7,571	6,656	7,434	7,151	6,944	6,546	4,543
Total Sulfur (ad. %)*	2.42	1.91	1.35	2.87	1.66	0.35	0.28	0.31	0.26	0.40	0.35	2.53	0.19
Ultimate Analysis (daf. %)*													
Carbon	77.9	80.1	80.0	77.8	81.7	82.1	81.8	81.7	81.8	82.9	81.9	82.5	78.9
Hydrogen	5.55	6.17	6.07	6.33	6.11	5.81	5.79	6.00	5.71	5.38	5.73	5.99	6.26
Nitrogen	1.82	1.59	1.64	2.12	1.34	2.41	2.32	2.27	2.33	1.90	2.33	1.17	1.02
Oxygen	11.90	9.33	10.40	9.17	8.75	9.29	9.79	9.66	9.87	9.36	9.64	7.20	13.49
Free Swelling Index (FSI)*	1	1.5	1	1	2	1	2	1	1	2	1	2	1
Hardgrove Grindability I (HGI)**	64.5		55.3	56.0				54.3			54.2		
Ash Fusibility** (Reducing Atmosphere, deg. C)													
Deformation	1,075		1,425	1,360				1,170			1,505		
Sphere	1,115		1,505	1,425				1,255			1,545		
Hemisphere	1,120		1,510	1,430				1,265			1,550		
Fluid	1,140		1,535	1,460				1,300			1,580		
Ash Analysis (dry, %)**													
SiO_2	43.3		58.4	54.8				45.7			50.9		
Al_2O_3	19.69		26.78	26.25				29.73			31.91		
Fe_2O_3	16.19		4.89	10.33				4.56			3.40		
CaO	3.49		1.01	0.93				4.00			2.01		
MgO	5.45		1.70	1.56				4.00			2.90		
Na_2O	1.91		0.23	0.17				1.24			0.46		
K_2O	2.54		2.97	2.68				3.30			3.36		
SO_3	4.12		0.60	0.71				3.23			1.37		
P_2O_5	0.56		0.25	0.15				1.65			0.37		
TiO_2	1.07		1.27	1.04				1.03			1.05		
MnO	0.03		< 0.01	0.01				0.04			< 0.01		

*Analysis in GSD Sarawak, **Analysis in Japan
Analytical basis ar: as received, ad: air dried, daf: dry ash free
Sample No. in ( ): sampled in Phase1

Table 6-1-2

COAL ANALYSIS - SOUTHWEST MALIBAU AREA

Sample No.	SW25	SK022	YK031	SK015	YK027	SK042	SK025-1	SK025-2	SW37	SW36	SK020	SK010	YK021	SK044	SK002	SK040	SK039	NK140	SW18	SW20	NK117	NK129	NK134	SK024	NK141-U	NK141-M	NK141-D	NK104	KK011
Coal Seam No.	SF	SE2	SE2	SE2	SE2	SE2	SE1	SE1	SE1	SE1	SE1	SE1	SE1	SE1	SD	SD	SC4	SC3	SC3	SC2	SC1	SC1	SB2	SB1	SB1	SB1	SB1	SB1	Ocean Seam
Sample Thickness (m)	1.60	1.23	1.45	2.00	1.10	1.01	2.07	1.40	4.86	2.75	1.54	0.90	0.75	2.35	1.40	1.80	0.95	0.90	1.20	1.05	0.92	1.25	1.60	0.45	3.05	0.73	1.15	3.40	
Total Moisture (ar. %)*	4.2	3.7	12.7	4.2	6.7	4.6	7.2	5.8	4.1	8.5	4.4	4.6	3.7	6.8	5.6	5.2	4.7	4.6	4.7	4.0	4.4	3.9	4.9	5.8	4.7	5.3	5.3	3.9	2.8
Proximate Analysis (ad. %)*																													
Moisture	3.0	3.2	4.8	4.4	3.2	3.2	4.9	4.8	3.3	2.9	3.5	3.7	3.1	5.2	5.1	4.2	3.2	4.0	4.2	3.4	3.3	3.1	4.7	4.8	4.4	5.0	5.0	3.7	1.7
Ash	19.9	21.1	9.4	6.2	4.8	30.3	7.6	5.2	15.7	2.9	15.2	4.1	9.3	21.6	6.6	7.9	8.2	6.6	15.3	7.6	8.3	21.8	9.3	19.3	5.1	43.0	5.1	21.2	17.3
Volatile Matter	37.2	37.6	38.4	40.7	44.4	31.8	38.6	40.1	38.1	45.1	37.5	42.7	42.4	34.9	40.6	39.6	41.9	39.6	36.6	43.0	42.6	36.7	38.9	36.1	42.4	26.1	41.9	35.9	39.0
Fixed Carbon	39.9	38.1	47.4	48.7	47.6	34.7	48.9	49.9	42.9	49.1	43.8	49.5	45.2	38.3	47.7	48.3	46.7	49.8	43.9	46.0	45.8	38.4	47.1	39.8	48.1	25.9	48.0	39.2	42.0
Calorific Value (ad. Kcal/kg)*	5,887	5,732	6,302	6,891	7,246	4,810	6,554	6,766	6,213	7,397	6,306	7,456	6,730	5,127	6,624	6,685	6,846	6,923	5,986	6,911	6,909	5,702	6,465	5,461	6,879	3,371	6,724	5,650	6,564
Total Sulfur (ad. %)*	0.89	2.69	1.27	0.36	0.45	0.60	0.72	0.41	0.97	0.65	0.41	0.35	0.54	2.80	0.34	0.30	2.68	0.44	0.29	2.84	2.56	2.75	0.29	1.97	0.27	0.63	0.33	0.87	1.83
Ultimate Analysis (daf. %)*																													
Carbon	78.5	77.3	77.5	79.8	81.1	76.4	78.7	78.7	79.3	81.2	80.1	80.2	79.1	73.8	78.4	79.1	79.1	80.1	77.8	78.7	79.3	77.4	78.6	75.5	78.9	70.4	77.9	78.7	81.0
Hydrogen	6.15	6.13	5.35	5.79	5.79	6.23	5.61	5.59	5.99	5.90	5.98	5.79	5.96	5.67	5.74	5.84	5.93	5.57	5.73	5.87	5.84	5.89	5.50	5.73	5.66	5.73	5.63	6.15	6.48
Nitrogen	1.13	1.27	1.24	1.38	1.48	1.20	1.30	1.41	1.26	1.44	1.39	1.51	1.27	1.07	1.35	1.43	1.21	1.24	1.32	1.09	1.17	1.11	1.22	1.45	1.23	1.06	1.18	1.17	1.11
Oxygen	13.06	11.75	14.43	12.62	11.14	15.27	13.56	13.84	12.26	10.77	12.03	12.12	13.05	15.64	14.12	13.29	10.73	12.60	14.79	11.15	10.79	11.94	14.35	14.72	13.91	21.60	14.92	12.83	9.15
Free Swelling Index (FSI)*	1/2	1	0	1/2	1	1/2	1/2	1/2	1	1	1/2	1	1	1/2	1/2	1/2	1	1	1/2	1	1	1	1/2	1/2	1/2	1/2	1/2	1/2	2
Hardgrove Grindability I (HGI)**	53.0			40.4					48.9							53.6			50.1			54.9						49.9	54.9
Ash Fusibility**																													
(Reducing Atmosphere, deg. C)																													
Deformation	1,495			1,155					1,345							1,315			1,240			1,100						1,290	1,385
Sphere	1,555			1,190					1,400							1,375			1,280			1,145						1,380	1,420
Hemisphere	1,565			1,200					1,405							1,390			1,280			1,160						1,390	1,430
Fluid	1,590			1,225					1,430							1,440			1,305			1,190						1,410	1,455
Ash Analysis (dry, %)**																													
SiO_2	51.4			27.2					51.4							36.9			44.3			48.2						46.1	45.4
Al_2O_3	31.09			31.74					28.56							38.20			30.75			22.42						30.50	32.74
Fe_2O_3	8.31			7.46					6.52							3.97			4.14			17.34						9.42	11.01
CaO	1.00			8.29					2.13							5.68			4.64			2.59						2.66	1.81
MgO	1.70			7.97					2.92							5.23			5.83			2.59						3.07	1.93
Na_2O	0.36			4.01					0.78							0.77			1.10			0.30						0.60	2.35
K_2O	2.37			1.17					2.25							0.98			2.04			1.38						2.19	0.32
SO_3	1.06			8.47					2.22							4.24			4.14			3.52						2.82	1.76
P_2O_5	0.08			1.24					0.09							1.76			0.65			0.07						0.37	0.06
TiO_2	0.84			1.38					1.39							1.36			1.19			0.83						1.23	1.72
MnO	0.02			0.03					< 0.01							0.02			0.03			0.02						0.02	< 0.01

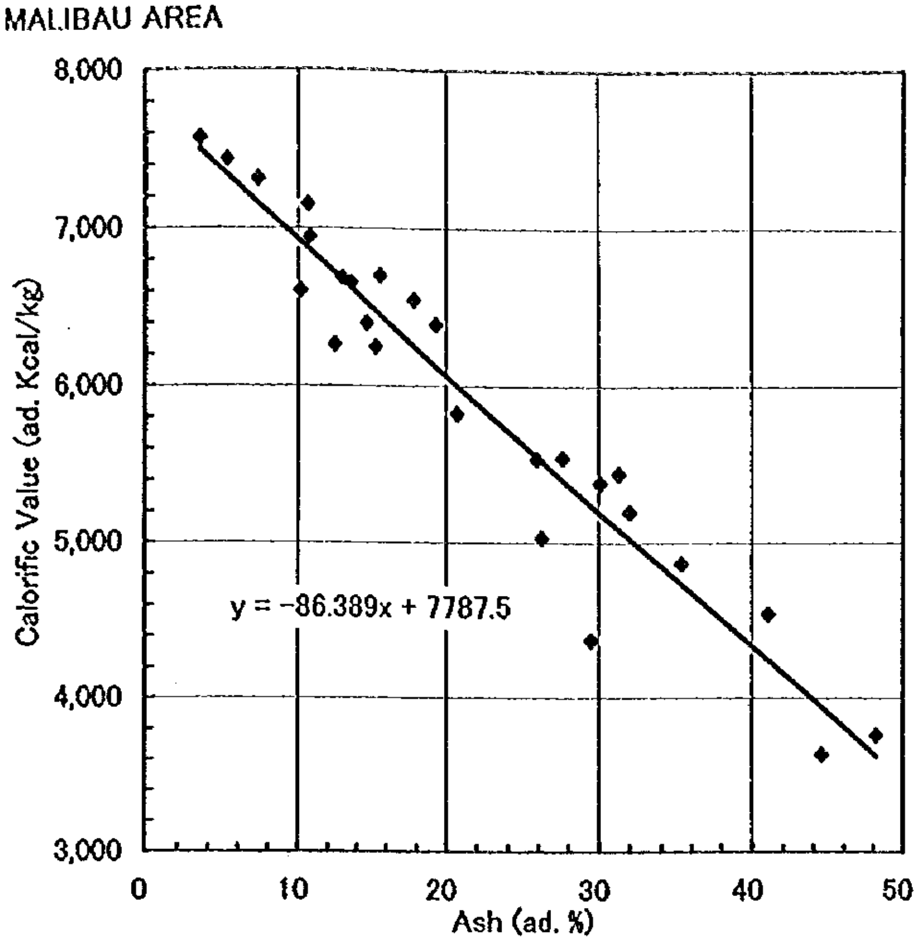
*Analysis in GSO Sarawak, **Analysis in Japan

Table 6-2 SUMMARY OF MAIN QUALITY PARAMETERS

AREA	MALIBAU		SW-MALIBAU		SILIMPOPON
	Average	(Range)	Average	(Range)	(1 sample)
Proximate Analysis (%)					
Moiture (ad)	2.7	(0.6 - 6.2)	4.0	(2.9 - 5.2)	1.7
Ash (ad)	21.5	(3.4 - 48.2)	12.8	(2.9 - 43.0)	17.3
Volatile Matter (daf)	46.6	(43.9 - 51.2)	46.9	(44.3 - 50.2)	48.1
Fuel Ratio	1.15	(0.95 - 1.28)	1.13	(0.99 - 1.26)	1.08
Calorific Value (kcal/kg)					
(air dried b.)	5,923	(3,633 - 7,571)	6,305	(3,371 - 7,456)	6,564
(dry ash-free b.)	7,818	(6,795 - (8,679)	7,560	(6,482 - (,087)	8,103
Total Sulphur (ad. %)	1.46	(0.26 - 3.79)	1.05	(0.29 - 2.84)	1.83
Ultimate Analysis (daf. %)					
Carbon	79.40	(72.30 - 82.90)	78.27	(70.40 - 81.20)	81.00
Nitrogen	1.69	(0.85 - 2.41)	1.27	(1.07 - 1.51)	1.11
Oxygen	11.10	(7.20 - 18.43)	13.33	(10.73 - 15.64)	9.15
Free Swelling Index (FSI)	1.1	(0 - 2)	0.7	(0 - 1)	2
Hardgrove Gridability I. (H	58.0	(51.9 - 70.1)	50.1	(40.4 - 54.9)	54.9
Ash Fusion Temp. (deg.C)					
Initial Deformation T.	1,317	(1,075 - 1,505)	1,277	(1,100 - 1,495)	1,385
Hemispherical T	1,377	(1,120 - 1,550)	1,341	(1,160 - 1,565)	1,430
Ash Analysis (dry, %)					
SiO2	50.26	(43.30 - 58.40)	43.64	(27.20 - 51.40)	45.40
Al2O3	27.07	(19.69 - 31.91)	30.52	(22.42 - 38.20)	32.74
Fe2O3	8.38	(3.40 - 16.19)	8.17	(3.97 - 17.34)	11.01
CaO	2.23	(0.93 - 4.00)	3.85	(1.00 - 5.68)	1.81
MgO	2.77	(1.70 - 5.45)	4.19	(1.70 - 7.97)	1.93
Na2O	0.73	(0.23 - 1.91)	1.13	(0.30 - 4.01)	2.35
K2O	2.82	(1.94 - 3.36)	1.77	(0.98 - 2.37)	0.32
TiO2	1.13	(1.03 - 1.38)	1.18	(0.84 - 1.39)	1.72
Coal Rank	hvAb	(hvAb - hvCb)	hvBb	(hvBb - hvCb)	hvAb

Table 6-3 ANALYSIS OF QUEEN SEAM (PREVIOUS REPORT)

Sample No.	Phase I			Collenette's Report			
	KK011-1	KK011-2	KK011-3	(1913)	(1926)	(1948)	(1952)
Sample thickness (m)	0.34	0.17	0.73	-	-	-	-
Total Moisture (ar. %)	7.9	8.8	6.5	-	-	-	-
Proximate Analysis (ad. %)							
Moisture	0.9	1.1	1.1	-	3.0	1.3	1.6
Ash	20.6	28.3	9.0	-	11.1	4.0	12.4
Volatile Matter	40.3	35.7	46.2	-	44.1	48.3	44.8
Fixed Carbon	38.2	34.9	43.7	-	41.8	46.4	41.2
Calorific Value (ad. kcal/k	6,239	5,398	7,555	7,415	6,731	7,639	7,228
Total Sulphur (ad. %)	2.29	1.72	2.18	2.47	2.27	4.70	2.52
Ultimate Analysis (daf. %)							
Carbon	79.40	78.60	83.20	79.93	79.37	80.20	-
Hydrogen	6.10	6.06	6.18	6.36	6.33	6.20	-
Nitrogen	0.74	0.78	1.05	0.85	1.65	-	-
Oxygen	10.84	12.12	7.15	9.96	10.01	-	-
Free Swelling Index (FSI)	1.5	1	6	-	-	5.5	4.5



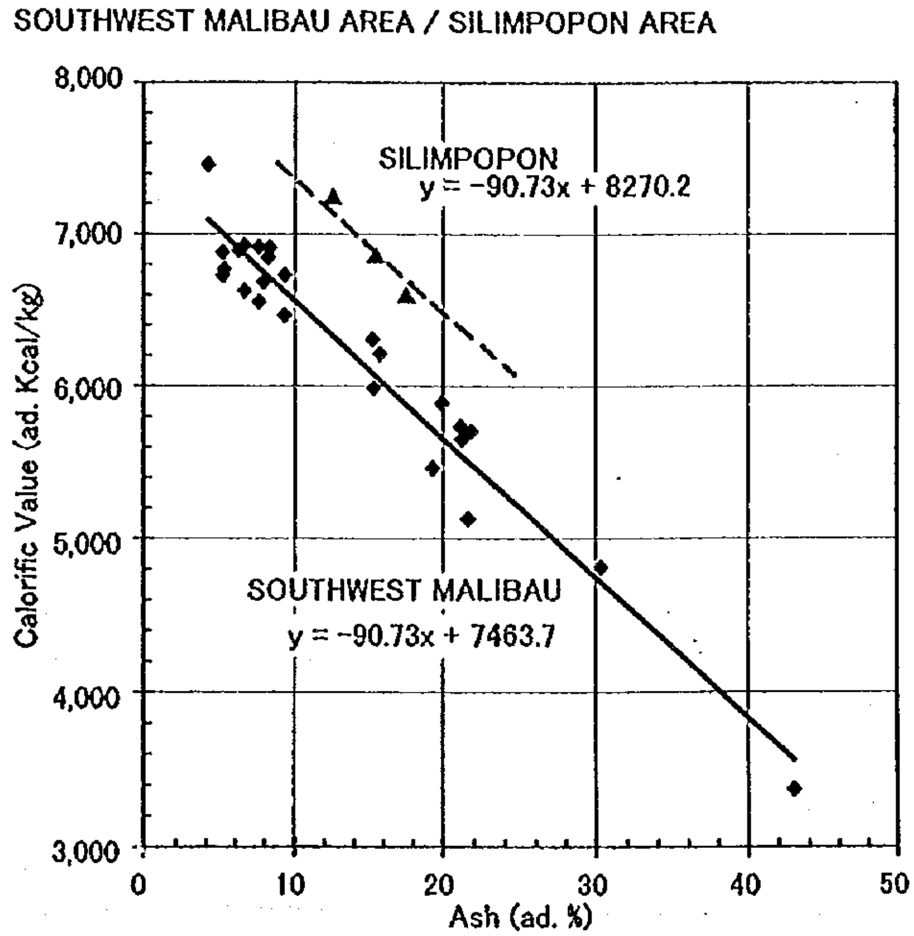


Figure 6-1 Calorific V. - Ash Relationship

Making a comparison between two diagrams, calorific value of Malibau coal is about 350 kcal/kg higher than that of Southwest Malibau coal at same ash content. Based on these diagrams, calorific value of unweathered Malibau coal is approximately estimated at 7,100 kcal/kg for 10 % ash and 6,650 kcal/kg for 15% ash, while those of Southwest Malibau coal is 6,750 kcal/kg and 6,300 kcal/kg respectively. Calorific value of the Queen Seam in Silimpopon seems to be further 150 kcal/kg higher than Malibau coal.

(5) Total Sulphur

Sulphur content is higher in the order of Silimpopon, Malibau, and Southwest Malibau. In Malibau area, 15 samples out of 26 contain more than 1 % of sulphur but all samples from MA seam group show remarkably low sulfur content. In Southwest Malibau area, the majority of samples (20 samples out of 28) are of less than 1 % and most of the remainders are of more than 2 % with few middle values. It is supposed that sulphur concentration occurred very locally in some part of the coal seams in Southwest Malibau. Within both areas, it seems that high sulphur coals occur in the eastern part of each area.

The sulphur content of the Queen Seam in Silimpopon is high, as already indicated in Phase 1 study. Previous report also shows sulphur content of not less than 2 %. One result of analysis on the Forms of Sulphur has been given in the previous report as shown below :

Sulphide	0.04 %
Sulphate	0.24
Organic	2.24
Total	2.52

The above analysis indicates that most of the sulphur exists in the form of organic sulphur which is incorporated into the hydrocarbon compounds of the coal structure, and the amount of sulphide, mostly pyrite, is very little.

(6) Ultimate Analysis

In general, carbon content increases as degree of coalification becomes higher, while oxygen content changes in the opposite way. From this point of view, it is supposed that degree of coalification may be higher in the order of Silimpopon, Malibau, and Southwest Malibau. This supposition agrees with the analytical result of moisture content (ad) and calorific value (daf) but disagrees with higher volatile matter content in the Queen Seam.

Nitrogen content is low in Southwest Malibau and Silimpopon areas and moderate in Malibau area. In Southwest Malibau area, it is less than 1.5 % in almost all samples, while in Malibau area, it is more than 2 % in seven samples.

(7) Free Swelling Index (FSI)

All samples show low FSI values ranging from 0 to 2. Although FSI is very sensitive to weathering, the coal seams in the area are thought to be of low coking property. In Silimpopon area, however, three analytical results in previous report show exceptionally high FSI value from 4.5 to 6 as shown in Table 6-3. Compared with ash content of these samples, it is possible that low ash portion of the Queen Seam possesses high FSI.

(8) Hardgrove Grindability Index (HGI)

HGI is generally high enough for quality requirement of steaming coal (>40-45). All samples have HGI of more than 50 except one of Southwest Malibau which shows a marginal value of 40.4.

(9) Ash Fusion Temperature (AFT) and Ash Analysis

These test and analysis related to ash were carried out for the purpose of predicting the behavior of ash during combustion, particularly the tendency of slagging and fouling. Several indices are used for this purpose based on the fusion temperatures and mineral composition of ash. Most of the analytical results satisfy the quality requirements for combustion but several samples show the marginal values in some of those indices. This matter is discussed in more detail in the next section.

(10) Coal Rank

The analytical result indicates that the coal in the study area are classified as high volatile

A to B bituminous (hvAb to hvBb) in coal rank according to the ASTM standard. Although some samples are fallen under hvCb in rank, they seem to be affected by weathering which resulted in increase of moisture content and decrease of calorific value. In comparison of three areas, coal rank seems to be the highest in Silimpopon and the lowest in Southwest Malibau.

6.2. Evaluation of Coal Utilization

Generally speaking, the coal in the study area shows suitable quality as steaming coal. In this section, analytical result is evaluated from the view point of utilization as steaming coal, mainly fof power generation purpose.

Table 6-4 Quality Requirements for Power Plant

Quality Parameter	Unit	Limit
Gross Calorific Value	kcal/kg	> 6,000 - 6,200
Total Moisture	ar %	< 10 - 12
Ash	ad %	< 15 - 20
Volatile Matter	ad %	> 18 - 20
Fuel Ratio		< 2.0 - 2.5
Sulphur	ad %	< 1.0 - 1.2
Nitrogen	daf %	< 1.8 - 2.2
Grindability (HGI)		> 40 - 45
Ash Fusibility		
Initial Deformation T.	deg. C	> 1,150 - 1,250
Hemispherical T.	deg. C	> 1,250 - 1,300
Ash Composition		
Na_2O	dry %	< 2.0 -3.0
Base/Acid Ratio		< 0.5
Slagging Factor		< 0.6
Fouling Factor		< 0.2

Table 6-4 summarizes the typical coal quality requirements for power generation, commonly used for imported coal in Japan. Limiting values in the table are not definite standard and a little different by power companies. The following is the evaluation of the analytical result in comparison with Table 6-4 :

(1) Total Moisture

High moisture content is disadvantageous for coal utilization. Not only it reduces calorific value, but also causes problems in coal handling, such as blocking of hoppers, freezing in cold weather and grinding problem in mills. Spontaneous combustion is also promoted by high moisture content.

Total moisture consists of surface and inherent moisture and the amount of surface moisture is normally not more than 10 %. Therefore, in the case of the coal with a few percent of inherent moisture as in this area, total moisture can be easily kept within its limit shown in the Table 6-4.

(2) Ash

Raw ash content of the main coal seam in the area is low in Southwest Malibau, low to medium in Silimpopon and medium in Malibau in general. When considering the mining plan, however, the ash content of mined coal highly depends on the selection of mineable seam and mining method. This matter is discussed later in the study of mine development plan.

(3) Volatile Matter

Volatile matter content of coal is an important property in many aspects of combustion, such as ignition, length of flame and flame stability. Fuel ratio, which is derived from volatile matter content, is also a indicator of combustibility. Low volatile coals cause some problems in those aspects of combustion. High volatile bituminous coal as in this area is regarded as the most suitable for combustion in terms of volatile matter content.

(4) Sulphur

Upper limit of sulphur content is determined from the environmental point of view. During the combustion, the majority of sulphur in coal is transformed to sulphur dioxide (SO_2) and emitted in the air. As SO_2 emission standard becomes strict, the most of the traded coal in the market have less than 1% sulphur.

In addition to the environmental problem, high sulphur in coal and ash increases the tendency of fouling in boiler surface. Only one advantage of high sulphur content is that it increases the efficiency of dust collection by lowering the electric resistivity of fly ash, although priority is given to the environmental aspect.

Sulphur content of the main coal seams in Malibau and Southwest Malibau area are in an acceptable level. In Silimpopon area, however, the Queen Seam contains about 2% sulphur. Further study is required on utilization of Silimpopon coal, including sulphur reduction by washing and utilization for cement industry which allows the use of higher sulphur coal than power station.

(5) Nitrogen

In the same way as sulphur, the nitrogen content in coal is an important issue with the air pollution by nitrogen oxides (NOx) but no effect is known to combustibility. The nitrogen content of coal in the area is low and no problem on utilization.

(6) Calorific Value

Needless to say, calorific value is an important parameter in the evaluation of steaming coal. It varies with ash and moisture content and coal rank. Limiting value shown in Table 6-4 is an example which is commonly used in Japanese power companies for imported coal. Even the coal of much lower calorific value can be used in an appropriate type of boiler to meet its quality specification.

In order to obtain the coal of 6,500 kcal/kg, the corresponding ash content in each area is approximately estimated as follows based on Figure 6-1 : 17% in Malibau, 13% in Southwest Malibau, and 19% in Silimpopon.

(7) Hardgrove Grindability Index (HGI)

In the most coal-burning plant, very finely ground (pulverized) coal is used recently. HGI is a measure of the relative grindability or easiness of pulverization of coal. The higher the HGI, the easier to grind coal and thus, HGI is important in the design of mill equipments and determination of its capacity. HGI of the coal in the area is more than 50 compared with the requirement of 40 to 45 for steaming coal.

(8) Ash Fusion Temperatures (AFT)

Ash deposition is an important problem in combustion operation which creates slagging and fouling in the boiler. Ash fusion temperatures are often used to predict the slagging and fouling tendency of coal. In this test, small cones of coal ash are gradually heated and the temperatures are measured at four points at which the shape of the cone are observed in the following shape :

Initial deformation temperature (IDT) : initial rounding of cone tip
Softening temperature (ST) : height of cone equals to width
Hemispherical temperature (HT) : height equals to half width
Fluid temperature (FT) : cone flattens with melting

Although the limiting value of AFT is different by companies, IDT of more than 1,200℃ is commonly used for pulverized coal combustion. Table 6-1-1 and 6-1-2 shows that four samples out of fifteen have lower IDT than 1,200℃.

(9) Ash Analysis

It is difficult to predict the actual ash behaviour in boiler based on the analytical data in laboratories, because of the difference of the physical conditions between two circumstances. However, it is thought that the tendencies of slagging and fouling are related to the mineral component of ash. Among the many kinds of indices proposed for the purpose of predicting slagging and fouling tendencies, some examples are shown below with commonly used limiting value in parenthesis :

(a) Base-acid Ratio (<0.5) : $Fe_2O_3 + CaO + MgO + Na_2O + K_2O / SiO_2 + Al_2O_3 + TiO_2$
(b) Slagging factor (<0.6) : Base-acid ratio x S% (dry)
(c) Fouling factor (<0.2) : Base-acid factor x Na_2O%
(d) Na_2O % (<2.0)

It is understood in general that the basic components of ash, especially Fe_2O_3, CaO and MgO, lower the ash fusion temperatures and the presence of sulphur and sodium (Na_2O) have a bad effect on boilers with respect to slagging and fouling. However, all these indices are relative indicator of ash behaviour and several indices, not a particular index alone, should be considered together in evaluation of coal quality.

The calculated values of the above indices including IDT on each sample are shown in Table 6-5, in which the values beyond the limit are underlined. In this table, slight tendencies of slagging and fouling are found in several samples, for instance, SK238 and SK246 in Malibau and SK015 and NK129 in Southwest Malibau.

Table 6-5 Summary of Ash Indices

Indices	IDT (℃)	B/A ratio	Slagging F.	Fouling F.	Na_2O (%)
Requirement	>1,200	< 0.5	< 0.6	< 0.2	< 2.0
Malibau					
SK208	1,300	0.25	0.48	0.14	0.55
SK224	1,385	0.18	0.40	0.10	0.53
SK238	1,075	0.46	1.16	0.88	1.91
SK217	1,425	0.42	0.17	0.03	0.23
SK230	1,360	0.19	0.56	0.03	0.17
SK246	1,170	0.22	0.07	0.28	1.24
HK026	1,505	0.14	0.05	0.07	0.46
SW Malibau					
SW25	1,495	0.16	0.15	0.05	0.36
SK015	1,155	0.48	0.18	1.95	4.01
SW37	1,345	0.18	0.18	0.14	0.78
SK040	1,315	0.22	0.07	0.17	0.77
SW18	1,240	0.23	0.07	0.25	1.10
Nk129	1,100	0.34	0.97	0.10	0.30
NK104	1,290	0.23	0.21	0.14	0.60
Silimpopon					
KK011	1,385	0.22	0.41	0.52	2.35

7. Preliminary Study of Coal Mine Development

7. Preliminary Study on Coal Mine Development

Based on the geological assessment of coal seam conditions in the area, the coal mine development plan has been studied. Since the exploration is still in the early stage without any exploratory drilling to the deeper part except for several old boreholes in Silimpopon area, the mine plan is also preliminary and conceptual. Some assumptions have been applied in mine planning as well as cost estimate.

Malibau area was excluded from the area for mine plan, because of small thickness of coal seams in the area. As stated in the previous section 4.1, only 12 coal outcrops out of 164 exceed 1 m in seam thickness and many coal seams show sporadic mode of occurrence. It was concluded from this fact that coal seams in Malibau area were too thin to be mined economically by underground mining method.

The preliminary mine plan in Silimpopon and Southwest Malibau areas has been prepared after reviewing geological data from the mining point of view and inspecting the proposed mine site. In the present study, only the underground mine plan has been prepared, because of difficult geological and topographical conditions for opencut mining, particularly in Southwest Malibau area. The following is the explanation of the mine plan in these two areas.

7.1. Silimpopon Area

7.1.1. Basic Consideration

(1) General Situation

The proposed mine site is situated in the southeastern corner of the whole study area and accessible by road from Tawau at a distance of about 100 km. The surface of the area is gently undulating land ranging from 75 m to 50 m in elevation and covered by the plantation of oil palm for the most part. Silimpopon river and its tributaries flow toward the south within the area.

(2) Old Colliery's Records

In the northern part of the area, there was a colliery which was operated for 27 years from 1906 to 1932. Production record gives the total tonnage of 1,348,952 tons (probably in long ton) between 1909 and 1929, although that of first and last three years is unknown. The average annual production is 64,236 tons and the maximum is 90,012 tons in 1924. Several inclines, adits and shafts were driven and the coal seam was mined by "pillar and stall method".

Product coal was transported by rail from the mine to No.2 Wharf, about 7 km south along Silimpopon river. At the Wharf, the coal was loaded into lighters and they were towed by a launch to the Coaling Station on Sebatik Island. Some lighters not unloaded at Sebatik Island were towed to Sandakan directly. The coal was mainly used as the fuel for steamships.

The mine was closed in 1932 owing to decreasing production and resultant large loss in mine operation. Coal production could not attain to the expected level throughout mine life. It is reported that the mining problems, such as falls of weak roof, acid water from roof and spontaneous heating, prevented a systematic mining and increase in production. Poor market situation seems to have been one of the cause of mine closure.

(3) Mining Area

Figure 19 and 20 were used as a base map for mine planning, in which all geological information of the Queen Seam are shown, including outcrop lines, isopachs of seam thickness, structure contours as well as the area of old Silimpopon Colliery.

The selected mining area is bounded on the southeast by an isopach line of 1.2 m which was adopted as the minimum mining thickness in this study. On the southwestern side, the positions of two boreholes, Isler No.1 and No.4, were excluded from the mining area, because there is the possibility of deterioration of the Queen Seam in these boreholes. On the northern side, 100 m along the seam from the old mine and coal outcrops are to be left unmined as safety barriers in order to prevent water inflow into the mine.

(4) Recoverable Reserves

Recoverable reserves have been estimated according to the mine plan mentioned in the next section. Reserve calculation was made on raw coal basis in each panel and roadway using the following formula :

Recoverable reserves (t) = mining area (m^2) x mining thickness (m) x specific gravity x recovery factor (%)

The values applied for the parameters in the above formula are as follows :

mining area (m^2)	: measured on the mining plan, excluding coal barriers on the both sides of slopes and between upper and lower panels
mining thickness (m)	: 1.2 - 1 85 (determined by isopach map)
recovery factor (%)	: longwall - 95, board and pillar - 33, roadway - 100
specific gravity	: 1.4 (raw coal)

Total recoverable reserves in the planned area is approximately 3.7 million tonnes. Reserves in each panel and roadways are shown in Table 7-1.

7.1.2. Mine Design and Mining Method

(1) Mine Access and Roadway Development

General layout of the underground mine in Silimpopon is shown in Figure 7-1.
The position of portal is selected at sufficiently higher place from the river level to avoid water inflow by flooding. From there two parallel slopes are driven in the rock above the Queen Seam at an interval of 50 m. The inclination of the rock slopes is 18 degrees. After reaching the Queen Seam at about 320 m from the portals, the slopes are driven along the seam at an inclination of about 6 degrees. One of the slopes is used for intake of fresh air and transportation of coal, materials and workers, while another one is used for exhaust of polluted air by the main fan installed near the portal.

As in-seam slopes advance, nearly horizontal roadways, slightly upward, are driven to the both sides of the slopes at regular intervals. They become the upper and the lower roadways of the mining panel, of which size is 100 m in width and 500 m to 1,700 m in length. Coal

Table 7-1 Recoverable Reserves of Silimpopon Mine

		Mining						Roadway	
		Length (m)	Area (1000m2)	Thick (m)	In-situ (1000t)	Reco. F. %	Reserves (1000t)	Length (m)	Reserves (1000t)
Slope									21.2
W1	W1-1	185	18.5	1.85	47.9	95	45.5	1,260	10.2
	W1-2	305	30.5	1.85	79.0	33	26.1		
		490	49.0	1.85	126.9	56.4	71.6		
W2	W2-1	450	45.0	1.85	116.6	95	110.8	1,680	13.7
	W2-2	250	25.0	1.85	64.8	33	21.4		
		700	70.0	1.85	181.4	72.9	132.2		
W3	W3-1	70	7.0	1.85	18.1	33	6.0	1,920	15.6
	W3-2	570	57.0	1.85	147.6	95	140.2		
	W3-3	180	18.0	1.85	46.6	33	15.4		
		820	82.0	1.85	212.3	76.1	161.6		
W4	W4-1	360	36.0	1.85	93.2	33	30.8	2,470	20.1
	W4-2	555	55.5	1.85	143.7	95	136.5		
	W4-3	180	18.0	1.85	46.6	33	15.4		
		1,095	109.5	1.65	283.5	64.4	182.7		
W5	W5-1	275	27.5	1.80	69.3	95	65.8	2,910	23.4
	W5-2	440	44.0	1.82	112.2	33	37.0		
	W5-3	480	48.0	1.85	124.3	95	118.1		
	W5-4	120	12.0	1.85	31.1	33	10.3		
		1,315	131.5	1.83	336.9	68.6	231.2		
W6	W6-1	100	10.0	1.73	24.2	33	8.0	3,040	24.1
	W6-2	350	35.0	1.75	85.8	95	81.5		
	W6-3	395	39.5	1.75	96.8	33	31.9		
	W6-4	585	58.5	1.75	143.3	95	136.1		
		1,430	143.0	1.75	350.1	73.6	257.5		
W7	W7-1	300	30.0	1.63	68.6	33	22.6	3,470	24.9
	W7-2	475	47.5	1.65	109.7	95	104.2		
	W7-3	360	36.0	1.65	83.2	33	27.5		
	W7-4	460	46.0	1.65	106.3	95	101.0		
		1,595	159.5	1.65	367.8	69.4	255.3		
W8	W8-1	390	39.0	1.55	84.6	33	27.9	3,700	25.1
	W8-2	590	59.0	1.56	128.5	95	122.1		
	W8-3	300	30.0	1.59	66.6	33	22.0		
	W8-4	430	43.0	1.57	94.3	95	89.6		
		1,710	171.0	1.56	374.0	69.9	261.6		
W9	W9-1	565	56.5	1.55	122.6	95	116.5	480	18.5
	W9-2	290	29.0	1.55	62.9	33	20.8		
	W9-3	390	39.0	1.51	82.5	95	78.4		
		1,245	124.5	1.54	268.0	80.5	215.7		
West total		10,400	1,040.0	1.72	2,500.9	70.8	1,769.4	20,930	175.6
E1	E1-1	480	48.0	1.85	124.3	33	41.0	1,580	12.6
	E1-2	210	21.0	1.85	54.4	95	51.7		
		690	69.0	1.85	178.7	51.9	92.7		
E2	E2-1	970	97.0	1.84	249.5	33	82.3	2,140	17.3
		970	97.0	1.84	249.5	33	82.3		
E3	E3-1	340	34.0	1.62	77.0	95	73.2	2,640	20.4
	E3-2	880	88.0	1.82	223.7	33	73.8		
		1,220	122.0	1.76	300.7	48.9	147.0		
E4	E4-1	480	48.0	1.51	101.6	95	96.5	2,890	21.1
	E4-2	240	24.0	1.87	56.0	33	18.5		
	E4-3	350	35.0	1.78	87.2	95	82.8		
	E4-4	275	27.5	1.85	71.2	33	23.5		
		1,345	134.5	1.68	316.0	70.0	221.3		
E5	E5-1	480	48.0	1.40	94.4	95	89.7	3,060	21.1
	E5-2	270	27.0	1.57	59.3	33	19.6		
	E5-3	580	58.0	1.71	139.0	95	132.1		
	E5-4	100	10.0	1.79	25.1	33	8.3		
		1,430	143.0	1.59	317.8	78.6	249.7		
E6	E6-1	510	51.0	1.32	94.0	95	89.3	3,040	19.5
	E6-2	250	25.0	1.47	51.4	33	17.0		
	E6-3	570	57.0	1.62	128.9	95	122.5		
	E6-4	90	9.0	1.70	21.4	33	7.1		
		1,420	142.0	1.49	295.7	79.8	235.9		
E7	E7-1	310	31.0	1.26	54.9	95	52.2	2,620	18.1
	E7-2	310	31.0	1.40	60.6	33	20.0		
	E7-3	470	47.0	1.52	99.7	95	94.7		
	E7-4	120	12.0	1.60	26.9	33	8.9		
		1,210	121.0	1.43	242.1	72.6	175.8		
E8	E8-1	140	14.0	1.24	24.3	95	23.1	2,210	13.1
	E8-2	250	25.0	1.30	45.6	33	15.0		
	E8-3	430	43.0	1.42	85.5	95	81.2		
	E8-4	185	18.5	1.50	38.9	33	12.8		
		1,005	100.5	1.38	194.3	68.0	132.1		
E9	E9-1	190	19.0	1.24	33.0	33	10.9	1,820	10.4
	E9-2	430	43.0	1.33	80.2	95	76.2		
	E9-3	190	19.0	1.43	38.1	33	12.6		
		810	81.0	1.33	151.3	65.9	99.7		
E10	E10-1	560	56.0	1.30	101.6	95	96.5	1,400	7.8
		560	56.0	1.30	101.6	95	96.5		
East total		10,660	1,066.0	1.57	2,347.7	65.3	1,533.0	23,400	159.6
Total		21,060	2,106.0	1.64	4,848.6	68.1	3,302.4	44,330	356.4
Total									3,658.8

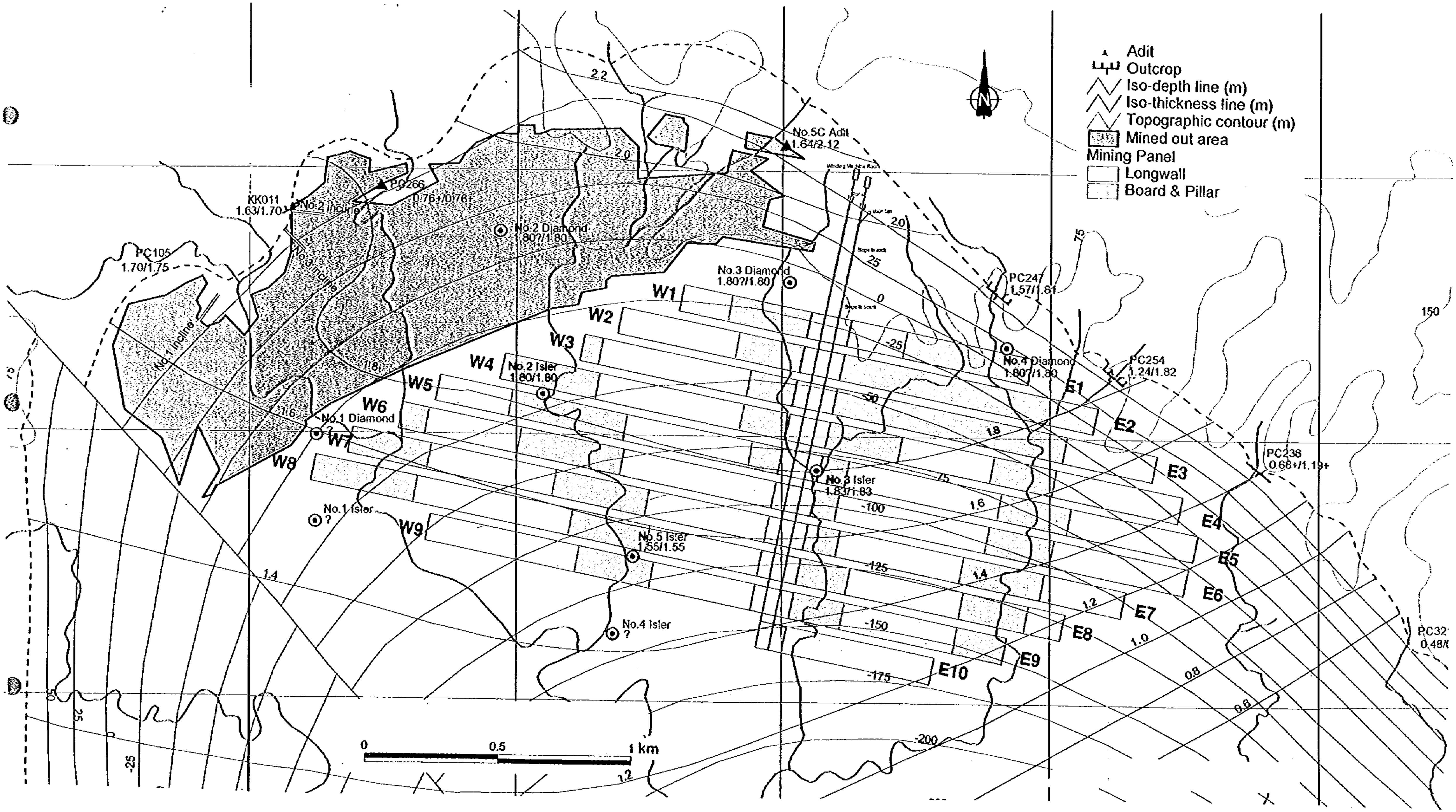


Figure 7-1 Mining plan - Silimpopon

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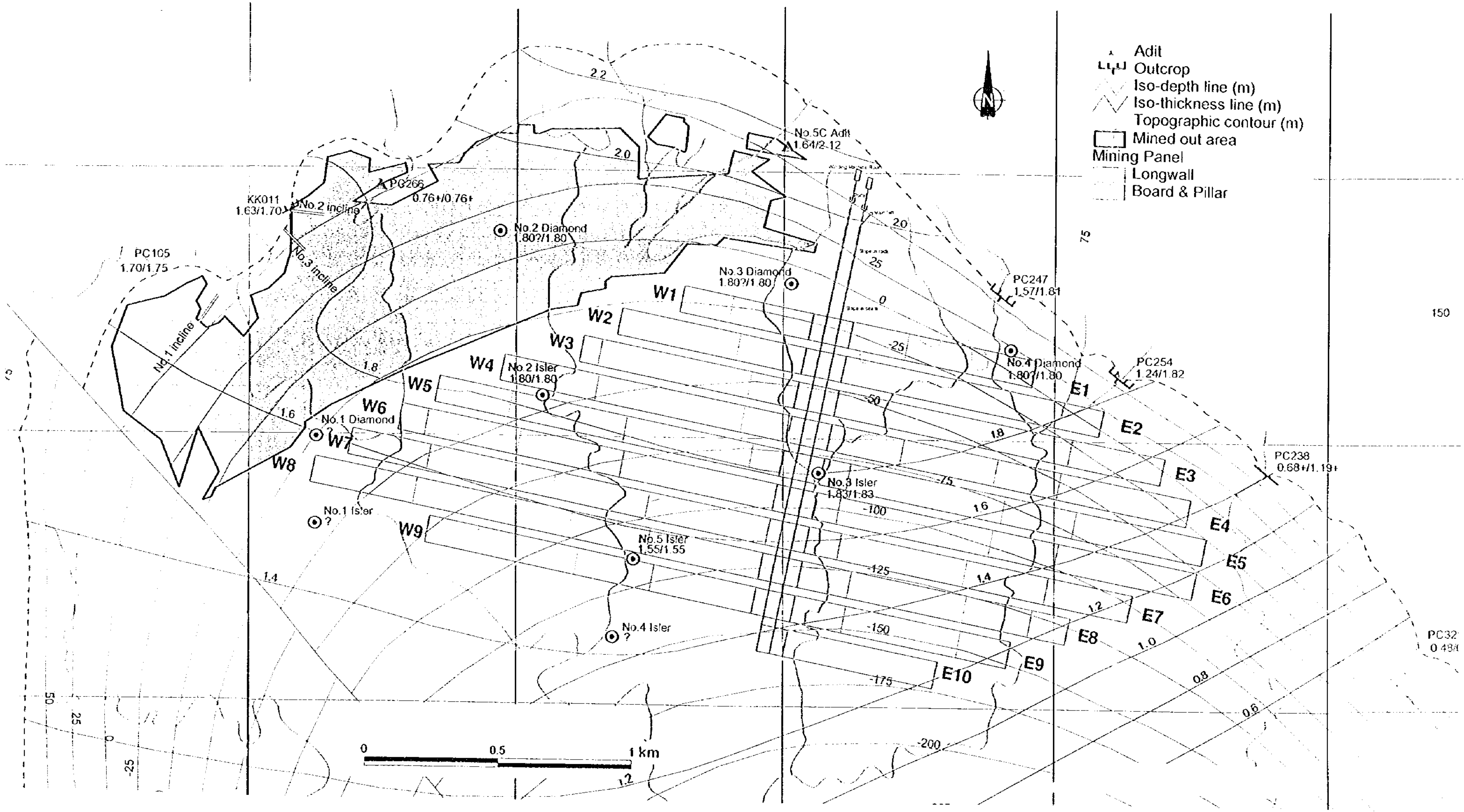

Figure 7-1 Mining plan - Silimpopon

barriers of 20 m is left between upper and lower panels.

(2) Mining Method

"Semi-mechanized "longwall mining" (L/W) and "board and pillar mining" (B/P) were selected as the suitable mining methods for the geological condition in the area. The latter is applied under the river to the extent of 100 m on both sides of the river, so as to minimize the effect of mining on the surface due to its small mining recovery rate and consequently, to prevent water inflow from the river.

In L/W mining, coal is broken by blasting and coal picks and moved by chain conveyors from working face to lower roadway. For roof supporting, three hydraulic props are set up at intervals of 0.6 m combined with steel link bars of 1.2 m long. Mining operation start from the end of a panel and move back toward the slopes (retreating system).

In B/P mining, either of the following combination is applied :

(a) blasting + side dump loader (or face loader) + chain conveyors
(b) road header (or continuous miner) + chain conveyors

In this system, coal of 5 m wide is mined upward at right angle to roadway and next 10 m coal is left unmined as a pillar. Thus, coal extraction rate lowers to one thirds (33%) in a mining block.

In roadway driving, same combinations of equipments as above are also used. Dimensions of all roadways including slopes are as follows :

width - 4 m at roof, 5.2 m at floor. height - 3 m.

Mined coal is transferred from chain conveyors into mine cars at a lower level roadway, then hauled by battery locomotives. Finally, they transported to the surface through the slope by a winding machine installed near the portal.

7.1.3. Coal Production

Schedule of roadway development and coal production has been estimated on the following assumptions.

(1) Work Schedule

The mine operation is carried out on the following basis :

Working days = 5 days/week x 52 weeks/year - public holidays (10 days)
= 250 days/year

Working shifts = 8 operating hours x 3 shifts/day

Number of teams working in each face is as follows :

(a) Roadway driving

mine years	1 - 5	6 - 11	12 - 21
number of team(s)	2	1 - 2	1

(b) L/W mining

regular team : 1 team/shift x 3 shifts/day

additional team : 1 team in a separate panel,
years 11 to 22 - 1 shift/day, afterward 2 shifts/day

(c) B/P mining

regular team : 4 teams/shift x 3 shifts/day

additional team : ① years 6 and 9 - 3 teams/day, ② years 11 to 22 - 4 teams/day

Notes : (i) L/W and B/P mining are operated alternately.

(ii) One L/W team can be divided to four B/P teams, as the number of workers at a L/W face is 23 compared with 5 at a B/P face.

(iii) The above variation in the number of each working face was planned taking into account of necessary driving distance of roadways in each year and keeping constant annual coal production.

(2) Rate of Advance and Coal Production

(a) Roadway driving

Table 7-2 Advance Rate and Coal Production

	Rock Slope	In-seam Slope	In-seam Road
Advance Rate (m/shift)	1.0	1.2	2.4
(m/day)	3.0	3.6	7.2
Coal Production (t/m)*	-	8.1 - 11.3	7.4 - 11.3
(t/shift)	-	29.2 - 40.7	53.3 - 81.4

* depending on coal seam thickness

(b) L/W mining

An advance rate of longwall face is estimated in the following way :

- intervals of hydraulic props : 0.6 m
- number of hydraulic props moved ahead in a shift by two crews : 100 props
- advancing distance of a prop at one time : 1.2 m
- total length of mining face (1 cycle) : 100 m
- coal production by 1 m advance in 100 m long face : 165 t - 246 t (depending on seam thickness, 95% recovery ratio)

Using the above parameters, the advancing distance of L/W face and the rate of coal production is calculated as follows:

Cutting distance along the face : 60 m/shift → 180 m/day
Average advance of the face (cycle) : 0.72 m/shift → 2.16 m/day
Rate of coal production : 119 t - 177 t/shift → 357 - 531 t/day

(c) B/P mining

Advance rate : 3.6 m/shift/team → 10.8 m/day/team
regular team : 4 teams/shift x 3 shifts/day → 43.2 m/day
additional team : ① 3 teams/day → 10.8 m/day (years 6 and 9)
② 4 teams/day → 14.4 m/day (years 11 to 22)

Coal production rate : 8.7 - 13.0 t/m
regular team : 375 - 562 t/day
additional team : ① 140 t/day, ② 152 - 179 t/day

(3) Production Schedule

Based on the above standards and assumptions, the coal production schedule has been established as shown in Table 7-3. Detail of mine development schedule and production by mining methods is attached in Appendix 4.

According to this schedule, the average annual production during full production period is about 160,000 tonnes on raw coal basis including 15,000 tonnes from roadway development. Estimated recoverable reserves of 3.7 million tonnes will be exhausted after twenty four years' mining operation.

7.1.4. Work Force

Table 7-4 is a summary of required number of work force on the registered basis in the whole mine organization.

Table 7-4 Summary of Work Force

	Section	Staff	Worker	Total
Mine Management		2	-	2
Production	Underground	34	191	225
	Washing Plant	7	40	47
	Subtotal	41	231	272
Safety	Subtotal	16	7	23
Mechanical & Electrical	Underground	12	28	40
	Surface	11	22	33
	Subtotal	23	50	73
Mine Engineering	Planning & Control	4	-	4
	Survey & Designing	3	6	9
	Subtotal	7	6	13
Accounting	Warehouse	4	4	8
	Accounting	5	8	13
	Subtotal	9	12	21
Administration	Subtotal	14	40	54
Total		112	346	458

Table 7-3 Production schedule Silimpopon Mine (1,000 t)

Panel	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20	Y21	Y22	Y23	Y24	
West 1		[133d] 71.6																							71.6
East 1		[19d] 10.6	[152d] 82.1																						92.7
West 2			[98d] 52.2	[145d] 80.0																					132.2
East 2				[101d] 55.4	[49d] 26.9																				82.3
West 3					[201d] 107.0	[102d] 54.6																			161.6
East 3						[148d] 69.0	[145d] 78.0																		147.0
West 4						[174d] 24.1	[12d] 62.5 [105d]	[180] 96.1																	182.7
East 4								[20d] 30.4 [145d]	[250d] 134.9	[106d] 56.0															221.3
West 5										[144d] 75.0	[250d] 133.7	[39d] 22.5													231.2
East 5												[111d] 85.3	[250d] 131.5	[86d] 42.9											249.7
West 6											[110d] 18.6	[250d] 41.9	[250d] 42.4	[250d] 39.3	[250d] 41.9	[250d] 41.9	[189d] 31.5								257.5
East 6														[144d] 62.1	[250d] 108.7	[139d] 65.1									235.9
West 7																[111d] 52.5	[250d] 120.3	[174d] 82.5							255.3
East 7																	[61d] 7.4	[250d] 30.3	[250d] 32.8	[250d] 36.1	[250d] 36.3	[127d] 33.1			175.8
West 8																		[18d] 35.1	[250d] 111.8	[250d] 112.8	[2d] 1.9				261.6
East 8																						[123d] 30.1	[250d] 67.2	[124d] 34.8	132.1
West 9																					[248d] 110.3	[240d] 105.4			215.7
East 9																						[10d] 3.8	[247d] 95.9		99.7
East 10																							[3d] 1.1	[250d] 95.5	96.6
Working face		82.2	154.1	135.4	133.9	147.7	140.5	126.5	134.9	131.0	152.3	149.7	163.9	144.3	159.6	159.5	159.2	147.9	144.4	149.9	147.5	172.4	164.2	130.3	3,302.5
Road develop	3.6	25.0	19.1	26.7	26.6	17.8	25.6	25.6	17.7	25.7	17.1	12.9	12.1	10.8	11.1	12.2	12.8	8.0	12.0	10.9	11.9	1.2	0.0	0.0	356.4
Total	3.6	107.2		162.1	160.5	165.5	166.1	152.1	152.6	156.7	169.4	162.6	176.0	155.1	161.7	171.7	172.0	155.9	156.4	160.8	159.4	173.6	164.2	130.3	3,658.9
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20	Y21	Y22	Y23	Y24	

━━━━ Regular team

■ ■ ■ ■ Additional team

The number of work force allocated in each shift is as follows :

	Shift 1	Shift 2	Shift 3	Total
Staff	67	24	21	112
Workers	156	105	85	346
Mine Total	223	129	106	458

Among these department, breakdown of work force in production department, which plays an important role in mine operation, is given in Table 7-5 and explained below. Details of other departments are shown in Appendix 4.

Production department

For estimate of required number of registered workers, the following attendance rate is applied, namely, 85% for direct production groups (mining and roadway driving) and 90% for other groups.

(a) L/W and B/P mining

At a L/W face, following works and number of workers are required :

Drilling and blasting	:	4
Extending link bars and setting up hydraulic props	:	4
Shoveling coal and driving chain conveyors	:	4
Removing hydraulic props in third row	:	6
Making stable room and other works	:	4
Checking link bars and hydraulic props	:	1
Total	:	23 → 27 registered/shift

L/W and B/P mining are operated alternately and 27 workers are divided into four teams and placed at four faces of B/P mining.

(b) Roadway driving

Two roadway faces are driven regularly and five workers are required at one driving face.

Required workers : 2 x 5 = 10/shift → 12 registered / shift

Tablo 7-5 Work Force of Production Department

Number of workers

		required workers				registered workers			
		shift 1	shift 2	shift 3	subtotal	shift 1	shift 2	shift 3	subtotal
U/G	L/W , B&P	23	23	23	69	27	27	27	81
	Headings	10	10	10	30	12	12	12	36
	Maintenance	8	8	8	24	9	9	9	27
	Transportation	11	11	11	33	12	12	12	36
	Fixed shift 1	8			8	9			9
	Office works	2			2	2			2
	Subtotal	62	52	52	166	71	60	60	191
W/P	Hand picking	12	12		24	13	13		26
	Operaters	6	6		12	7	7		14
	Subtotal	18	18		36	20	20		40
Production Dep total		80	70	52	202	91	80	60	231

Number of staff (registered)

			shift 1	shift 2	shift 3	subtotal
Depatment head			1			1
U/G	Superintended		1			1
	Section chief		1			1
	Group chief		1	1	1	3
	General staff	L/W	3	3	3	9
		Heading	2	2	2	6
		Maintenance	2	2	2	6
		Transportation	2	2	2	6
		Fixed shift 1	1			1
	U/G subtotal		13	10	10	33
W/P	Superintended		1			1
	Group chief		1	1		2
	General staff		2	2		4
	W/P subtotal		4	3		7
Production department total			18	13	10	41

(c) Maintenance

Eight workers are required for maintenance of roadways and other various works.

Required workers : 8 → 9 registered / shift

(d) Transportation

In horizontal roadways, one battery locomotive is used in upper level road and two are used in lower level to haul mine cars. A locomotive is run by an operator and a conductor. For transportation in slope, two conductor are required. Additionally, one locomotive is used in various work on the surface with an operator, a conductor and a helper. Therefore, the total required number is :

Horizontal road	:	1 x 2 + 2 x 2	= 6
Slope	:	1 x 2	= 2
Surface	:	1 x 3	= 3
Total	:		11 → 12 registered /shift

(e) Fixed shift 1

This group is engaged in various important work only in first shift and consists of eight skilled workers.

(f) Washing plant

In the present study, introduction of a simple washing plant is planned together with hand-picking system. Operation of two shifts is required for processing total run-of-mine judging from the planned capacity of the facilities.

Required workers : 12 (hand-picking) + 6 (plant operator)

= 18 → 20 registered / shift

The requirement of washing plant is discussed later in the section 7.3.

7.2. Southwest Malibau Area

7.2.1. Basic Consideration

(1) General Situation

The area is situated at the western part of the whole study area and accessible by main logging road at a distance of 75 km from Kalabakan, where saw mills and facilities for timber loading into barges are in operation. The proposed mine site is located at a distance of about 8 km away from the main road along a track of old logging road which is passable only on foot.

The area is a steep mountain land with the altitude ranging from 550 m to 850 m above sea level, which is 250 m to 550 m higher than the level of main logging road. Logging operation was finished several years ago and the surface is covered by secondary jungle at present. Several tributaries of Kuamut river form steep valleys and flow for the most part toward the southwest.

(2) Mineable Coal Seams and Mining Area

As previously stated in the section 4.2, a total of 11 coal seams exist in the area and they are divided into six groups, namely, SA to SF from the bottom to the top. Although the coal seams are generally thicker than other areas, they show variable thickness and occur in different parts of the area with various extent of continuity.

Among these coal seams, SE1 and SE2 Seams in the western part and SB1 Seam in the middle-eastern part have been selected as the mineable coal seams for the present mining study from the view points of thickness and extent of continuity. Other coal seams are thinner than minimum mining thickness (1.2 m) or have short distance of continuity in spite of enough thickness.

Thickness and extent of these three mineable seams is as follows :

Table 7-6 Mineable Coal Seams

Area	West	West	East
Coal Seam	SE2	SE1	SB1
Thickness : min.- max. (m)	1.20 - 2.61	1.05 - 4.86	1.10 - 5.23
Extent of Mineable Thickness (m)	900	1,700	1,400

As a result of the selection of mineable coal seams as above, mining area is separated into two areas, namely, western area for SE1 and SE2 Seams and eastern area for SB1 Seam.

(3) Recoverable Reserves

Recoverable reserves have been estimated according to the mine plan to be explained in the next section. Reserve calculation was made on raw coal basis in each panel and roadway using the following formula :

Recoverable reserves (t) = mining area (m^2) x mining thickness (m) x specific gravity x recovery factor (%)

Values applied to the parameters in the above formula are as follows :

(a) Mining area

In-seam roadway : 3.2 m x distance of roadway

(3.2 m - length of coal seam in roadway face with 3 m height)

Mining panel : 50 m x length of panel

(50 m - distance along coal seam between upper and lower roadways)

Coal barriers of 15 m between upper and lower panels are not included in the reserves. The lowest level of mining area is 310 m in vertical distance from the uppermost roadway.

(b) Mining thickness

Maximum mining thickness was determined at 2.4 m in the present study. For reserve calculation, average thickness of outcrops of each seam exposed in the mining area was used, by applying the upper limit of 2.4 m to the outcrops thicker than 2.4 m. Average mining thickness of each coal seam is as follows :

Table 7-7 Average Mining Thickness

Coal seam	SE2	SE1	SB1
Number of outcrops	9	11	6
Total thickness (m)	14.65	18.81	11.20
Average thickness (m)	1.63	1.71	1.87
Thickness used in calculation(m)	1.60	1.70	1.90

(c) Recovery factor : mining panel - 95%, roadway - 100%

(d) Specific gravity : 1.4 (raw coal)

Table 7-8 shows the summary of recoverable reserves estimated according to the above criteria. Details of reserves in each level and panel are shown in Table 7-9.

Table 7-8 Summary of Recoverable Reserves

Coal Seam	Mining (t)	Roadway (t)	Total (t)
SE2	356,200	62,400	418,600
SE1	589,000	93,600	682,600
Subtotal	945,200	156,000	1,101,200
SB1	605,900	105,500	711,400
Total	1,551,100	261,500	1,812,600

7.2.2. Mine Design and Mining Method

(1) Basic Idea of Mine Design

As stated previously, mining area is separated into two areas, namely, SB1 Seam in the east (East Pit) and SE1 and SE2 Seams in the west (West Pit). Accordingly, different system of mine access is required in each pit. However, the following basic idea of mine design is common to both pit.

(a) Vertical length of a mining panel is 50 m and 15 m of coal barrier is left unmined between upper and lower panels.

(b) Five levels of mining panels are planned in each pit at intervals of 15 m coal barriers. The elevation of top and bottom of mining panels are as follows :

		West Pit	East Pit
Top level (m)	:	680	700
Bottom level (m)	:	370	390

Table 7-9　Detail of Recoverable Reserves of Southwest Malibau

		Mining				Roadway		Total
		road length (m)	area (m2)	working T (m)	Reserves (t)	Length (m)	Reserves (t)	
East Pit								
SB1 seam	No.1	420	21,000	1.9	53,067	1,390	11,815	
	No.2 West	340	17,000	1.9	42,959	2,235	18,998	
	No.2 East	525	26,250	1.9	66,334			
	No.3 West	520	26,000	1.9	65,702	2,510	21,335	
	No.3 East	670	33,500	1.9	84,655			
	No.4 West	665	33,250	1.9	84,023	2,800	23,800	
	No.4 East	445	22,250	1.9	56,226			
	No.5 West	885	44,250	1.9	111,820	2,800	23,800	
	No.5 East	325	16,250	1.9	41,064			
	Raise(9x100m)					900	5,742	
East Pit Sub-total					605,850	12,635	105,490	711,340
West Pit								
SE1 seam	No.1	610	30,500	1.7	68,961	1,558	11,841	
	No.2	846	42,300	1.7	95,640	1,877	14,266	
	No.3	1,045	52,250	1.7	118,137	2,289	17,396	
	No.4 West	232	11,600	1.7	26,228	3,316	25,201	
	No.4 Middle	382	19,100	1.7	43,185			
	N0.4 East	735	36,750	1.7	83,092			
	No.5 West	228	11,400	1.7	25,775	3,273	24,875	
	No.5 Middle	562	28,100	1.7	63,534			
	No.5 East	570	28,500	1.7	64,439			
	Raise(9x100m)					900	5,148	
	Sub-total				588,991	12,313	93,579	682,570
SE2 seam	No.1	364	18,200	1.6	38,730	1,052	7,574	
	No.2	604	30,200	1.6	64,266	1,550	11,160	
	No.3	792	39,600	1.6	84,269	1,782	12,830	
	No.4 West	386	19,300	1.6	41,070	1,896	13,651	
	N0.4 East	414	20,700	1.6	44,050			
	No.5 West	560	28,000	1.6	59,584	1,876	13,507	
	No.5 East	228	11,400	1.6	24,259			
	Raise(7x100m)					700	3,710	
	Sub-total				356,228	8,856	62,432	418,660
West Pit Sub-total					945,219	21,169	156,011	1,101,230
Mine Total					1,551,069	33,804	261,501	1,812,570

*Note S.G. = 1.4　Recovery Factor= 0.95

(c) As far as the topographic condition permits, in-seam roadways at higher levels are opened by means of adits from coal exposures, after removing overburden and coal seam to a necessary extent for making a flat ground. In the West Pit, five adits are opened in SE2 Seam and three adits are opened in SE1 Seam. Lower two levels of SE1 Seam are not opened on the surface but connected to SE2 with underground crosscuts. In the East Pit, only the top level is opened in this way. Coal reserves deeper than the lowest adit level are developed by means of rock slopes and cross cuts.

General layout of East an West Pit is shown in Figure 7-2.

(2) East Pit (SB1 Seam)

Figure 7-3-1 shows a mining plan of the East Pit of Southwest Malibau Mine.

Among ten in-seam roadways necessary to prepare the mining panels at five levels, only the top level (700 ml) is opened from the surface. Other roadways are connected with rock slopes through crosscuts.

Two slopes are constructed on the floor side (or northeastern side) of SB1 Seam at an inclination of 16 degrees and nearly parallel to the strike direction of the seam. One is used for intake of air and transportation of coal, workers and material, while the other is used mainly for exhaust of air. Portals of intake and exhaust slopes are located at 655 m and 650 m in elevation respectively, which are high enough for preventing flooding of river water. A total length of each slope is 961.4 m for intake slope and 761.9 m for exhaust slope.

From intake slope, crosscuts are driven to the coal seam at following nine levels : 650, 635, 585, 570, 520, 505, 455, 440 and 390 meter levels (ml). From exhaust slope, four crosscuts are driven which are connected to the upper roadways of each mining panel. A total distance of the crosscuts is 1,888 m.