FINAL REPORT

THE REPUBLIC OF VENEZUELA
MINISTRY OF ENVIRONMENT
AND NATURAL RESOURCES
DGSPROA - LNH

JAPAN INTERNATIONAL
COOPERATION AGENCY

STUDY ON COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN

FINAL REPORT

VOLUME III

SUPPORTING REPORT

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This report consist of the following five volumes.

VOLUME I : EXECUTIVE SUMMARY

VOLUME II : MAIN REPORT

VOLUME III : SUPPORTING REPORT

PART-A	:	TOPOGRAPHIC SURVEY
PART-B	:	GEOLOGICAL AND GEOMORPHOLOGICAL STUDIES
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VOLUME IV : DATA BOOK I

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(As of February 17, 1993)

PART-A

TOPOGRAPHIC SURVEY

STUDY ON COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN

FINAL REPORT

VOLUME III : SUPPORTING REPORT
PART-A : TOPOGRAPHIC SURVEY

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I. GENERAL

The purpose of the topographic survey is to get field topographic data and information necessary for the study of river behavior of both rainy season and dry season.

The field work in phase 1 was done from the beginning of May to the end of July, 1992 as rainy season survey and that in phase 2 from the beginning of January to the middle of March, 1993 as dry season survey.

The work consists of the following items:

1) Cross sectional survey
2) Leveling
3) Data processing

The survey sites are shown in Fig. 1.1.1.

II. CROSS SECTIONAL SURVEY FOR CHANNEL OBSERVATION

Three sites were selected to observed the variation of the river bed feature. The survey sites were shown in Fig. 1.1.1. Total station (Geodimeter 140T) and digital echo sounder (PS 20R) were used as main equipment in this survey. The control point survey, cross sectional survey and data processing were carried out by JICA Study Team. The results of the survey are as described hereinafter.

2.1 Control Point Survey

(1) Guasdualito Site

The horizontal coordinates of the cross section posts were observed from the Porvenir ICN (Institute de Cartografia Nacional) station as known point. The survey was carried out by means of traverse survey method and the azimuth of the post was observed by solar observation. The accuracy of distance was 1/63,000 and the accuracy of azimuth angle was 2'46". Each accuracy is within the limit.

The elevation of the cross section posts were observed from the BM NOD027A station at Guasdualito ICN by means of the leveling. The accuracy of the leveling was 40 mm/5 km at maximum, which is within the limit of the specification. The result of the control point survey at Guasdualito site is shown in Tables 2.1.1 and 2.1.2.

(2) Bruzual Site

The horizontal coordinates of the cross section posts were observed from the Bruzual ICN station and San Vicente ICN station as known points. The survey was carried out by means of traverse survey method and the azimuth of the post was calculated by closed network. The accuracy of distance was 1/22,000 - 1/9,200 and the accuracy of azimuth angle was 12". Each accuracy is within the limit.

The elevation of the cross section posts were observed from the BM-AB-1A ICN station at the school of Bruzual by means of the leveling. The accuracy of the leveling was 12 mm/5 km at maximum, which is within the limit of the specification. The result of the control point survey at Bruzual site is shown in Tables 2.1.3 and 2.1.4.

(3) Camaguan Site

The horizontal coordinates of the cross section posts were observed from the C-01-I to C-52-I. The cross section posts of C-01-I and C-01-D were observed by the Global Positioning System as known points. The survey was carried out by means of traverse survey method and the azimuth of the post was calculated by open network.

The elevations of the cross section posts were observed from the BM IGLESIA SSC-A ICN station at Camaguan by means of the leveling. The accuracy of the leveling was 12 mm/5 km at maximum, which is within the limit of the specification. The result of the control point survey at Camaguan site is shown in Tables 2.1.5 and 2.1.6.

The control point survey in phase 2 was carried out as follows:

As a first step of the survey works, cross section posts installed in the previous phase were inspected. According to the inspection, a lot of damaged and lost posts were found due to much erosion of river bank or sedimentation at the installed posts. These posts were recovered.

The horizontal and vertical positions of recovered cross section posts were measured with a EDM (Theodolite with electrical distance meter) and total station (Geodimeter 140T). The coordinates of recovered cross section posts are shown in Tables 2.1.2, 2.1.4 and 2.1.6.

2.2 Cross Sectional Survey

A total station was installed at a cross section post on the river bank and distance and angle were measured by the total station. The data were recorded to the personal computer (Toshiba J-3100-SX) and the position of the survey boat was calculated by the range-bearing method.

A survey boat was sailed along the cross section line for measuring the river bed topography. Depth data were measured by a digital echo sounder and recorded to the personal computer (NEC PC-9801). Cross sectional survey was carried out at the following three sites by JICA Study Team.

(1) Guasdualito Site

Guasdualito site which is spread between Remolino bridge and a point of 3 km downstream from the Uribante river junction of the Apure river. The cross section line interval is approximately 500 m.

(2) Bruzual Site

Bruzual site which is spread between San Vicente and a point of 3 km downstream from the Bruzual bridge of the Apure river. The cross section line interval is approximately 500 m.

(3) Camaguan Site

Camaguan site which is spread between Camaguan and a point of 10 km upstream from Camaguan of the Portuguesa river. The cross section line interval is approximately 200 m. The cross sectional survey in phase 2 were repeated at the above mentioned three sites in phase 1, but 6 lines of Bruzual site could not be surveyed due to shallow water depth.

2.3 Additional Cross Sectional Survey

Additional cross sectional survey sites were selected to grasp the basic river information at the Apure river. The cross sectional survey in phase 1 was carried out at the following site :

1) San Fernando de Apure	3 sections
2) Setenta	1 section
3) Masparro	1 section
4) Uribante	1 section

The additional cross sectional survey in phase 2 was carried out at the following sites:

1) Apurito to San Fernando de Apure	14 sections
2) El Negro to La Maciera	21 sections

The result of cross sectional survey is shown in Data Book I as cross section charts.

III. LEVELING

Leveling work was carried out by the Oceanographic Mercator, C.A. under the sub-letting contract and supervision by JICA Study Team. The survey sites are shown in Fig. 1.1.1.

3.1 Leveling for Cross Section Post

The work was carried out along the river banks in order to give elevation to the cross section posts. The results of the leveling is shown in Tables 2.1.1 to 2.1.7.

3.2 Leveling for Water Level Gauge Station

The work was carried out to establish bench marks near the proposed water level gauge stations. The leveling work was carried out from the known bench marks shown in Table 3.2.1.

(1) Guanarito

The bench mark was established at the point of near the right side of Guanarito bridge. The elevation of the Guanarito bench mark was observed from the BM-3FB-23 station at Guanarito ICN. The accuracy of the leveling was 5 mm/km, which is within the limit of the specification.

(2) El Baul

The bench mark was established at the point of near the west side of Puerto El Baul (under construction), left bank of Portuguesa river. The elevation of the El Baul bench mark was observed from the BM-CB-1 station at El Baul ICN. The accuracy of the leveling was 4 mm/km, which is within the limit of the specification.

(3) Suripa

The bench mark was established at the point of near the house of Mr. Bernardo Rivas (Escuela suripa), left bank of the Apure river. The elevation of the Suripa bench mark was observed from the BM-2FC-50 station at Suripa ICN. The accuracy of the leveling was 2 mm/km, which is within the limit of the specification.

(4) Santa Rosalia

The bench mark was established at the point of near the east side of the house of Mr. Jose Ramon Perez, Santa Rosalia. The elevation of the Santa Rosalia bench mark was observed from the BM-2FC-48 station at Suripa ICN. The accuracy of the leveling was 29 mm/3 km, which is within the limit of the specification.

Result of leveling works are shown in Table 3.2.2.

3.3 Leveling for Staff Gauge

The work was carried out to establish bench marks near the staff gauge for inundation observation. The leveling work was carried out from the known bench marks shown in Table 3.2.1.

(1) La Union

The bench mark was established at the point of about 700 m west side of the junction the Guanare river and the Portuguesa river. The elevation of the La Union bench mark is observed from the BM-17-I station at Portuguesa (PROA 1991). The accuracy of the leveling was 1 mm/km, which was within the limit of the specification.

(2) San Antonio

The bench mark was established at the point of the west side of Mr. Jose Felix's house about 2.5 km along the road from San Antonio to Las Flores. The elevation of the San Antonio bench mark was observed from the BM-AB-53A station at El Saman ICN. The accuracy of the leveling was 5 mm/km, which is within the limit of the specification.

(3) Capilla (1)

The bench mark was established at the point of near the west side of Capilla. The elevation of the Capilla (1) bench mark was observed from the BM-3FB-23 station at Guanarito ICN. The accuracy of the leveling was 27 mm/3 km, which is within the limit of the specification.

(4) Capilla (2)

The bench mark was established at the 4.6 km from La Plaza Bolivar in La Capilla town to Mata Larga. The elevation of the Capilla (2) bench mark was observed from the

Capilla (1) station at Capilla OMERCA. The accuracy of the leveling was 3 mm/3 km, which is within the limit of the specification.

(5) Paso Igues

The bench mark was established at the point of 1.2 km from the north side of Igues bridge to El Baul along road No. 8. The elevation of the Paso Igues bench mark was observed from the BM-CB-1 station at the Portuguesa river (PROA 1991). The accuracy of the leveling was 3 mm/3 km, which is within the limit of the specification.

(6) Coco de Mono

The bench mark was established at the point of 700 m from the north side of Militar bridge to Camaguan along the national road No. 2. The elevation of the Coco de Mono bench mark was observed from the BM-CPM-13 station at La Caracara ICN. The accuracy of the leveling was 8 mm/2 km, which is within the limit of the specification.

(7) Costa de Guanare

The bench mark was established at the point of 12 km east side from Arismendi. The elevation of the Costa de Guanare bench mark was observed from the BM-CBA-51A station at Circuito, Arismendi ICN. The accuracy of the leveling was 12 mm/3 km, which is within the limit of the specification.

(8) Los Caballos

The bench mark was established at the point of 500 m from house of Mr. Eusebio Taisan along the Guanare river, which is located at the point 10 km from La Union. The elevation of the Los Caballos bench mark was observed from La Union (1992). The accuracy of the leveling was 4 mm/km, which is within the limit of the specification.

Results of leveling works are shown in Table 3.2.2.

IV. DATA PROCESSING

Data processing and drawing of cross section chart were carried out at the LNH office in Caracas by JICA Study Team. System flow chart is shown in Fig. 4.1.1.

4.1 Work Procedure

In the field, the position and depth data were recorded in different type of personal computer. Data processing work was carried out by the following procedure.

(1) Data Correction

The field recording data have some irregular values in the position and depth file, and therefore the data are corrected manually one by one.

(2) Data Integration

The position and depth data are separately recorded in the micro floppy disk. In this stage, the depth data are converted to IBM format and both data were integrated in one file.

(3) Data Compilation

The angle and distance from total station, coordinate of boat, elevation of river bed, deviation from the course line are calculated based on the integrated file. The calculated data stored in the compilation file.

(4) Chart Drawing

Finally, the cross section chart of the river is produced from the compilation file using a computer and plotter.

4.2 Main Equipment

River survey system software is an application program for the hydrographic positioning, data storage and chart drawing. The software includes chart drawing of cross section survey and longitudinal section survey.

The main hardware used for data processing are as follows :

1) Personal computer (IBM PS 2/70)	1 no.
2) Color display (IBM 8515)	1 no.
3) Printer (Epson LQ 2550)	1 no.
4) Plotter (Graphtec FP 6150)	1 no.
5) Digitizer (Graphtec KD 5500)	1 no.

4.3 Cross Section Chart

The specifications of the cross section chart are as follows :

1) Chart Size	A 1
2) Horizontal Scale	1/1,000
3) Vertical Scale	1/100

The results of the cross section survey were shown in Data Book I as cross section charts.

1) Phase 1 Survey	73 sheets
2) Phase 2 Survey	65 sheets

TABLES

Table 2.1.1 RESULT OF CONTROL POINT SURVEY AT GUASDUALITO IN 1992 (1/2)

Station	Northing	Easting	Elevat.
G-01-I	800,696.255	299,120.881	130.560
G-01-D	800,462.301	299,291.361	130.727
G-02-I	800,748.249	299,404.345	131.840
G-02-D	800,586.047	299,441.087	130.564
G-03-I	800,784.317	299,597.685	130.650
G-03-D	800,599.098	299,605.646	130.672
G-04-I	800,803.491	299,695.839	130.560
G-04-D	800,598.557	299,705.627	130.624
G-05-I	800,818.398	300,086.324	130.500
G-05-D	800,555.734	300,143.525	130.766
G-06-I	800,807.645	300,582.716	130.270
G-06-D	800,617.037	300,651.538	130.416
G-07-I	800,976.764	301,171.005	130.250
G-07-D	800,646.377	301,267.937	130.184
G-08-I	801,232.713	301,596.822	130.180
G-08-D	800,997.498	301,826.139	130.014
G-09-I	801,637.685	301,940.508	129.910
G-09-D	801,414.159	302,057.798	129.837
G-10-I	801,965.024	302,329.459	129.920
G-10-D	801,628.150	302,467.720	129.813
G-11-I	802,044.340	302,841.175	129.840
G-11-D	801,670.942	302,890.391	129.624
G-12-I	801,873.873	303,463.855	129.480
G-12-D	801,649.019	303,501.107	129.513
G-13-I	801,855.149	304,042.110	129.450
G-13-D	801,622.186	304,003.913	129.426
G-14-I	801,476.042	304,397.876	129.160
G-14-D	801,280.990	304,194.428	129.325
G-15-I	800,974.919	304,516.610	129.050
G-15-D	800,915.716	304,329.993	129.065
G-16-I	800,761.058	304,822.874	129.070
G-16-D	800,485.708	304,955.768	128.860
G-17-I	801,055.660	304,960.061	128.170
G-17-D	800,963.089	305,169.767	128.670
G-18-I	801,393.999	305,365.431	128.590
G-18-D	801,161.797	305,342.267	128.756
G-19-I	801,015.367	305,725.795	128.460
G-19-D	800,933.892	305,571.942	128.349
G-20-I	800,914.116	305,888.491	128.390
G-20-D	800,506.545	306,031.339	128.381
G-21-I	801,001.777	306,032.215	128.410
G-21-D	800,949.520	306,341.590	128.142
G-22-I	801,502.346	306,234.638	128.330
G-22-D	801,326.345	306,330.376	128.200
G-23-I	801,706.179	306,684.829	127.870
G-23-D	801,564.723	306,727.204	127.614
G-24-I	801,948.663	307,135.125	128.080
G-24-D	801,776.529	307,224.734	128.354
G-25-I	802,167.482	307,607.679	127.830
G-25-D	801,997.934	307,674.342	128.400

Table 2.1.1 RESULT OF CONTROL POINT SURVEY AT GUASDUALITO IN 1992 (2/2)

Station	Northing	Easting	Elevat.
G-26-I	802,431.472	308,038.481	127.490
G-26-D	802,003.115	308,223.120	127.679
G-27-I	802,561.864	308,530.207	127.500
G-27-D	802,035.560	308,587.769	127.551
G-28-I	802,542.195	309,017.134	127.300
G-28-D	802,278.347	309,037.427	127.512
G-29-I	802,602.920	309,546.089	127.320
G-29-D	802,287.557	309,556.593	127.115
G-30-I	802,663.415	309,958.721	126.910
G-30-D	802,346.447	310,066.695	127.790
G-31-I	802,896.803	310,307.779	127.120
G-31-D	802,681.331	310,525.033	126.795
G-32-I	803,205.301	310,579.068	126.560
G-32-D	803,137.104	310,745.455	126.745
G-33-I	803,719.351	310,682.863	126.560
G-33-D	803,588.632	310,997.160	126.500
G-34-I	804,464.624	311,226.728	126.190
G-34-D	803,992.039	311,486.591	126.565
G-35-I	804,724.074	311,603.148	126.490
G-35-D	804,405.753	311,695.839	126.322
G-36-I	804,756.838	312,099.108	126.320
G-36-D	804,485.415	312,091.807	126.202
G-37-I	804,706.144	312,654.234	126.200
G-37-D	804,429.869	312,562.900	125.916
G-38-I	804,559.609	313,155.848	125.800
G-38-D	804,210.531	313,074.743	125.497
G-39-I	804,503.394	313,364.439	125.470
G-39-D	804,358.484	313,471.643	125.863
G-40-I	805,004.584	313,410.642	125.470
G-40-D	804,992.497	313,599.703	125.661
G-41-B	805,445.594	313,607.785	125.670
G-41-A	805,451.288	313,705.001	125.657
G-41-D	805,420.600	313,376.958	125.460
G-41-C	805,483.737	313,553.386	125.735
G-42-I	806,077.063	313,434.933	125.110
G-42-D	806,077.653	313,608.123	125.546
G-43-I	806,614.714	313,431.912	125.140
G-43-D	806,579.347	313,648.644	125.396
G-44-I	807,103.765	313,483.663	124.750
G-44-D	807,111.663	313,734.690	124.158
G-45-I	807,628.935	313,410.173	124.830
G-45-D	807,597.898	313,718.090	124.924
G-46-I	808,110.019	313,675.325	124.580
G-46-D	807,991.214	313,951.327	124.707
G-47-I	808,549.707	314,174.527	124.330
G-47-D	808,433.361	314,325.214	124.821
G-48-I	808,928.693	314,275.742	124.710
G-48-D	808,827.104	314,622.394	124.575

Table 2.1.2 RESULT OF CONTROL POINT SURVEY AT GUASDUALITO IN 1993 (1/2)

Station	Northing	Easting	Elevat.	
AV-14	792,458.147	303,796.799		
PORVEIR	793,242.105	310,339.976		
G-01-I	800,696.255	299,120.881	130.560	
G-01-D	800,462.301	299,291.361	130.727	
G-02-I	800,748.249	299,404.345	131.840	
G-02-D	800,586.047	299,441.087	130.564	
G-03-I	800,784.317	299,597.685	130.650	
G-03-D	800,599.098	299,605.646	130.672	
G-04-I	800,803.491	299,695.839	130.560	
G-04-D	800,598.557	299,705.627	130.624	
G-05-I	800,818.398	300,086.324	130.500	
G-05-D	800,555.734	300,143.525	130.766	
G-06-I	800,807.645	300,582.716	130.270	
G-06-D	800,617.037	300,651.538	130.416	
G-07-I	800,976.764	301,171.005	130.250	
G-07-D	800,646.377	301,267.937	130.184	
G-08-I	801,232.713	301,596.822	130.180	
G-08-D	800,997.498	301,826.139	130.014	
G-09-I	801,646.115	301,936.084	130.010	※
G-09-D	801,414.159	302,057.798	130.004	※
G-10-I	801,965.024	302,329.459	129.920	
G-10-D	801,628.150	302,467.720	129.813	
G-11-I	802,044.340	302,841.175	129.840	
G-11-D	801,670.942	302,890.391	129.624	
G-12-I	801,873.873	303,463.855	129.480	
G-12-D	801,649.019	303,501.107	129.513	
G-13-I	801,855.149	304,042.110	129.450	
G-13-D	801,622.186	304,003.913	129.426	
G-14-I	801,476.042	304,397.876	129.160	
G-14-D	801,280.990	304,194.428	129.325	
G-15-I	800,993.189	304,574.199	129.052	※
G-15-D	800,915.716	304,329.993	129.065	
G-16-I	800,600.205	304,900.470	128.602	※
G-16-D	800,485.708	304,955.768	128.860	
G-17-I	801,055.660	304,960.061	128.170	
G-17-D	800,940.099	305,221.847	128.796	※
G-18-I	801,412.652	305,367.292	128.252	※
G-18-D	801,161.797	305,342.267	128.756	
G-19-I	801,037.673	305,767.917	128.418	※
G-19-D	800,933.892	305,571.942	128.349	
G-20-I	800,914.116	305,888.491	128.390	
G-20-D	800,468.796	306,044.569	128.481	※
G-21-I	801,001.777	306,032.215	128.410	
G-21-D	800,943.820	306,375.337	127.803	※
G-22-I	801,502.346	306,234.638	128.330	
G-22-D	801,326.345	306,330.376	128.200	
G-23-I	801,706.179	306,684.829	127.870	
G-23-D	801,564.723	306,727.204	127.614	
G-24-I	801,948.663	307,135.125	128.080	
G-24-D	801,776.529	307,224.734	128.854	

※ Recovered Point

Table 2.1.2 RESULT OF CONTROL POINT SURVEY AT GUASDUALITO IN 1993 (2/2)

Station	Northing	Easting	Elevat.	
G-25-I	802,167.482	307,607.679	127.830	
G-25-D	801,997.934	307,674.342	128.400	
G-26-I	802,420.548	308,043.190	127.597	※
G-26-D	802,003.115	308,223.120	127.679	
G-27-I	802,561.864	308,530.207	127.500	
G-27-D	802,333.923	308,555.137	127.912	※
G-28-I	802,561.695	309,015.634	127.006	※
G-28-D	802,278.347	309,037.427	127.512	
G-29-I	802,602.920	309,546.089	127.320	
G-29-D	802,287.557	309,556.593	127.115	
G-30-I	802,663.415	309,958.721	126.910	
G-30-D	802,528.157	310,004.796	126.925	※
G-31-I	802,896.803	310,307.779	127.120	
G-31-D	802,681.331	310,525.033	126.795	
G-32-I	803,205.301	310,579.068	126.560	
G-32-D	803,137.104	310,745.455	126.745	
G-33-I	803,719.351	310,682.863	126.560	
G-33-D	803,588.632	310,997.160	126.500	
G-34-I	804,464.624	311,226.728	126.190	
G-34-D	803,992.039	311,486.591	126.565	
G-35-I	804,724.074	311,603.148	126.490	
G-35-D	804,405.753	311,695.839	126.322	
G-36-I	804,756.838	312,099.108	126.320	
G-36-D	804,485.415	312,091.807	126.202	
G-37-I	804,706.144	312,654.234	126.200	
G-37-D	804,429.869	312,562.900	125.916	
G-38-I	804,561.930	313,154.438	125.978	※
G-38-D	804,384.248	313,111.636	125.569	※
G-39-I	804,504.427	313,362.029	125.970	※
G-39-D	804,358.976	313,468.563	125.902	※
G-40-I	805,004.584	313,410.642	125.470	
G-40-D	804,992.497	313,599.703	125.661	
G-41-D	805,420.600	313,376.958	125.460	
G-41-C	805,483.737	313,553.386	125.735	
G-42-I	806,077.063	313,434.933	125.110	
G-42-D	806,077.653	313,608.123	125.546	
G-43-I	806,614.714	313,431.912	125.140	
G-43-D	806,579.347	313,648.644	125.396	
G-44-I	807,103.765	313,483.663	124.750	
G-44-D	807,111.663	313,734.690	125.153	
G-45-I	807,623.935	313,410.173	124.830	
G-45-D	807,597.898	313,718.090	124.924	
G-46-I	808,110.019	313,675.325	124.580	
G-46-D	807,991.214	313,951.327	124.707	
G-47-I	808,549.707	314,174.527	124.330	
G-47-D	808,433,361	314,325.214	124.821	
G-48-I	808,928.693	314,275.742	124.710	
G-48-D	808,827.104	314,622.394	124.671	※

※ Recovered Point

Table 2.1.3 RESULT OF CONTROL POINT SURVEY AT BRUZUAL IN 1992 (1/3)

Station	Northing	Easting	Elevat.
B-00-B	890,375.797	465,771.758	78.065
B-00-A	890,250.318	465,802.855	78.296
B-00-D	890,977.391	465,822.870	78.480
B-00-C	890,589.267	465,945.104	78.415
B-01-B	890,221.499	465,297.147	78.429
B-01-A	890,072.955	465,332.998	78.740
B-01-D	890,908.229	465,365.060	78.460
B-01-C	890,538.200	465,383.722	78.628
B-02-C	890,853.805	464,920.556	78.490
B-02-B	890,341.794	464,857.739	78.908
B-02-A	890,185.319	464,787.648	78.951
B-03-I	890,892.593	464,343.061	79.000
B-03-D	890,375.548	464,275.827	79.400
B-04-I	890,807.466	463,763.529	79.990
B-04-D	890,509.003	463,768.278	79.648
B-05-I	890,805.888	463,663.593	80.110
B-05-D	890,508.669	463,668.299	79.452
B-06-I	890,821.747	463,474.651	81.790
B-06-D	890,499.126	463,552.777	79.636
B-07-I	890,976.577	462,937.003	78.890
B-07-D	890,507.441	463,047.710	78.908
B-08-B	890,655.940	462,516.470	78.290
B-08-A	890,336.644	462,540.341	78.986
B-08-D	891,087.058	462,514.494	79.000
B-08-C	890,894.685	462,407.433	78.698
B-09-B	890,466.624	461,955.968	79.464
B-09-A	890,260.507	461,991.521	79.000
B-09-D	891,286.307	462,053.175	79.260
B-09-C	891,096.454	462,032.278	78.072
B-10-B	890,550.361	461,437.845	79.306
B-10-A	890,303.172	461,388.415	79.420
B-10-D	891,363.133	461,516.270	79.340
B-10-C	891,251.534	461,499.881	79.206
B-11-B	890,596.922	460,826.039	78.874
B-11-A	890,347.251	460,788.706	79.150
B-11-D	891,337.800	460,965.256	79.590
B-11-C	891,201.295	461,018.466	79.352
B-12-B	890,917.491	460,425.501	79.513
B-12-A	890,389.947	460,378.909	79.300
B-12-D	891,201.588	460,563.554	79.640
B-12-C	891,076.559	460,625.414	79.440
B-13-I	890,953.024	460,018.248	79.952
B-13-D	890,377.425	460,146.242	79.600
B-14-B	890,169.893	459,387.816	79.712
B-14-A	889,988.209	459,457.578	79.500
B-14-D	890,794.767	459,313.503	79.180
B-14-C	890,347.739	459,319.611	79.390
B-15-B	890,024.537	458,946.467	79.659
B-15-A	839,843.187	458,939.277	79.690
B-15-D	890,822.460	458,788.716	79.820
B-15-C	890,344.176	458,795.974	79.854

Table 2.1.3 RESULT OF CONTROL POINT SURVEY AT BRUZUAL IN 1992 (2/3)

Station	Northing	Easting	Elevat.
B-16-B	890,032.890	458,448.400	79.629
B-16-A	889,899.662	458,418.027	79.790
B-16-D	890,842.327	458,380.877	79.810
B-16-C	890,343.891	458,300.793	79.944
B-17-B	890,188.628	458,067.329	79.899
B-17-A	889,989.888	458,045.364	80.300
B-17-D	890,984.499	457,715.142	80.310
B-17-C	890,655.021	457,607.837	79.961
B-18-B	890,447.853	457,599.061	80.028
B-18-A	890,295.924	457,493.852	80.000
B-18-D	891,189.530	457,228.457	80.610
B-18-C	890,983.020	457,127.227	79.410
B-19-B	890,799.027	456,996.443	80.072
B-19-A	890,689.583	456,929.717	80.150
B-19-D	891,484.244	456,855.068	80.750
B-19-C	891,243.225	456,641.035	79.880
B-20-B	891,053.503	456,490.024	80.134
B-20-A	890,958.797	456,437.828	80.270
B-20-D	891,934.678	456,159.796	80.440
B-20-C	891,573.191	456,029.716	80.220
B-21-B	891,271.842	456,017.310	80.670
B-21-A	891,178.511	456,008.333	80.120
B-21-D	892,073.862	455,723.903	80.920
B-21-C	891,865.149	455,567.674	80.318
B-22-B	891,344.899	455,608.755	80.206
B-22-A	891,268.677	455,597.695	80.000
B-22-D	892,312.946	455,363.326	80.762
B-22-C	892,030.219	455,255.489	80.611
B-23-B	891,246.149	455,143.438	80.224
B-23-A	891,176.604	455,232.796	80.304
B-23-D	892,394.740	454,681.558	79.940
B-23-C	891,850.944	454,691.227	80.688
B-24-B	890,774.368	455,073.082	80.310
B-24-A	890,724.721	455,131.752	80.552
B-24-D	892,435.765	453,808.580	81.040
B-24-C	891,838.383	453,960.348	80.884
B-25-B	890,659.208	454,712.838	81.000
B-25-A	890,571.228	454,702.918	80.116
B-25-D	892,278.677	453,175.369	81.130
B-25-C	891,977.962	453,179.065	80.990
B-26-B	890,928.874	454,142.810	80.912
B-26-A	890,870.203	454,095.336	80.600
B-26-D	892,292.588	452,664.249	81.105
B-26-C	891,998.981	452,660.273	80.800
B-27-B	891,279.246	453,769.644	80.944
B-27-A	891,209.959	453,710.169	80.530
B-27-D	892,376.112	451,892.233	81.087
B-27-C	892,069.735	451,925.229	81.020
B-28-B	891,467.688	453,586.175	80.763
B-28-A	891,467.596	453,526.104	80.470

Table 2.1.3 RESULT OF CONTROL POINT SURVEY AT BRUZUAL IN 1992 (3/3)

Station	Northing	Easting	Elevat.
B-29-B	891.725.112	453.126.086	80.264
B-29-A	891.636.086	453.090.914	80.160
B-29-D	892,243.015	451.410.429	80.482
B-29-C	891,966.436	451.587.999	81.150
B-30-I	891,872.448	451,000.302	80.938
B-30-D	891,658.099	451,166.613	81.040
B-31-I	891.505.378	450,618.878	81.342
B-31-D	891,276.303	451,029.287	81.730
B-32-B	890,900.749	450,401.440	81.358
B-32-A	890,732.777	450,816.715	81.580
B-32-D	891,212.848	450,245.435	81.473
B-32-C	891,014.434	450,384.844	80.858
B-33-B	890,265.212	450,294.230	81.468
B-33-A	890,116.012	450,636.835	81.580
B-33-D	891,045.104	449,766.533	81.332
B-33-C	890,781.907	449,825.275	81.480
B-34-B	889,738.302	450,448.311	80.674
B-34-A	889,778.874	450,620.505	81.190
B-34-D	890,768.331	448,876.958	81.700
B-34-C	890,600.116	448,936.529	81.696
B-35-B	889,601.234	449,782.477	81.912
B-35-A	889,169.976	450,306.405	81.690
B-35-D	890,277.471	448,129.506	81.456
B-35-C	890,175.413	448,196.488	82.000
B-36-B	889,223.799	449,249.911	81.970
B-36-A	888,875.261	449,338.952	81.848
B-36-D	890,152.471	447,562.221	81.458
B-36-C	889,939.497	447,621.236	82.200
B-37-B	889,031.872	448,338.126	82.150
B-37-A	888,557.719	448,446.259	82.172
B-37-D	890,041.915	447,111.144	81.950
B-37-C	889,935.225	447,134.908	81.828
B-38-D	889,609.079	446,944.179	81.210
B-38-C	889,748.759	447,007.752	81.972
B-38-(I)	888,469.738	447,724.282	82.120
B-38-(D)	888,196.449	448,071.872	82.230
B-39-D	889,405.977	447,428.639	81.992
B-39-C	889,679.671	447,430.655	82.240
B-40-D	889,156.978	447,682.530	82.122
B-40-C	889,195.466	447,827.980	81.850
B-41-D	888,775.681	447,810.498	82.115
B-41-C	888,853.119	447,942.984	82.490
B-42-I	888,042.170	447,522.265	81.304
B-42-D	887,889.419	447,928.394	82.520
B-43-I	887,596.058	447,495.567	82.396
B-43-D	887,562.167	447,887.961	82.480
B-44-I	886,955.079	447,610.325	81.206
B-44-D	886,882.438	447,789.639	82.578
B-45-I	886,440.586	447,321.336	82.724
B-45-D	886,278.097	447,557.675	82.800

Table 2.1.4 RESULT OF CONTROL POINT SURVEY AT BRUZUAL IN 1993 (1/2)

Station	Northing	Easting	Elevat.	
S.Vicent	885,047.053	445,460.564		
Bruzual	890,162.049	464,532.767		
B-00-D	890,977.391	465,822.870	78.408	※
B-00-C	890,589.267	465,945.104	78.415	
B-01-D	890,908.229	465,365.060	78.460	
B-01-C	890,538.200	465,383.722	78.628	
B-02-C	890,853.805	464,920.556	78.490	
B-02-B	890,341.794	464,857.739	78.908	
B-02-A	890,185.319	464,787.648	78.951	
B-03-I	890,892.593	464,343.061	79.000	
B-03-D	890,375.548	464,275.827	79.400	
B-04-I	890,807.466	463,763.529	79.990	
B-04-D	890,509.003	463,768.278	79.648	
B-05-I	890,805.888	463,663.593	80.110	
B-05-D	890,508.669	463,668.299	79.452	
B-06-I	890,821.747	463,474.651	81.790	
B-06-D	890,499.126	463,552.777	79.636	
B-07-I	890,976.577	462,937.003	78.890	
B-07-D	890,472.573	463,055.938	77.617	※
B-08-B	890,655.940	462,516.470	77.556	※
B-08-A	890,334.456	462,540.505	79.278	※
B-08-D	891,087.992	462,515.014	79.170	※
B-08-C	890,894.685	462,407.433	78.698	
B-09-B	890,466.624	461,955.968	79.644	※
B-09-A	890,260.507	461,991.521	79.378	※
B-09-D	891,286.307	462,053.175	79.260	
B-09-C	891,096.454	462,032.278	78.072	
B-10-B	890,550.361	461,437.845	79.306	
B-10-A	890,303.172	461,388.415	79.420	
B-10-D	891,370.915	461,517.413	79.658	※
B-10-C	891,246.587	461,499.155	78.830	※
B-11-B	890,596.922	460,826.039	79.312	※
B-11-A	890,347.251	460,788.706	79.459	※
B-11-D	891,347.219	460,961.585	79.373	※
B-11-C	891,201.295	461,018.466	79.352	
B-12-B	890,817.879	460,416.703	78.231	※
B-12-A	890,389.947	460,378.909	79.300	
B-12-D	891,201.588	460,563.554	79.640	
B-12-C	891,061.466	460,632.881	79.721	※
B-13-I	890,959.857	460,016.729	79.954	※
B-13-D	890,377.425	460,146.242	79.600	
B-14-D	890,794.767	459,313.503	79.180	
B-14-C	890,347.739	459,319.611	79.390	
B-15-D	890,822.460	458,788.716	79.820	
B-15-C	890,279.293	458,796.959	78.708	※
B-16-D	890,842.327	458,380.877	79.810	
B-16-C	890,293.290	458,292.346	80.113	※
B-17-D	890,984.499	457,715.142	80.310	
B-17-C	890,646.594	457,595.187	80.257	※
B-18-D	891,189.530	457,228.457	80.610	
B-18-C	890,970.301	457,120.992	79.410	

※ Recovored Point

Table 2.1.4 RESULT OF CONTROL POINT SURVEY AT BRUZUAL IN 1993 (2/2)

Station	Northing	Easting	Elevat.	
B-19-D	891,484.244	456,855.068	80.750	
B-19-C	891,243.146	456,641.868	79.880	
B-20-D	891,934.678	456,159.796	80.440	
B-20-C	891,573.191	456,029.719	80.220	
B-21-D	892,073.862	455,723.903	80.920	
B-21-C	891,865.149	455,567.674	80.318	
B-22-D	892,312.946	455,363.326	80.762	
B-22-C	891,835.180	455,181.097	80.043	※
B-23-D	892,394.740	454,681.558	79.940	
B-23-C	891,807.096	454,692.009	80.678	※
B-24-D	892,435.765	453,808.580	81.040	
B-24-C	891,838.383	453,960.348	80.884	
B-25-D	892,278.677	453,175.369	81.130	
B-25-C	891,977.962	453,179.065	80.990	
B-26-D	892,292.588	452,664.249	81.105	
B-26-C	891,996.981	452,660.246	80.984	※
B-27-D	892,376.112	451,892.233	80.839	※
B-27-C	892,069.735	451,925.229	80.870	※
B-29-D	892,250.395	451,409.908	80.990	※
B-29-C	891,966.436	451,587.999	81.150	
B-30-I	891,872.448	451,000.302	81.124	※
B-30-D	891,657.111	451,167.324	81.735	※
B-31-I	891,505.378	450,618.878	81.164	※
B-31-D	891,269.389	451,041.674	81.354	※
B-32-B	890,900.749	450,401.440	81.358	
B-32-A	890,729.325	450,822.363	81.392	※
B-33-B	890,265.212	450,294.230	81.468	
B-33-A	890,110.023	450,650.588	81.539	※
B-34-B	889,738.302	450,448.311	78.685	※
B-34-A	889,784.416	450,644.026	81.323	※
B-35-B	889,601.234	449,782.477	81.912	
B-35-A	889,169.976	450,306.405	81.690	
B-36-B	889,223.799	449,249.911	81.970	
B-36-A	888,868.941	449,340.567	81.566	※
B-37-B	889,031.872	448,338.126	82.007	※
B-37-A	888,557.719	448,446.259	82.172	
B-38-(I)	888,510.909	447,671.918	81.885	※
B-38-(D)	888,196.449	448,071.872	82.230	
B-40-D	839,156.978	447,682.530	81.841	※
B-40-C	889,195.466	447,827.980	81.850	
B-41-D	888,736.020	447,742.643	81.651	※
B-41-C	888,978.096	448,156.801	82.360	※
B-42-I	888,042.170	447,522.265	81.710	※
B-42-D	887,887.606	447,933.214	82.403	※
B-43-I	887,596.058	447,495.567	82.396	
B-43-D	887,561.580	447,894.751	82.722	※
B-44-I	886,955.079	447,610.325	80.072	※
B-44-D	886,874.667	447,808.821	82.399	※
B-45-I	886,440.586	447,321.336	82.724	
B-45-D	886,276.964	447,559.323	82.734	※

※ Recovered Point

Table 2.1.5 RESULT OF CONTROL POINT SURVEY AT CAMAGUAN IN 1992 (1/3)

Station	Northing	Easting	Elevat.
C-01-I	895,490.000	653,977.000	47.403
C-01-D	895,451.165	653,839.787	47.460
C-02-I	895,686.536	653,915.223	47.440
C-02-D	895,634.208	653,781.385	46.278
C-03-I	895,853.353	653,807.199	47.430
C-03-D	895,774.810	653,707.415	46.677
C-04-I	895,891.864	653,775.542	47.390
C-04-D	895,814.606	653,672.767	47.320
C-05-I	896,008.138	653,651.660	48.157
C-05-D	895,929.016	653,567.722	47.770
C-06-I	896,131.416	653,507.433	47.836
C-06-D	896,029.339	653,440.678	47.649
C-07-I	896,211.605	653,345.164	48.678
C-07-D	896,014.790	653,380.126	48.090
C-08-I	895,821.079	653,173.268	46.768
C-08-D	895,852.507	653,324.350	47.610
C-09-I	895,648.272	653,204.883	47.114
C-09-D	895,649.994	653,351.206	47.840
C-10-I	895,360.995	653,202.317	47.360
C-10-D	895,336.830	653,331.086	47.772
C-11-I	895,070.303	653,141.365	47.550
C-11-D	895,030.439	653,235.489	47.689
C-12-I	894,860.450	653,065.640	47.580
C-12-D	894,814.077	653,161.257	47.892
C-13-I	894,740.902	653,013.945	47.470
C-13-D	894,679.685	653,104.860	47.891
C-14-I	894,644.475	652,887.748	47.900
C-14-D	894,499.921	652,956.691	48.028
C-15-I	894,592.025	652,669.496	47.728
C-15-D	894,442.555	652,669.893	47.830
C-16-I	894,612.369	652,397.374	47.824
C-16-D	894,455.982	652,375.902	47.820
C-17-I	894,675.957	651,973.172	47.740
C-17-D	894,505.662	651,946.871	47.706
C-18-I	894,687.197	651,592.993	47.670
C-18-D	894,555.642	651,589.672	48.100
C-19-I	894,677.143	651,334.113	47.830
C-19-D	894,555.705	651,289.174	47.960
C-20-I	894,869.009	651,238.197	47.850
C-20-D	894,906.642	651,174.078	47.904
C-21-I	894,961.670	651,521.290	48.130
C-21-D	895,104.350	651,494.223	47.807
C-22-I	894,921.710	651,324.719	47.780
C-22-D	895,073.796	651,852.602	46.970
C-23-I	894,876.802	652,169.782	47.620
C-23-D	895,036.644	652,155.222	46.700
C-24-I	894,975.227	652,475.891	47.378
C-24-D	895,099.991	652,383.501	45.980
C-25-I	895,231.073	652,727.227	47.980
C-25-D	895,316.373	652,597.666	46.408

* Coordinates are shown by the GPS.

Table 2.1.5 RESULT OF CONTROL POINT SURVEY AT CAMAGUAN IN 1992 (2/3)

Station	Northing	Easting	Elevat.
C-26-I	895,507.031	652,841.959	47.840
C-26-D	895,528.514	652,694.434	45.714
C-27-I	895,768.505	652,814.454	47.900
C-27-D	895,736.418	652,666.505	45.358
C-28-I	895,944.461	652,705.420	48.050
C-28-D	895,870.452	652,587.801	46.430
C-29-I	896,100.197	652,533.200	48.340
C-29-D	895,995.453	652,468.336	47.991
C-30-I	896,239.962	652,304.665	47.910
C-30-D	896,104.623	652,228.141	48.030
C-31-I	896,358.899	652,120.663	47.932
C-31-D	896,266.379	652,009.637	48.050
C-32-I	896,534.012	651,968.333	47.650
C-32-D	896,443.487	651,849.427	48.310
C-33-I	896,726.975	651,847.646	48.260
C-33-D	896,651.526	651,712.442	48.032
C-34-I	896,900.519	651,753.532	48.170
C-34-D	896,845.748	651,642.833	48.520
C-35-I	897,070.220	651,693.388	48.100
C-35-D	897,044.860	651,585.724	47.195
C-36-I	897,293.933	651,647.392	48.370
C-36-D	897,267.669	651,534.322	47.708
C-37-I	897,543.728	651,573.695	48.230
C-37-D	897,502.569	651,472.501	47.635
C-38-I	897,769.321	651,480.319	47.810
C-38-D	897,704.823	651,375.318	47.794
C-39-I	897,923.153	651,375.008	47.380
C-39-D	897,871.222	651,283.800	47.803
C-40-I	898,104.460	651,244.827	47.500
C-40-D	898,039.343	651,152.685	47.866
C-41-I	898,245.781	651,126.439	48.015
C-41-D	898,170.743	651,044.386	47.930
C-42-I	898,383.570	651,003.049	47.490
C-42-D	898,308.077	650,923.369	47.410
C-43-I	898,525.828	650,889.307	48.330
C-43-D	898,421.648	650,787.376	47.612
C-44-I	898,645.735	650,704.496	47.520
C-44-D	898,516.708	650,627.567	47.533
C-45-I	898,750.899	650,494.588	47.780
C-45-D	898,625.218	650,413.841	47.543
C-46-I	898,823.761	650,346.212	47.230
C-46-D	898,685.672	650,271.123	47.374
C-47-I	898,930.069	650,136.959	47.810
C-47-D	898,801.019	650,085.475	47.872
C-48-I	899,041.030	649,941.727	48.040
C-48-D	898,916.777	649,863.663	47.743
C-49-I	899,133.800	649,722.800	47.500
C-49-D	899,018.483	649,659.013	47.978
C-50-I	899,238.770	649,479.197	48.150
C-50-D	899,119.554	649,423.067	47.922

* Coordinates are shown by the GPS.

Table 2.1.5 RESULT OF CONTROL POINT SURVEY AT CAMAGUAN IN 1992 (3/3)

Station	Northing	Easting	Elevat.
C-51-I	899,345.189	649,204.805	47.780
C-51-D	899,210.805	649,172.738	48.287
C-52-I	899,418.582	649,026.104	48.370
C-52-D	899,290.182	648,991.372	47.742

* Coordinates are shown by the GPS

Table 2.1.6 RESULT OF CONTROL POINT SURVEY AT CAMAGUAN IN 1993 (1/2)

Station	Northing	Easting	Elevat.	
C-01-I	895,490.000	653,977.000	47.403	
C-01-D	895,451.165	653,839.787	47.460	
C-02-I	895,686.536	653,915.223	47.440	
C-02-D	895,634.208	653,781.385	46.278	
C-03-I	895,859.457	653,809.873	47.501	※
C-03-D	895,774.810	653,707.415	46.677	
C-04-I	895,891.864	653,775.542	47.390	
C-04-D	895,814.606	653,672.767	47.532	※
C-05-I	896,008.138	653,651.660	48.157	
C-05-D	895,929.016	653,567.722	47.770	
C-06-I	896,131.416	653,507.433	47.836	
C-06-D	896,029.339	653,440.678	47.649	
C-07-I	896,211.605	653,345.164	48.678	
C-07-D	896,012.256	653,380.576	47.918	※
C-08-I	895,821.079	653,173.268	46.629	※
C-08-D	895,852.507	653,324.350	47.610	
C-09-I	895,648.272	653,204.883	46.729	※
C-09-D	895,649.994	653,351.206	47.840	
C-10-I	895,360.995	653,202.317	47.360	
C-10-D	895,336.830	653,331.086	47.772	
C-11-I	895,070.303	653,141.365	47.550	
C-11-D	895,030.439	653,235.489	47.689	
C-12-I	894,860.450	653,065.640	47.580	
C-12-D	894,814.077	653,161.257	47.828	※
C-13-I	894,740.902	653,013.945	47.470	
C-13-D	894,679.685	653,104.860	47.891	
C-14-I	894,644.475	652,887.748	47.900	
C-14-D	894,499.921	652,956.691	48.028	
C-15-I	894,592.025	652,669.496	47.728	
C-15-D	894,442.555	652,669.893	47.830	
C-16-I	894,613.836	652,397.575	47.754	※
C-16-D	894,455.982	652,375.902	47.810	※
C-17-I	894,675.957	651,973.172	47.740	
C-17-D	894,505.662	651,946.871	47.706	
C-18-I	894,687.197	651,592.993	47.670	
C-18-D	894,555.642	651,589.672	48.100	
C-19-I	894,677.143	651,334.113	47.830	
C-19-D	894,555.705	651,289.174	47.960	
C-20-I	894,869.009	651,288.197	47.850	
C-20-D	894,906.642	651,174.078	47.904	
C-21-I	894,961.670	651,521.290	48.130	
C-21-D	895,104.350	651,494.223	47.807	
C-22-I	894,919.251	651,824.268	47.821	※
C-22-D	895,073.796	651,852.602	47.028	※
C-23-I	894,871.004	652,170.301	47.620	
C-23-D	895,036.644	652,155.222	46.788	※
C-24-I	894,975.227	652,475.891	47.878	
C-24-D	895,099.991	652,383.501	46.007	※
C-25-I	895,231.966	652,733.216	47.990	※
C-25-D	895,316.373	652,597.666	46.408	

* Coordinates are shown by the GPS.

※ Recovered Point

Table 2.1.6 RESULT OF CONTROL POINT SURVEY AT CAMAGUAN IN 1993 (2/2)

Station	Northing	Easting	Elevat.	
C-26-I	895,505.611	652,851.709	47.840	
C-26-D	895,528.514	652,694.434	46.351	※
C-27-I	895,768.641	652,815.081	47.900	
C-27-D	895,736.418	652,666.505	46.212	※
C-28-I	895,944.461	652,705.420	48.050	
C-28-D	895,870.452	652,587.801	46.946	※
C-29-I	896,100.197	652,533.200	48.340	
C-29-D	895,986.332	652,462.688	47.991	
C-30-I	896,239.962	652,304.665	47.910	
C-30-D	896,101.394	652,226.315	48.030	
C-31-I	896,358.899	652,120.663	47.932	
C-31-D	896,266.379	652,009.637	48.050	
C-32-I	896,534.012	651,968.333	47.766	※
C-32-D	896,440.406	651,845.380	48.310	
C-33-I	896,726.975	651,847.646	48.260	
C-33-D	896,650.313	651,710.269	48.032	
C-34-I	896,900.519	651,753.532	48.170	
C-34-D	896,845.748	651,642.833	48.520	
C-35-I	897,070.220	651,693.388	48.100	
C-35-D	897,044.860	651.585.724	47.195	
C-36-I	897,293.933	651,647.392	48.370	
C-36-D	897,267.669	651,534.322	47.708	
C-37-I	897,543.728	651,573.695	47.941	※
C-37-D	897,502.569	651,472.501	47.635	
C-38-I	897,769.321	651,480.319	47.810	
C-38-D	897,704.823	651,375.318	47.794	
C-39-I	897,923.153	651,375.008	47.380	
C-39-D	897,871.222	651,283.800	47.803	
C-40-I	898,104.460	651,244.827	47.500	
C-40-D	898,039.343	651,152.685	47.866	
C-41-I	898,245.781	651,126.439	48.015	
C-41-D	898,170.743	651,044.386	47.930	
C-42-I	898,383.570	651,003.049	47.490	
C-42-D	898,308.077	650,923.369	47.410	
C-43-I	898,525.828	650,889.307	48.330	
C-43-D	898,421.648	650,787.376	47.612	
C-44-I	898,645.735	650,704.496	47.520	
C-44-D	898,516.708	650,627.567	47.593	※
C-45-I	898,750.899	650,494.588	47.697	※
C-45-D	898,625.218	650,413.841	47.543	
C-46-I	898,823.761	650,346.212	47.230	
C-46-D	898,694.347	650,275.840	47.877	※
C-47-I	898,930.069	650,136.959	47.810	
C-47-D	893,801.019	650,085.475	47.872	
C-48-I	899,041.030	649,941.727	48.040	
C-48-D	898,916.777	649,863.663	47.743	
C-49-I	899,133.800	649,722.800	47.500	
C-49-D	899,018.483	649,659.013	48.013	※
C-50-I	899,238.770	649,479.197	48.150	
C-50-D	899,119.554	649,428.067	47.922	

* Coordinates are shown by the GPS.

※ Recovered Point

Table 2.1.7 RESULT OF CONTROL POINT SURVEY AT SAN FERNANDO IN 1992

Station	Northing	Easting	Elevat.
S-01-I	874,181.553	668,386.028	45.640
S-01-D	873,741.289	668,478.350	48.155
S-02-I	874,209.436	668,543.711	45.350
S-02-D	873,727.032	668,606.666	48.118
S-03-I	874,227.731	668,642.136	45.050
S-03-D	873,739.306	668,705.776	47.213

Table 2.1.8 RESULT OF CONTROL POINT SURVEY ADDITIONAL SITE IN 1993 (1/2)

Station	Northing	Easting	
A-01-I	879,179	585,899	
A-01-D	879,173	586,145	
A-02-I	880,748	591,929	
A-02-D	880,700	591,902	
A-03-I	884,200	598,782	
A-03-D	884,083	598,780	
A-04-I	882,729	602,658	
A-04-D	882,645	602,526	
A-05-I	882,492	602,619	
A-05-D	882,447	602,650	
A-07-I	887,243	616,851	
A-07-D	887,135	616,870	
A-08-I	884,743	610,836	
A-08-D	884,674	610,905	
A-09-I	884,702	612,746	
A-09-D	884,540	612,749	
A-10-I	884,292	623,055	
A-10-D	884,151	622,989	
A-11-I	884,493	626,322	
A-11-D	884,373	626,392	
A-12-I	881,742	629,178	
A-12-D	881,560	629,210	
A-14-I	883,913	637,783	
A-14-D	883,664	637,932	
A-15-I	880,703	644,391	
A-15-D	880,701	644,507	
A-16-I	880,409	650,065	
A-16-D	880,130	649,831	
A-17-I	861,116	681,154	
A-17-D	861,186	680,853	
A-18-I	854,610	688,696	
A-18-D	854,605	688,599	
A-19-I	858,754	694,079	
A-19-D	858,491	694,399	
A-20-I	857,723	695,970	
A-20-D	857,752	695,811	
A-21-I	859,218	695,557	
A-21-D	859,307	695,683	
A-22-I	861,593	695,732	
A-22-D	861,661	695,695	
A-23-I	862,428	694,421	
A-23-D	862,378	694,466	
A-24-I	860,294	696,226	
A-24-D	860,156	696,055	
A-25-I	853,616	707,455	
A-25-D	853,362	707,542	

* Coordinates are shown by the GPS.

Table 2.1.8 RESULT OF CONTROL POINT SURVEY ADDITIONAL SITE IN 1993 (2/2)

Station	Northing	Easting	
A-26-I	860,358	711,625	
A-26-D	860,111	711,674	
A-27-I	858,893	722,802	
A-27-D	858,728	722,808	
A-28-I	859,420	723,973	
A-28-D	859,345	724,039	
A-29-I	858,166	724,103	
A-29-D	858,126	723,959	
A-30-I	857,240	728,343	
A-30-D	857,105	728,414	
A-31-I	855,289	728,325	
A-31-D	855,261	728,243	
A-32-I	843,685	733,376	
A-32-D	843,500	733,304	
A-33-I	851,249	736,411	
A-33-D	851,185	736,332	
A-34-I	848,386	747,502	
A-34-D	848,478	747,465	
A-36-I	847,701	748,349	
A-36-D	847,581	748,312	
A-37-I	845,478	750,422	
A-37-D	845,668	750,504	
A-38-I	846,666	752,128	
A-38-D	846,462	752,163	

* Coordinates are shown by the GPS.

Table 3.2.1 BENCH MARKS REFERRED FOR SURVEY IN 1992

	Station	Name of BM	BM Elevation (El. m)	BM Location	Remarks
1.	San Vicente	BM-AB-1A	79.202	Bruzual	ICN
2.	El Jobal (BM-4)	BM-CSFA-5	46.050	S. Fernando	ICN
3.	Los Caballos	La Union	48.400	La Union	
4.	Guanarito	BM-3FB-23	92.058	Guanare	ICN
5.	El Baul	BM-CB-1	67.030	El Baul	ICN
6.	Suripa	BM-2FC-50	94.984	Hdo Suripa	ICN
7.	Santa Rosalia	BM-2FC-48	96.307	Suripa	ICN
8.	La Union	BM-17-1	49.708	La Union	PROA
9.	San Antonio	BM-AB-53A	66.060	El Saman	ICN
10.	Capilla (1)	BM-3FB-23	92.058	Guanare	ICN
11.	Capilla (2)	Capilla (1)	74.506	Capilla	MERCA 1992
12.	Paso Igues	BM-CB-1	67.030	Igues	PROA
13.	Coco de Mono	BM-CPM-13	45.173	Camaguan	ICN
14.	Costa de Guanare	BM-CBA-51A	60.861	Arismendi	ICN
15.	Fondo Cano	Coco de Mono	46.677	Camaguan	MERCA 1992
16.	Esquina del Puente	Fondo Cano	43.917	Camaguan	MERCA 1992

* Los Caballos was surveyed in 1993.

Table 3.2.2 RESULT OF LEVELING SURVEY IN 1992

	Station	BM Elevation (El. m)	Zero of Gauge (El. m)	Remarks
1.	San Vicente	83.760	79.202	Staff 0 m
2.	El Jobal (BM-4)	44.364	42.954	Top of #8 Staff
3.	Los Caballos	49.952	40.002	Staff 0 m
4.	Guanarito	89.862	–	
5.	El Baul	62.204	–	
6.	Suripa	94.336	–	
7.	Santa Rosalia	96.662	–	
8.	La Union	48.400	48.410	Staff 0 m
9.	San Antonio	59.995	58.213	"
10.	La Capilla (1)	74.506	72.717	"
11.	La Capilla (2)	74.553	72.038	"
12.	Paso Igues	61.825	58.932	"
13.	Coco de Mono	46.677	44.260	"
14.	Costa de Guanare	56.555	56.075	"
15.	Fondo Cano	43.917	–	
16.	Esquina del Puente	48.667	–	

* Los Caballos was surveyed in 1993.

FIGURES

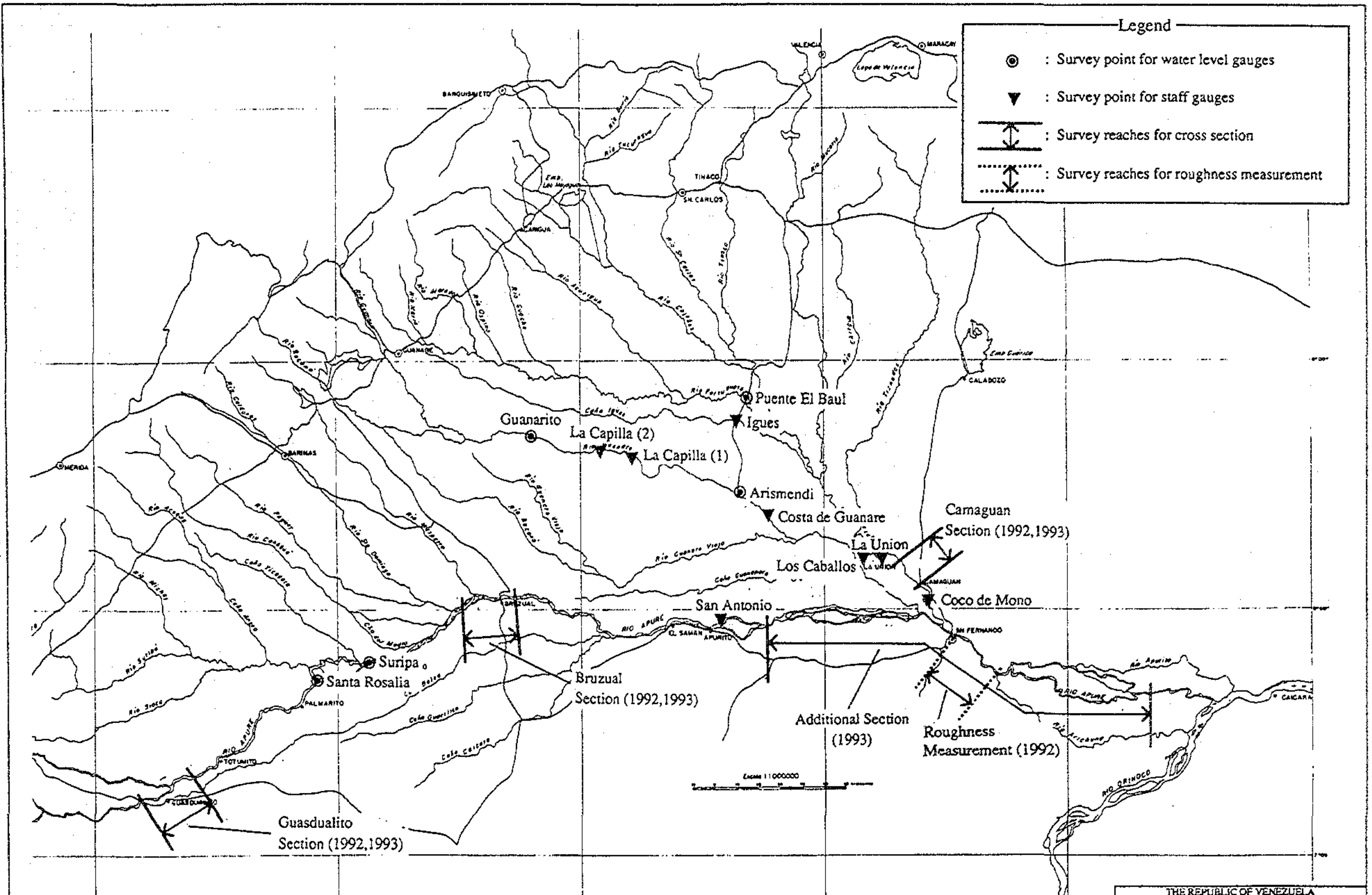

Fig. 1.1.1 Location of Topographic Survey

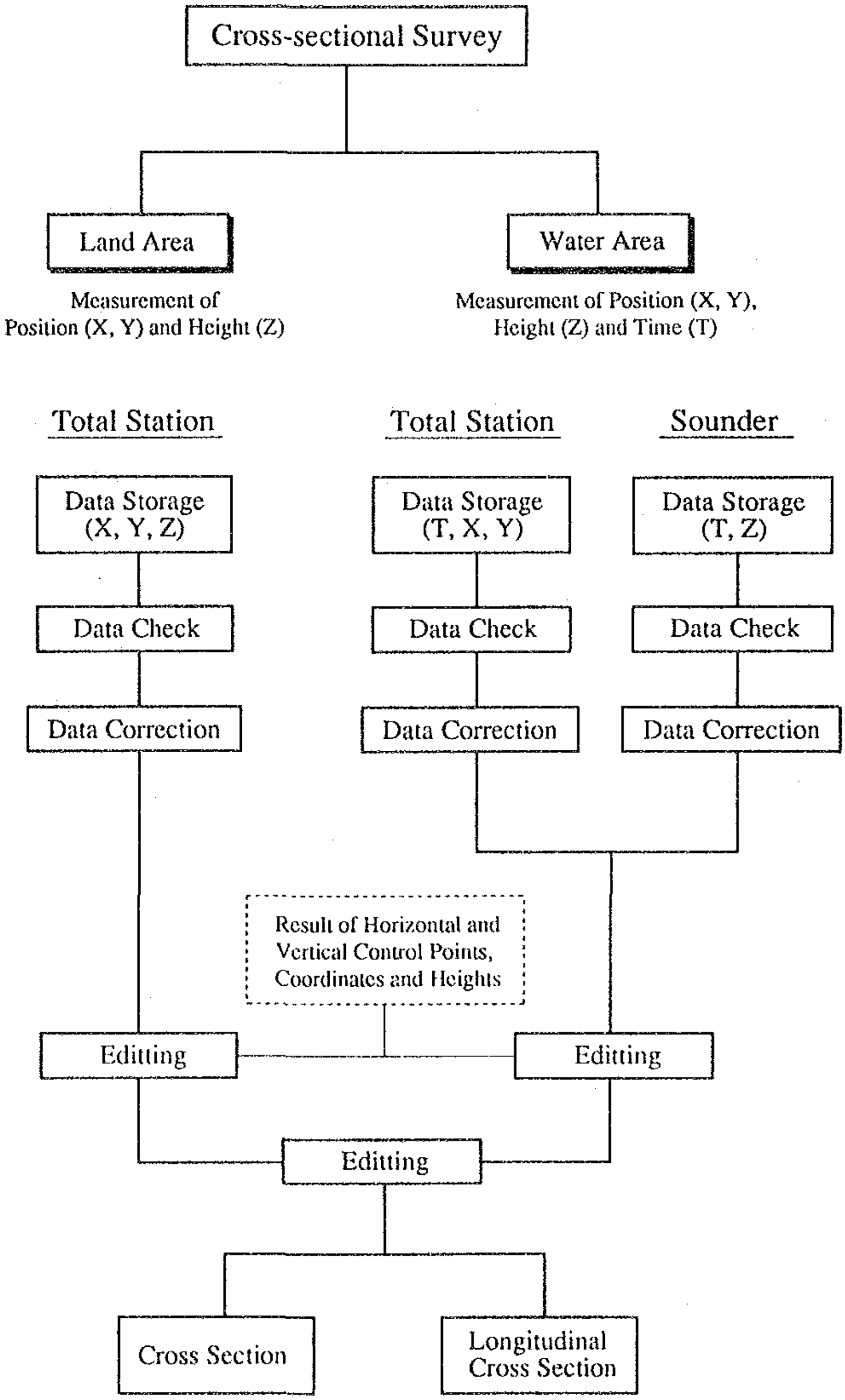

Fig. 4.1.1 System Flow Chart for Data Processing

THE REPUBLIC OF VENEZUELA COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN
JAPAN INTERNATIONAL COOPERATION AGENCY

PART-B

GEOLOGICAL AND GEOMORPHOLOGICAL STUDIES

STUDY ON COMPREHENSIVE IMPROVEMENT OF THE APURE RIVER BASIN

FINAL REPORT

VOLUME III : SUPPORTING REPORT
PART-B : GEOLOGICAL AND GEOMORPHOLOGICAL STUDIES

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I. INTRODUCTION

This report presents the results of studies for geomorphology and geology in the Apure River Basin. Its purpose is to supply basic geomorphological and geological information for comprehensive improvement of the Apure river basin is called the "Basin" throughout the entire text. To realize the above-mentioned purpose, the following three investigation works were carried out through collection of existing data, field work and analysis of obtained data.

(1) Geomorphological Investigation

One purpose of the geomorphological investigation is to grasp the geomorphological outline and form of outflow in the Basin. Another purpose is to recognize the inundation areas in the dry season and rainy season by interpretation of satellite images.

(2) Geological Investigation

One purpose of the geological investigation is to determine the geological condition and form of erosion and sedimentation of rivers in the Basin. Furthermore, the geological stratigraphy of river banks will be investigated by borehole drillings.

(3) Material Investigation

River bed and river bank materials were collected along the Apure river and its tributaries. Laboratory soil tests were carried out on these materials.

Sampling method and quantities are as follows:

- Sampling of river bed materials by hand : 39 sites
- Sampling of river bank materials by borehole drilling : 13 sites
- Sampling of river bank materials by test pits: 13 sites
  in-situ physical test was carried out for all materials while compaction tests were only carried out for test pit samples to obtain the design value of embankment material.

II. PRESENT CONDITION OF STUDY AREA

2.1 Geomorphology

The geomorphological divisions of the Venezuelan Llanos are shown in Fig. 2.1.1. According to Leonel Vivas (1984), the Venezuelan Llanos is divided into the Oriental Llanos, the Central Llanos, and the Western Llanos. The Basin is located in the Western Llanos and covers most of its area. The Western Llanos is geomorphologicaly divided into the following three sub-divisions.

1) Piedmont : Hills including river terraces (a height from 100 to 200 m)
2) Upper Llanos : Alluvial fans and natural levees (a height from 100 to 200 m)
3) Lower Llanos : Flood plains and inland delta (a height from 40 to 100 m)

The inland delta slopes vary gradually and its elevation is under 50 m above sea level. In the delta the Apure river, Portuguesa river, Guanare river and many other rivers flow into each other. Consequently, a big swampland has formed. A part of the geomorphological map of the Basin by Michel Pouyllau (1985) is shown in Fig. 2.1.2. According to this map, a wide sand dune zone arranged from southwest to northeast is distributed on the south bank of the Apure river. A part of these sand dunes has spread to the north bank of the Apure river. These sand dunes were formed under dry climatic conditions during the last ice age. Presently the sand dunes are partly covered with alluvial formations.

2.2 Geology

A geological map of the Basin is shown in Fig. 2.2.1. On the west side of the Basin, the Andes Mountains (Merida Mountains) run in a direction from northeast to southwest. The Andes Mountains mainly consist of Paleozoic granitic rocks and meta-sedimentary rocks accompanied with Mesozoic meta-sedimentary rocks and sedimentary rocks in the Precambrian basement.

At the piedmont of the Andes Mountains, tertiary sedimentary rocks lie on older rocks. The Andes Mountains are highly cut by northeast-Southwest normal faults. Among them, the biggest one is the Bocono Fault running in the central part of the Mountains. This fault is a first class active one and divides the Andes Mountains into two parts. The direction of displacement is right lateral and many earthquakes have occurred along this fault.

On the north side of the Basin, the Coastal Mountains run in a east-west direction. The Coastal Mountains consist of Mesozoic sedimentary rocks, meta-sedimentary rocks, meta-volcanic pyroclastic rocks, and granitic rocks in the Paleozoic basement. At the piedmont of the Coastal Mountains, tertiary sedimentary rocks lie on older rocks.

In the Coastal Mountains, many active faults run in the same direction as the axis of the Mountains. The biggest one is the Caribe Fault running along the north edge of the Mountains. This fault is a right-arterial fault, the same as the Bocono fault in the Andes Mountains. This fault meets with the Bocono fault in the Barquisimeto basin.

The Mesozoic rocks and tertiary rocks make contact with many over-thrust faults in the piedmont. Along the Caribe Fault, many earthquakes have occurred. Since the Cretaceous, the Andes and the Coastal Mountains have been affected by up-lift crustal movement. On the other hand, the Basin has been affected by subsidence. Consequently, the Mesozoic and Tertiary formations are deposited thickly in the Basin. These formations are presently covered with Quaternary formations.

III. FIELD WORKS

3.1 River Bed Material Investigation

3.1.1 Purpose and Method

This investigation was carried out to obtain basic bed load data.

Sampling sites are as follows.

Apure river	9 sites
Portuguesa river	5 sites
Sarare river (Puente Remolino)	1 site
Cojedes river (EI Baul)	1 site
Guanare river (Arismendi)	1 site
Orinoco river (Pto. Ordaz)	2 sites
Tributaries at Crossing of Route 5	15 sites
Tributaries at Crossing of Route 13	5 sites
Total	39 sites

The location of sampling sites are shown in Fig. 3.1.1, Fig. 3.1.2, and Table 3.1.1.

Sampling positions are located in the point bars of present river channels. Sampling works were carried out using shovels. After removal of surface soils, abut 5 kg of fine soil about 5-10 kg of medium soil, and about 15 kg of coarse soil were collected. The collected soils were deposited in vinyl bags to avoid changes in natural moisture content and then taken to the laboratory by car.

3.1.2 Results of Investigation

The maximum diameter of gravels (refer to Fig. 3.1.3) collected in tributaries along the piedmont of the Andes Mountains and Coastal Mountains were compared. The investigation sites are located at the foot of the Coastal Mountains and Andes Mountains at an elevation of about 200 m. Generally, the maximum diameters of these materials ranged from 10 to 50 cm. Materials with smaller diameters were found at sites M-17 (Verde river), M-21 (Cojedes river) and M-35 (Uribante river). They consist of sands. The Tiznado dam lies in the upper reaches of the Verde river in Piedmont. Therefore, coarse materials deposit in the dam reservoir and are not transported to the lower reaches. The

Barquisimeto basin lies in the middle reaches of the Cojedes river. Coarse materials from the upper reaches deposit in the Barquisimeto basin. The mountain areas located downstream of the Barquisimeto basin are strongly eroded and wide valleys have formed. Consequently, most coarse materials are not transported to the lower reaches. The sampling sites of the Uribante river are far from the mountain areas and are located in a flood plain. Furthermore, a dam reservoir is located in the upper reaches of the Uribante river. For the above reasons, river bed materials at these sampling sites mainly consist of fine materials.

On the other hand, materials with larger diameter were found at sites M-18 (Pao river), M-30 (Canagua river), M-31 (Acequia river), and M-32 (Bumbum river). In the Pao river, a boulder with a diameter of 200 cm was found, the largest among the investigation sites. This exceptional boulder seems to be a remain of old big floods. After construction of the Balsa dam in the upper reaches of the Pao river, coarse materials deposit in the dam reservoir and presently only fine materials are transported to the sampling site.

The Canagua, Acequia, and Bumbum rivers flow rapidly down from the Andes Mountains and transport mainly coarse materials. Similarly, the Santo Domingo, Paguey, and Socopo rivers transport coarse materials, but the diameters of these materials are smaller.

The Tucupido, Bocono and Masparo rivers are also rapidly flowing. But in the upper reaches of these rivers, dam reservoirs are present. Consequently, the diameter of these river materials are smaller than the materials of the above rivers.

Laboratory test results of collected soils are described later.

3.2 Borehole Drilling Investigation

3.2.1 Purpose and Method

Borehole drilling investigations were carried out for the purpose of obtaining design values for construction of dikes. The investigation sites are as follows.

Apure river	9 sites
Portuguesa river (El Socorro, Camaguan)	2 sites
Sarare river (Puente Remolino)	1 site
Cojedes river (El Baul)	1 site
Total	13 sites

The investigation sites are shown in Fig. 3.1.1 and Table 3.1.1. The borehole drilling sites were located on river banks from 2 to 10 m above river beds. Each borehole was 20 m deep.

Hydraulic drilling machines with a 66 mm diameter bit were used. Standard penetration tests (SPT) were carried out at 1 m intervals. SPT samples were put in vinyl bags and later carried to a laboratory for tests.

3.2.2 Results of Investigation

The results of the investigations are shown in the attached drilling logs, site sketches, and situation maps by soil types. N-values of drilling holes are as follows:

(1) Borehole No. P-1, Puente Remolino (Sarare river).

This site is located on the left river bank which is about 2 m above the river bed near Guasdualito city. The drilling results are as follows:

- Depth 0.0 - 7.5 m (N = 4 ~23) — silty clay, solid clay, sandy clay (first clay)
- Depth 7.5-15.5 m (N = 12~28) — fine sand, silty fine sand (first sand)
- Depth 15.5-16.5 m (N = 14) — sandy clay (second clay)
- Depth 16.5-20.0 m (N = 14~56) — fine sand, silty fine sand (second sand)

At more than 18.5 m in depth, this site consists of hard sand with an N-value from 48 to 50.

(2) Borehole No. P-2, Totumito (Apure River)

This site is located on the right river bank about 3 m above the river bed near Totumito town. The right bank has been eroded by the stream. Rows of concrete piles, which are 30 cm in diameter and 30 m in length at 2 m intervals, were installed to protect the bank. The drilling results are as follows:

- Depth 0.0 - 2.5 m (N = 17~27) solid clay (first clay)
- Depth 2.5 - 6.5 m (N = 22-34) silty fine sand (first sand)
- Depth 6.5-20.0 m (N = 50 <) solid clay (second clay)

At more than 6.5 m in depth, this site consists of solid clay with an N-value of more than 50.

(3) Borehole No. P-3, Palmarito (Apure River)

This site is located on the right river bank about 3 m above the river bed near Palmarito town. The drilling results are as follows:

- Depth 0.0 - 1.5 m (N = 6~40) solid clay (first clay)
- Depth 1.5 - 7.5 m (N = 12~46) medium sand ~ coarse sand (first sand)
- Depth 7.5 - 9.5 m (N = 49~51) solid clay (second clay)
- Depth 9.5-11.5 m (N = 35~48) silty fine sand (second sand)
- Depth 11.5 - 17.5 m (N = 22~69) solid clay (third clay)
- Depth 17.5 - 20.0 m (N = 23~26) clayey fine sand (third sand)

The mean N-value between 7.5 m and 15.5 m in depth is 52 which seems to be high enough for the bearing layer of the proposed dike. But the mean N-value at depth below 15.5 m is 23 which is not sufficient for the bearing layer. At this site, it is necessary to decide the depth of the bearing layer corresponding to the scale of embankment.

(4) Borehole No. P-4, Suripa (Apure River)

This site is located on the right river bank about 4 m above the river bed nearly opposite Suripa town. Here, the Suripa river meets the Apure river from the left bank. The drilling results are as follows:

- Depth 0.0 - 0.3 m (N = 6) clayey silt (first clay)
- Depth 0.3 - 20.0 m (n = 6 ~ 26) silty fine sand, fine sand (first sand)

This site consists of soft clay and sand. Especially, the section between 0.3 m and 15.0 m in depth is very soft. The mean N-value of this section is only 12. At this site, it is necessary to apply some geotechnical measures for construction of the proposed dike.

(5) Borehole No. P-5, San Vicente (Apure River)

This site is located on the right river bank about 6 m above the river bed at San Vicente town. The right bank has been eroded and concrete piles have been installed to protect the bank. The drilling results are as follows:

- Depth 0.0 - 0.3 m (N = 8) solid clay (first clay)
- Depth 0.3 - 3.5 m (N = 11~42) medium - fine sand (first sand)
- Depth 3.5 - 9.5 m (N = 10~53) solid clay (second clay)
- Depth 9.5 - 20.0 m (N = 17~45) silty fine sand (second sand)

At more than 5.0 m in depth, this site consists of hard solid clay and sand. The mean N-value is 36 which seems sufficient for the bearing layer of the proposed dike.

(6) Borehole No. P-6, Bruzual (Apure River)

This site is located on the right river bank from 7 m to 8 m above the river bed under the Nutrias Bridge of Bruzual town. The drilling results are as follows:

- Depth 0.0 - 0.3 m (N = 14 ~ 16) organic clay (first clay)
- Depth 2.5 - 9.5 m (N = 22 ~ 51) solid clay (second clay)
- Depth 9.5 - 20.0 m (N = 20 ~ 26) silty fine sand (first sand)

At more than 9.5 m in depth, this site consists of hard sand with a mean N-value of 32. It seems that this site has enough strength for the bearing layer apart from the surface organic clay.

(7) Borehole No. P-7, El Saman (Apure River)

This site is located on the right river bank about 8 m above the river bed at El Saman town. The drilling results are as follows:

- Depth 0.0 - 0.2 m (N = 2) silty fine sand (first sand)
- Depth 0.2 - 5.0 m (N = 22~46) silty clay (first clay)
- Depth 5.0 - 5.5 m (N = 9) clayey fine sand (second sand)
- Depth 5.5 - 11.5 m (N = 12~60) solid clay (second clay)
- Depth 11.5 - 20.0 m (N = 32~48) silty fine sand (third sand)

At more than 7 m in depth, this site consists of hard clay and sand with a mean N-value of 40. This site has enough strength for the bearing layer.

(8) Borehole No. P-8, Apurito (Apure River)

This site is located on the right river bank about 8 m above the river bed near Apurito town. The drilling results are as follows:

- Depth 0.0 - 1.5 m (N = 5~8)	clayey silt (first clay)
- Depth 1.5 - 20.0 m (N = 5~30)	silty fine sand, fine sand, medium sand (first sand)

At more than 11 m in depth, this site consists of soft sand with a mean N-value of 23. At this site is necessary to apply some geotechnical measures for construction of the proposed dike.

(9) Borehole No. P-9, San Fernando (Apure River)

This site is located under an artificial dike on the right bank of the Apure river. San Fernando city is located on the right bank which is about 7 m above the river bed.

Along the right bank, an artificial dike with 10 m in width and 3 m in height is constructed. The bore hole drilling site is situated on the slope between the top of the dike and river bed about 5 m above the river bed. The drilling results are as follows:

- Depth 0.0 - 2.0 m (N = 1~10)	silty clay (first clay)
- Depth 2.5 - 4.5 m (N = 3~4)	silty fine sand (first sand)
- Depth 4.5 - 5.5 m (N = 6)	silty clay (second clay)
- Depth 5.5 - 13.5 m (N = 10~27)	silty fine sand, fine sand, medium sand (second sand)
- Depth 13.5 - 15.5 m (N = 5~7)	silty clay (third clay)
- Depth 15.5 - 20.0 m (N = 14~20)	silty sand (third sand)

This site consists of very soft sand and clay. The mean N-value of the sandy soil is 16 and the mean N-value of the clayey soil is only 4. This site has not enough strength for the bearing layer of the proposed dike. Furthermore, it seems that the present dike has a problem concerning its stability in such soft ground.

(10) Borehole No. P-10, Arichuna (Apure River)

This site is located on the right bank of the Apure river. Arichuna town is located on the right bank which is about 6 m above the river bed. The drilling site is located on the top of dike. The drilling results are as follows:

- Depth 0.0 - 3.0 m (N = 5~13) clay (embankment soil) (first clay)
- Depth 2.0 - 8.5 m (N = 20 - 47) silty clay (second clay)
- Depth 8.5 - 9.5 m (N = 25) fine sand (first sand), medium sand (second sand)
- Depth 9.5 - 12.5 m (N = 33~40) silty clay (third clay)
- Depth 12.5 - 20.0 m (N = 18~57) silty fine sand (third sand)

This site consists of solid silty clay and hard sand with an N-value between 20 and 40. It seems that this site has enough strength for the bearing layer, apart from the top embankment soil.

(11) Borehole No. P-11, El Baul (Cojedes River)

This site is located on the right river bank about 8 m above the river bed near El Bawl town. The drilling results are as follows:

- Depth 0.0 - 5.5 m (N = 16~43) silty clay, solid clay (first clay)
- Depth 5.5 - 8.0 m (N = 41 ~ 47) medium-fine sand (first sand)
- Depth 8.0 - 9.5 m (N = 63 ~ 75) calcareous sandy clay (second clay)
- Depth 9.5 - 10.5 m (N = 34) fine sand (second sand)
- Depth 10.5 - 13.5 m (N = 29~39) sandy clay(third clay)
- Depth 13.5 - 20.0 m (N = 22~33) silty fine sand (third sand)

This site consists of alternate hard sand and solid clay with an N-value of more than 30. Especially, the calcareous sandy clay is very hard with an N-value between 63 and 75. It seems that this site has enough strength for the bearing layer, apart from the top soft organic soil.

(12) Borehole No. P-12, El Socorro (Portuguesa River)

This site is located on the right river bank about 10 m above the river bed at El Socorro town. At this place, steep terraced cliffs were constructed along both banks of the river channel. The drilling results are as follows:

- Depth 0.0 - 8.5 m (N = 8~55) calcareous solid clay (first clay)
- Depth 8.5 - 14.5 m (N = 36 ~ 61) medium-fine sand (first sand)
- Depth 14.5 - 18.5 m (N = 27 ~ 50) silty clay (second clay)
- Depth 18.5 - 20.0 m (N = 34 ~ 36) silty sand (second sand)

At more than 3 m in depth, this site consists of alternated hard sand and solid clay with a mean N-value of 40. It seems that this site has enough strength for the bearing layer, apart from the top organic clay.

(13) Borehole No. P-13, Camaguan (Portuguesa River)

This site is located on an elbow of the left river bank. Camaguan town is also located on the left river bank which is about 6 m above the river bed. Steep cliffs have formed on the right bank. On the other hand, gentle slopes have formed on the left bank. The drilling results are as follows:

- Depth 0.0 - 7.5 m (N = 1~10)	organic clay (first clay)
- Depth 7.5 - 9.5 m (N = 25 ~ 38)	calcareous clay (second clay)
- Depth 9.5 - 20.0 m (N = 22 ~ 77)	silty fine sand (first sand)

The top organic soil is very soft with an N-value under 10. There is a possibility that consolidation settlement will occur from loading of the layer. At more than 7.5 m in depth, the mean N-value is 26 and there is no strength problems.

3.2.3 Classification of Geological Formation by N-value

Geological formations were classified based on N-value by SPT. The classification standard was founded on outcrop observations, drilling samples and existing data concerning geological age. At the drilling sites, Alluvium and Diluvium are widely distributed. Generally, the matrix of the Diluvium formation is harder than the Alluvium formation. From outcrop observation, fan gravel has this tendency. However, among Alluvium formations, natural levee deposits and terrace deposits sometimes show very hard consolidation.

Because these deposits are located over the water table. They are often affected by calcareous cementation and dry-shrinking. Taking into account the above facts, classification of geological formations was made by observation and judgment of drilling core samples. The classification standard is as follows:

- Alluvium sandy soil	N = 0 - 30
- Alluvium clayey soil	N = 0 - 10
- Diluvium sandy soil	N = 30 <
- Diluvium clayey soil	N = 10 <

However if hard cemented or shrinking soils were located between soft soils, they were classified as Alluvium soil. On the other hand, weathered Diluvium formations often show very low N-value. These formations were classified as Diluvium formation in spite of the low N-value taking into account continuity of the formations.

Distribution of Alluvium and Diluvium in the investigation were already examined by MARNR. The results of its work were compiled in "Geomorphological Map of the Western Llanos" (1 : 500,000).

The geological classification was based on the data collected from a large area. The result of classification is shown in Table 3.2.1. As shown in this table, the mean N-values of Alluvium are between 6 and 18, and the mean N-values of Diluvium are between 34 and 41. This boundary between Alluvium and Diluvium is for convenience because exact determination of geological age depends on dating by use of radioactive elements.

3.3 Soil Investigation by Test Pitting

3.3.1 Purpose and Method

Disturbed samples were gathered by test pitting at 13 sites in the Basin. Compaction tests were carried out on these samples for propriety as embankment material. Sampling sites are shown in Fig. 3.1.1 and Table 3.1.1.

Sampling points are located within about 5 m from neighboring borehole sites on river banks between 2 m and 10 m above the river bed. The depth of sampling was about 1 m. Surface organic soils within 30 cm in depth were removed before sampling. Samples weighting about 100 kg were taken at each site. All samples were put in vinyl bags to protect the natural moisture content and later transported to a laboratory by car.

3.3.2 Results of Test Pitting

The types of soils collected by test pitting are shown below. The results of compaction tests are described later.

The types of soils are basically the same as topsoils found by borehole drilling. However, some test pit samples are different from drilling samples because of changing soil distribution. Sampling sites and soil types are shown below, and for reference N-values by SPT are shown with them.

TP No.	Sites	Soils	N-Values
1	Puente Remolino	silty clay	12 - 14
2	Totumito	silty clay	17 - 21
3	Palmarito	sandy clay	6 - 40
4	Suripa	fine sand	6 - 8
5	San Vicente	sandy clay	10 - 11
6	Bruzual	sandy clay	14 - 16
7	El Samoan	silty clay	22
8	Apurito	silty sand	5 - 8
9	San Fernando	silty clay	1 - 3
10	Arichuna	silty clay	10
11	El Baul	silty clay	16 - 19
12	El Socorro	sandy clay	11 - 12
13	Camaguan	sandy silt	6 - 31

3.4 Geomorphological and Geological Field Investigation

3.4.1 Purpose and Method

The purpose of this field investigation is to supply basic data for river channel planning and to obtain geomorphological information for interpretation of satellite images. It is not easy to carry out a detailed investigation during a limited short term on a wide area such as the Apure Basin. In this investigation, observation of geological formations composing bank cliff and micro land forms were carried out on the material investigation sites and other typical sites.

Macro geological and geomorphological studies were carried out by using small airplanes to observe vegetation and stagnant water. These results were utilized for analysis of topographic maps and interpretation of satellite images.

3.4.2 Results of Investigation

Geomorphological and geological conditions of the material investigation sites are shown in Table 3.4.1 with results of interview surveys for flood information. Piedmont of the Andes Mountains passing through Route 5 and the Coastal Mountains passing through Route 13 consist of fan shaped flood plains or terraced fans. These Alluvium deposits mainly consist of round gravel between 10 cm and 20 cm in diameter. Their matrixes are reddish brown unconsolidated sand.

Diluvium fan deposits are covered with Alluvium deposits. Faces of the Diluvium deposits are similar to the Alluvium deposits, but their matrixes are more consolidated than the Alluvium deposits. In some places, the Diluvium deposits are distributed on the surface and not covered with the Alluvium deposits as in the lower terraces. These areas are temporarily covered with water in flood which drains off rapidly to lowland areas.

At the piedmont between M-17 (Verde River) and M-34 (Caparo River), flood marks such as plant deposits are noticed on many bridge floors crossing rivers. In the past, some of these bridges were washed away by floods. In result, new bridges were constructed or are presently under construction. In the middle reach between M-11 (Paso La Portuguesa) and M-15 (Camaguan), Diluvial river terrace which is between 6 m and 10 m in height is distributed along the river channels. This terrace surface gradually slopes toward the Apure river. Finally, this surface is buried by Alluvial deposits of the natural levee near Camaguan.

According to verbal information, this terrace surface is rarely inundated with water. M-16 (Arismendi), located in the middle reaches of the Guanare river, is situated on a natural levee which is about 4 m above the river bed. At times this site has been damaged by floods. As a result of removing the main channel of the Guanare river to the south, the present danger of flood has remarkably decreased. In the main channel of the Apure river between Puente Remolino and San Vicente, a flood plain has formed which is between 2 m and 6 m above the river bed.

A natural levee which is between 6 m and 8 m in height is distributed between San Vicente and Arichuna. This natural levee is cut by other tributaries and old channels at various places. Generally, it is said that the area behind the natural levee is relatively safe from flood. However, the natural levee is sometimes covered with water during big floods. On the right bank of the Apure river between Palmarito and Bruzual and between Apurito and Arichuna, dike exists. However, the areas between Puente Remolino and El Saman are sometimes covered with water during big floods according to verbal information. Between Bruzual and Apurito, no dike has been constructed, however, height of the natural levee on the right bank is about 8 m. In spite of this, El Saman located in this area is still damaged by flood.

On the other hand, on the right bank of the Apure river between Apurito and Arichuna, dike exists on the natural levee. As a result, the danger of flood in this area is very low.

The most dangerous and poorly drained areas are the lowlands located in the northern parts of the natural levee zone and the old channels lacking natural levees on the left bank of the Apure river. These conditions were observed by airplane investigation.

IV. LABORATORY TEST

4.1 Method and Purpose

The laboratory tests were carried out on river bed materials, bank materials by borehole drilling and embankment material by test pitting. Physical tests (specific gravity, moisture content, grain size analysis, liquid limit, plastic limit) were carried out on river bed materials and bank materials. Compaction tests as well as physical tests were carried out on embankment materials. All the laboratory tests were based on ASTM (American Society for Testing and Material, 1992) Standards.

The aim of physical tests is to grasp the basic physical properties of the materials in the major rivers in the Basin for river channel planning, while the compaction tests were carried out to obtain basic data for construction of dikes. The number of tests is shown in Table 4.2.1.

4.2 Results of Laboratory Tests

4.2.1 River Bed Material

(1) Grain Size Analysis

The grain size distribution curves of river bed materials for the Apure river, Portuguesa river and tributaries of piedmont are shown in Figs. 4.2.1 to 4.2.3.

The changes in mean diameter are shown in Figs. 4.2.4 to 4.2.6. At first, the grain size distribution of the Apure river is mentioned. According to the grain size distribution curves shown in Fig. 4.3.1, these deposits consist of silts and fine sands, not gravel. The richest material in silt and clay was found in samples from M-10 (Arichuna) in the lower reaches.

The mean diameters of materials in the Apure river (refer Fig. 4.2.4) are very irregular and do not reduce orderly from the upper reaches to the lower reaches. Between Puente Remolino and San Fernando, the diameter changes irregularly and at M-10 (Arichuna) it shows minimum value.

This is due to tributaries having different diameters meeting the Apure river at this section. Between San Fernando and the confluence of the Orinoco river, the Apure river has no major tributaries. In this section, an inland delta is formed because of the gentle slope of the river bed. Thus, at M-1 (Arichuna) the minimum mean diameter of materials in the Apure river was recorded. On the other hand, at M-36 (Puerto Ordaz) located in the lower reaches, the maximum mean diameter was recorded.

For this reason, many tributaries joining the Orinoco river from the Oriental Llanos bring many coarse materials

The grain size distribution curves and mean diameters of materials in the Portuguesa river are shown in Figs. 4.2.2 and 4.2.5. The river bed materials of the Portuguesa river consist of sand, silt and clay. The content of silt and clay is greater than that of the Apure river. At M-12 (El Baul), a small quantity of coarse sands and gravels were found in the materials. These were, however, from the Cojedes river and not from the Portuguesa river. The materials at M-15 (Camaguan) were the richest in content of silt and clay. The maximum diameter was found at M-13 (Guadarrama) due to the influence of the Pao river.

At N-15 (Camaguan) located in the inland delta, the minimum diameter was recorded. However, at M-9 (San Fernando) after meeting with the Apure river, the mean diameter become larger immediately. This fact shows that the diameter of materials in the Apure river is larger than that in the Portuguese river.

Grain size distribution curves and mean diameters of materials in tributaries in piedmont are shown in Figs. 4.2.3 and 4.2.5. According to these figures, each river in piedmont has various grain size distribution. They mainly consist of coarse materials such as gravel and coarse sand. The sites where the recorded mean diameters were 10 mm or over are M-22 (Acarigua river), M-27 (Masparo river), M-31 (Aceguia river), M-32 (Bumbum river) and M-34 (Socopo river).

The mean diameters of materials of other sites were between 0.1 mm and 10 mm. The mean diameter of materials at M-17 (Verde river) was the minimum value among the piedmont rivers. The reason for this is that the Verde river (Tiznado river) has a dam in the upper reaches which collects coarse materials. As a result, only fine materials flow down to the lower reaches. At M-35 (Uribante river) a small mean diameter was also recorded.

M-35 is located in the flood plain, but not in the piedmont. Thus, only fine materials are deposited there. As mentioned above, the rivers in the piedmont transport coarse materials apart from the Verde river and Uribante river.

(2) Specific Gravity and Moisture Content

Mean values of specific gravity and moisture content in the Piedmont, Apure river, and Portuguesa river are given below:

River	Mean Specific Gravity	Mean Moisture Content (%)
Rivers in Piedmont	2.65	11.9
Apure river	2.66	14.8
Portuguesa river	2.68	19.4

Among these rivers, no remarkable differences was recognized. The mean specific gravities are close to general values for sand and silt (between 2.5 and 2.7). The mean moisture contents are lower than general values for sandy and silty soils (between 20 % and 60%).

(3) Liquid Limit and Plastic Limit

The mean liquid limit and mean plastic limit of fine material are given below:

River	Mean Liquid Limit (%)	Mean Plastic Limit (%)
Rivers in Piedmont	36.0	17.0
Apure river	27.4	19.5
Portuguesa river	45.0	23.0

No remarkable difference was recognized among these rivers. The liquid limit and plastic limit of fine materials are generally about 30 % and about 70 %, respectively. The values of the samples are in lower ranges. This is because the fine materials contain a lot of sandy soil.

4.2.2 River Bank Materials

Laboratory tests of bank materials were carried out on SPT samples obtained by drilling. Generally, grain size distribution of river deposits vary according to the distance downstream and stream velocity at the site. Therefore, grain size distribution on river banks in vertical profile changes diversely by flood velocity. Thus, grain size distribution in vertical profile and the physical properties of soils is geologically very useful to estimate the sedimentary environment in the past and the strength of the soil in terms of bearing capacity. Generally, the changes of soil faces in vertical profile are shown on drilling logs.

Judgment of soil faces is done by a geologist by observation of the drilling cores. However, it is very difficult to distinguish delicate changes of grain size by eye. In this investigation, analysis of grain size distribution of the SPT samples were carried out at intervals of 1 m. The results of laboratory tests for basic materials are as follows:

(1) Grain Size Analysis

Grain size analysis was carried out on all SPT samples from 1 m to 20 m in depth. The results of the tests are shown in the drilling logs. Grain size distributions from 1 m to 4 m in depth are shown below. They were compared with that of present river bed materials. The grain size distribution curves are shown in Fig. 4.2.7 and the mean diameters are shown Fig. 4.2.8.

According to these figures, topsoils of the river bank materials consist of fine materials such as clay and silty clay.

The topsoils found at P-4 (Suripa) and P-5 (San Vicente) consist of only sands. At all drilling sites, topsoils of the river bank material were smaller in grain size than that of the river bed materials. Because in the river channel, coarse materials are deposited by high stream velocity. On the other hand, on the river bank, flood water flows with low velocity and thus fine materials are deposited. As previously mentioned, the mean diameters change irregularly from the upper reaches to the lower reaches, and the bank materials show same tendency as the river bed materials

(2) Specific Gravity and Moisture Content.

Specific gravities and moisture contents by soil type are shown below:

Age	Soil Type	Mean Specific Gravity	Mean Moisture Content (%)
Holocene	first clay	2.70	21
	second clay	2.70	26
	third clay	2.74	36
	first sand	2.65	18
Pleistocene	first clay	2.71	17
	second clay	2.73	31
	first sand	2.74	18
	second sand	2.67	18

Generally, specific gravity of sandy soil is about 2.5 and clayey soil is about 2.7. The mean specific gravity of these sandy soils are between 2.65 and 2.74 and the clayey soils are between 2.70 and 2.74. The specific gravities of these sandy soils are higher because of mixture of sandy soils and clayey soil in the samples. On the other hand, the specific gravities of the clayey soils are close to the general value.

General value of moisture content for sandy soils is between 20 % and 40 %, and for clayey soil it is between 40 % and 80 %. The mean moisture content of the sampled sandy soils is 18% which is close to the general value. On the other hand, the moisture contents of the sampled clayey soils are between 17 % and 36 % which are much lower than the general value. However, this general value was taken from the Temperate Zones with a humid climate. These obtained values of clayey soils seem to correspond to the general value in the Tropical Zones during the dry season.

(3) Liquid Limit and Plastic Limit

Mean liquid limit and mean plastic limit by soil type are given below:

Age	Soil Type	Mean Liquid Limit (%)	Mean Plastic Limit (%)
Holocene	first clay	22	99
	second clay	17	33
	third clay	22	40
	first sand	NP	NP
Pleistocene	first clay	17	42
	second clay	19	37
	first sand	NP	NP
	second sand	NP	NP

General value of liquid limit for clayey soil is about 30 % and that of plastic limit for clayey soil is about 70 %. The mean liquid limit of these clayey samples is between 17 % and 22 %, and the mean plastic limit is between 33 % and 99 %. These values are relatively low apart from the first clay of the Holocene, because these samples contain a little sand in the clayey matrix. Besides, sandy soils are all non-plastic soils.

4.2.3 Embankment Material

Embankment materials were gathered by test pitting on 13 sites located near the drilling sites. Fine sand was found at TP-4 and silty fine sand was found at TP-8, while fine materials such as silty clay and sandy clay were found at all other test pits.

Results of physical tests only are shown below and results of compaction tests are mentioned later.

(1) Grain Size Analysis

The results of grain size analysis are shown in Fig. 4.2.9. Generally, the best embankment material is a sandy soil showing good grain size distribution and no consolidation settlement. The TP-4 sample is composed of a fine sand lacking fine materials. This sample shows bad grain size distribution and it seems that water permeability is high. As a result, this sample is not considered to be a good embankment material. On the other hand, the material from TP-8 is a silty fine sand and good grain size distribution. Thus, it is considered to be a good embankment material.

Materials from TP-12 and TP-13 are sandy silt. These samples are moderately mixed with sandy soil and clayey soil and they show very good grain size distribution. These samples are considered as the best embankment materials among all the samples.

The other samples mainly consist of silty clay and the content of clayey soil is very high. There is a possibility of consolidation settlement, but grain size distributions are good. From an economical view point, these soils can be used as embankment material, however, improvement works such as rolling compaction and consolidated-drainage should be carried out.

(2) Specific Gravity and Moisture Content

Maximum, minimum and mean values of all samples are given below:

Item	Maximum Value	Minimum Value	Mean Value
Specific Gravity	2.80	2.57	2.71
Moisture Content (%)	28.0	6.6	14.6

The specific gravity values are close to the general value for clayey soil which is about 2.7. The moisture content values are lower than the general values for clayey soils which are between 40 % and 80 %. Especially, it seems that the minimum value of moisture content is too low. It is uncertain whether this value is original or not.

If clayey soil is used as embankment material, a low moisture content is good to avoid consolidation settlement. If this moisture content value is to be used for design, it is necessary to reexamine this soil.

(3) Liquid Limit and Plastic Limit

Maximum, minimum and mean values of all samples are given below:

Item	Maximum Value	Minimum Value	Mean Value
Liquid Limit (%)	39	22	31
Plastic Limit (%)	17	7	11
Plastic Index	22	15	20

Liquid limit and plastic limit are lower than the general values of about 30 % and about 70 %. Plasticity charts of the samples are shown in Fig. 4.2.10. According to the figure, all plasticity indexes are above the A-line. This means that the compressibility is medium and these soils have enough strength in dry conditions.

V. GEOMORPHOLOGICAL AND GEOLOGICAL ANALYSIS

5.1 Geomorphological Analysis

5.1.1 Purpose and Method

To purpose of geomorphological analysis (analysis of micro land form) is to supply basic data for flood analysis. The investigation methods are as follows:

- Field investigation (including material investigation)
- Investigation by airplane (grasping macro land form)
- Analysis of topographic maps
- Analysis of satellite image
- Collection and analysis of existing data

The total geomorphological analysis was carried out by using the above investigation results. Topographic maps, aerial-photographs, satellite images and existing data used for the analysis are as follows:

- Topographic Map (1:250,000)	The entire Apure Basin.
- Topographic Map (1:100,000)	Between the Apure river and Route 13 to the north. Between the Apure river and Route 5 to the west.
- Geomorphological Map (1:25,000)	Middle reaches of the Bocono river, Guanare river, Masparro river and Portuguesa river.
- Geomorphological Map (1:250,000)	Western Llanos.
- Flooded surface Map (1:250,000) (Mapa de excesos de Agua Superficiales)	Western Llanos.
- Aerial Photograph (1:25,000)	Main channel of the Apure river and Guanare river.
- Satellite image of false color (1:250,000)	The entire Apure Basin.
- Satellite image of mono color	The entire Apure Basin.

The satellite images used for interpretation are shown in Table 5.1.1.

5.1.2 Analysis of Topographic Maps

A contour line map of the Basin is shown in Fig. 5.1.1 and a more detailed contour line map of the study area is shown in Fig. 5.1.2.

The contour line map of the Basin (refer Fig. 5.1.1) was drawn on a scale of 1:100,000 with an interval between contours of 20 m. This map mainly shows the area in the lower reaches of the piedmont which is at an elevation of 200 m or below. On the original topographic maps, contour lines at an interval of 10 m were added for the lowlands. However, these additional lines were insufficient and discontinuous. Subsequently, they were completed by using latitudinal points with extrapolation. This contour line map was prepared so as to be in harmony with the original land form estimated from the existing geomorphological map.

The contour line map of the study area (Fig. 5.1.2) has a contour interval of 5 m. This map was made using the same method as mentioned above. Originally, this map had a contour interval of 1 m, however, it was simplified to 5 m. A contour line map with intervals of 1 m was made to serve as basic data for flood analysis. The same contour interval was used for the topographic map on a scale of 1:25,000 and the topographic map on a scale of 1:100,000. Thus, the contour line maps were drawn on a scale of 1:100,000.

The Basin is divided into four subdivisions by elevation and geomorphological features. The four geomorphological features are as follows:

- Mountains : The Coastal Mountains and the Andes Mountains (a height from 500 m)
- Piedmonts : Hills including river terraces (a height from 200 m to 500 m)
- Upper Llanos : Alluvial fan and natural levees (a height from 100 m to 200 m)
- Lower Llanos : Flood plains and inland delta (a height from 40 m to 100 m)

As shown in Fig. 5.1.1, the contour line of 200 m runs in a northeast-southwest direction along the Andes Mountains and in east-west direction along the Coastal Mountains. Geomorphologically, the Piedmonts between 200 m and 500 m above sea level consist of the Tertiary hills and Quaternary river terraces. National highways, Route 5 and Route 13, run along the contour line of 200 m.

The upper Llanos which are between 100 m and 200 m above sea level consist of complex Alluvial fans and natural levees. The contour lines run parallel in the direction of the Andes Mountain and the Coastal Mountains. Many rivers which originate in these mountains cross at right angles to the parallels contour lines. However, the Uribante river and Sarare river in the most upper reaches of the Apure river do not form a clear land form of Alluvial fan at the Piedmont and upper Llanos. Very wide flood plains are distributed in this area.

On the other hand, the Apure river between Guasdualito and Bruzual flows about 200 km in southwest-northeast direction parallel with the Andes Mountains. If the Andes Mountains and Coastal Mountains form a continuous high axis, the axis along the main channel of the Apure river may be submerged. The Apure river flows through the lowest area in the Basin. If the Uribante and Sarare river basins are an extension of this submerged axis, it is considered that a big Alluvial fan will not be formed at this area.

The lower Llanos between 40 m and 100 m above sea level consist of flood plain and inland delta. In this area, a zone between 60 m and 100 m above sea level is a fan shaped flood plain. The distance between contours in this zone is wide because of gentle slopes.

Near Bruzual, the Apure river changes its direction to the east and flows down about 230 km toward San Fernando city located in the inland delta. On the north side of Bruzual, old alluvial fans from 70 m to 80 m above sea level are distributed like islands left by erosion. In the zone between the Coastal Mountains and the Portuguesa river, the El Baul Mountains from 200 m to 400 m above sea level rise like a big island in the sea.

According to Fig. 5.1.2, an enclosed contour line of 70 m above sea level is recognized on the north side of the El Baul Mountains. This contour line shows existence of an enclosed depression formed by damming of streams from the Coastal Mountains owing to existence of the El Baul Mountains. The area under 60 m above sea level is divided into the inland delta. In this area, the distance between contour lines is the widest and their arrangements are irregular.

On the west side between Guadarram and La Union along the Portuguesa river, enclosed contour lines were recognized and some enclosed depressions are in existence. In this area between the enclosed depression zone and San Fernando city, the main rivers in the Basin settle. Thus, it seems that this area is a center of submergence in the Basin.

5.1.3 River Profile

River profiles in the Basin are shown in Fig. 5.1.3. These profiles were made from topographic maps on a scale of 1:100,000. The river profiles were formed by erosion and sedimentation of streams. If there is no erosion and no sedimentation in a river channel, its river profile generally draws a smooth exponential curve near the bottom. However, this type of river is practically not in existence.

Generally, many rivers have some discontinuous points in their profiles along the channel. These discontinuous points are called "nick points". The location of a nick point moves toward the upper reaches with the progress of erosion. An active river in terms of erosion and sedimentation has many nick points.

The following reasons are considered as the cause of nick points:

- Existence of contact zones between hard rock and soft rock.
- Existence of faults
- Confluence with other rivers which supply many coarse materials
- Supply of debris material by land slide or rock fall.

According to the river profile of the Basin, many nick points are recognized in the upper reaches of mountain areas. These nick points may have originated in the presence of faults or geological boundaries. Besides those nick points, other nick points are present at the boundary between the mountains consisting of hard old rocks and the hills consisting of soft younger rocks near 600 m above sea level. These nick points are arranged in a straight line.

In the middle reaches, the nick points are located between 100 m and 120 m above sea level. These nick points exist at Totumito in the Apure river, 60 km downstream of Route 5 in the Portuguesa river, and 5 km down stream of Guanare city in the Guanare river. The nick point of Totumito may have been formed by faulting. The knick points of the Portuguesa river and Guanare river were formed by a geological boundary between old fan and new fan. On the other hand, there is no knick point in areas less than 100 m above sea level.

After comparing the river profile of the Apure river with the Portuguesa river, the following facts were clarified. The Portuguesa river has a gentle river profile compared with the Apure river, and flows through the lowest area in the Basin. On the other hand, the Apure river joins the Portuguesa river near San Fernando city like a tributary of the latter.

5.1.4 River Course Changing

For river channel planning, understanding of river course change is a very important element of the study. It is not easy to grasp the actual condition of river course change. Based on the geomorphological map on a scale of 1:250,000 and the topographic maps on a scale of 1:100,000 supplied by the Government of Venezuela, the river course change of three big rivers in the Basin are mentioned below:

(1) The Portuguesa River

The Portuguesa river is the most stable river in the Basin and its river course change is insignificant. However, its river course is different to other rivers. After flowing out of the Andes Mountains, the Portuguesa river changes its course from the southeast to the east. Near the south side of El Baul, the river changes its course to the southeast again. After that, the river flows toward the inland delta. The river course of the Portuguesa river is very discordant compared with other rivers which flow down at right angles to the direction of the Andes Mountains.

On the west side of El Baul, a stagnant water area exists through out the year. This area is a geo-tectonic submergence zone. The Portuguesa river flows into this zone cutting initial land forms. After that, the river flows toward a larger submerged zone in the inland delta. The Portuguesa river flows along the 60 m contour line cutting a deep valley on the west side of El Baul. The valley cliff is over 10 m in height at Paso La Portuguesa, about 1 m at El Socorro, about 8 m at La Union and about 6 m at Camaguan. As mentioned above , the main channel of the Portuguesa river is very stable between El Baul and the junction with the Apure river.

The Portuguesa river section between Route 5 and the junction with Caño Pilot, which links the Portuguesa river with the Acarigua river, there are some subchannels in the Alluvial fan. But at this point the main channel of the river is stable and big river course change is not recognized.

(2) The Guanare River

After flowing from the Andes Mountains, the Guanare river immediately changes its course to the east. After that, the river changes its course slightly to the southeast and flows into the inland delta. This direction of the channel seems discordant with other rivers the same as the Portuguesa river. However, the river course is not stable being differed from the Portuguesa river.

In the past, the Guanare river flew at right angles to the Andes Mountains the same as many other rivers. The river then joined the Guanaparo river (or the Guanare Viejo river) which was an old channel of the Apure river on the east side of Bruzual. After flowing at right angles to the Andes Mountains, the river then flew in a straight course to the east passing through the present channel of the Guanarito Viejo river. Finally, the river joined the Portuguesa river at Guadarrama.

As mentioned above, the Guanare river is affected by present tectonic movement. In recent years, the main channel of the river moved from Arismendi to the south at distance of about 20 km. A deep valley was not formed along the main channel of the Guanare river. At Arismendi in the middle reaches, height of the terrace from the river bed is about 4 m. In this section, lateral erosion to the river bank is stronger than deepening to the river bed. The Guanare river is a young and active river and the most unstable river in the Basin.

(3) The Apure River

The Apure river flows along the lowest area in the Basin. Its main channel is comparatively stable and large river course changing like the Guanare river is not recognized. However, it is judged that the Apure river is not as stable as the Portuguesa river.

Between Guasdualito and Suripa, the river is comparatively stable because of a few junctions with other big tributaries. Between Suripa and Bruzual, the Suripa river, the Canagua river, the Santo Doming river and the Masparro river from the Andes Mountains meet with the Apure river. In that section, the main channel of the Apure river forms a big meander zone with amplitudes of hundreds of meters.

Between Bruzual and Apurito, the meander zone continues from the upper streams. As the river approaches Apurito, the river channel gradually becomes stable because the number of big tributaries decreases. On the north bank of the Apure river, a big old channel is observed from Bruzual to the east in parallel with the present main channel.

This old channel extends along the Guanaparo river and meets again with the Apure river at San Fernando city. This old channel is called the Madre Viejo river. In this section, banked up waters are observed through the year. If a flood occurs, flood water of the Apure river flows into the this old channel.

In the lower reaches from Apurito, the Apure river flows in the inland delta which is 60 m above sea level. In this section, the river slope decreases further and thus many sub-channels branch off at random. On the south bank of the Apure river, the Apure Viejo river flows in parallel with the main channel from Apurito to San Fernando city.

Three big sub-channels branch off the main channel of the Apure river being 10 km wide in the same section. These sub-channels are called the Garzas river, Ruende river and Las Yeguos river from north to south respectively. Among these sub-channels, the main channel of the Apure river is the Ruede river in the central position. It seems that this section is the most unstable in the main channel of the Apure river.

As mentioned above, it seems that the most stable river is the Portuguesa river, while the Apure river shows medium stability, and the Guanare river is the most unstable river in the Basin.

5.1.5 Delineation of Flood Prone Area by Interpretation of Satellite Images

(1) Method of Interpretation

For analysis of the flood prone area, existing data from MARNR and satellite images provided by JICA were mainly used. The most valuable existing data is a report named "Los Excesos de Aguas Superficiales en los Llanos Occidentales" by MARNR in 1979.

Twenty false color images were received from LANDSAT 3, 4 and 5 from 1981 to 1989. These images have a scale of 1: 250,000 and they were obtained by using the Multi - Spectral Scanner (MSS) and Thematic Mapper (TM). The false color images obtained by MSS (band of 4.5.7) and TM (band of 2.3.4) are composed of blue, green and red colors for each band by wave length.

The images are generally used for remote sensing of resources because the natural features and landforms are expressed well. The land form information obtained from these images are as follows:

Black color	Clear water
Blue color	Muddy water
Blue gray color	Submerged land without vegetation
Greenish gray color	Submerged land with vegetation
Dark red color	Forest, woods
Light red color	Savanna
Gray color	Land without vegetation
Orange color	Cultivated land with greenish crops
Light blue gray color	City or town

These colors were confirmed in the investigation area by aerial observation.

Based on the above classifications, the interpretation was carried out. However, there are some difficulties in interpreting the satellite images because of cloud cover and bad receiving conditions. In the Basin, big inundations occurred in the rainy seasons in 1976 and 1981. However, the images at that time are not available. Therefore, the images for interpretation were chosen from the most clear images among available data for the rainy season and dry season.

The results of interpretation are shown in Figs. 5.1.4 and 5.1.5. The lower Llanos consist of micro landforms such as a low natural levees and back marshes along the river channel. The regular pool areas in the dry season are generally back marshes surrounded by low natural levees. The small back marshes disappear by evaporation during the dry season, but larger ones remain throughout the year although their areas are reduced in the dry season. On the other hand, if big inundation occurs, these enclosed depressions are filled with water. When the volume of water increases further, those depressions are connected to each other and river channels are formed. The overflowed water runs out through the channels toward other lower depressions.

Rivers in the Basin sometimes change their courses because of inundations over several decades. Many small natural levees are formed by overflowing water. As a result, micro relief forms of 2 to 3 m in relative height are widely distributed in the Basin.

Major micro relieves and pool areas are concentrated in some specific areas, as follows:

- Channel of the Apure river (north bank between Bruzual and San Fernando)
- Channel of the Guanare river (between Guanarito and Arismedi)
- Channel of the Guanaparo river and the Guanare Viejo river
- Middle and lower reaches of the Guanare river (between La Hoyada and La Union)
- Middle reaches of the Portuguesa river (between Nueva Florida and El Baul)
- Channel of the Igüés river (from the upper reaches to the lower reaches)

Some remarkable natural levee zones stretch from the piedmont of the Andes Mountains southeastward along the principal tributaries of the Apure river except the Portuguesa river.

In the lower Llanos, between the Guanare Viejo river and the Apure river and between the Portuguesa river and Guanare river, discontinuous natural levee zone exists. The pool in the lower Llanos in the dry season does not form a continuous water table controlled by distribution of micro landforms.

The various small pool areas which have different levels are formed discontinuously and irregularly. Their areas are determined by the scale of inundation. Furthermore, they are influenced by the dispersion of micro landforms. If a big inundation occurs in these areas, water in many enclosed depressions will overflow to the surrounding areas and flow down to the lower reaches with enormous width.

According to the satellite-image interpretation, one of the remarkable flood prone areas throughout the year is located on the east side of the northsouth line connecting El Baul with Apurito. This area is geomorphologicaly defined as inland delta. Low natural levees which rise to a relative height from 1 to 3 m are formed along the small river channels in this area. However, these natural levees are covered with water during the rainy season with the exception of some levees. This is a big flood prone area.

During the dry season, the limit of this flood prone area are steeply reduced, but some part still exist as lakes. This inland delta was formed because of the surrounding fan on the northeast side of the Portuguesa river and the old sand dunes on the south bank of the Apure river.

On the south and east sides of El Baul, a remarkable flood prone area exists along the main channel of the Portuguesa river in the rainy season. The Portuguesa river changes its course from the east to the southeast near El Baul. It is caused because of the Alluvial fan of the Pao river and the bad land with exposed base rock on the east side of El Baul.

The flood water of the Portuguesa river hits these obstacles, inundates the surrounding areas, and goes back upstream.

Other notable flood prone areas are found along the old river channels of the Guanare river and the Apure river. Historically, the Guanare river has often changed its course. As a result, this river has various old river channels and is the most unstable river in the Basin. Along the old channel of the Guanare river, many lakes remain in the dry season. The main channel of the present Guanare river is located on the south side of Arismendi.

The largest and oldest channel of the Apure river is on the north side of the present Apure river in parallel. This channel beginning at Bruzual flows eastward and enters the channel of the Guanaparo river. After, it joins the channel of the Apure river again at San Fernando. From the interpretation of satellite images, this old channel is clearly recognized as a flood prone zone in the rainy season, and even in the dry season, this channel is able to be traced at times.

Other geomorphological units consist of the combination of Alluvial fans, natural levees, and backmarshes. These prone areas are occur irregularly on a small scale throughout the Basin and it is impossible to recognize the area as an aggregate.

The present main channel of the Apure river is fixed by the old sand dunes located on the south bank of the river. Therefore, it seems that the Apure river will not change its course on a large scale in the future for the above reason.

As mentioned above, wide inundation areas in the rainy season and discontinuous inundation areas in the dry season are distributed along the main channel of the Portuguesa river, Guanare river, Apure river and their old channels. Especially, the inundation area of the Guanare river is very wide because of its river course changing.

The inundation areas are distributed as follows.

- All areas of the inland delta located on the east side of Route 8 connecting Arismendi and Apurito and between the Portuguesa river and Apure river.
- The north bank of the Portuguesa river between Nueva Florida and the south area of El Baul.
- Both banks of the Igues river between La Trinidad and Guadarram.
- Both banks of the old river channel of the Guanare river (present Guanarito Viejo river) between La Hoyada and Guadarrama.
- Both banks of the Guanare river between Guanarito and Arismendi.
- Both banks of the New Guanare river between La Hoyada and La Union.
- Both banks of the Guanare Viejo river (or Guanaparo river) between La Palmita and San Fernando in the north bank area of the Apure river.
- The both banks of the old channel of the Apure river (Madre Viejo river) between Bruzual and the junction with the Guanaparo Viejo river.
- The north bank of the Apure river between Bruzual and San Fernando.

5.2 Geological Analysis

5.2.1 Purpose and Method

The purpose of geological investigation is to outline geological condition in the Basin and condition of erosion and sedimentation in the Piedmonts and river banks. It is difficult to investigate the distribution of geological formations in the upper reaches during limited period. Thus, the distribution of old geological formations in the mountain areas mainly depend on existing data.

On the hand, grasping for the distribution of younger formations in the lowlands was determined by the results of borehole drilling and observation of the river banks at the sites of river material investigation.

The method of the geological investigation is as follows:

- Field investigation (including material investigation),
- Borehole drillings and
- Collection and analysis of existing data.

The main data used for analysis are as follows:

- Geological Map of Venezuela (1:500,000)
  Ministry of Mining and Petroleum (1976)
- Hydrogeological Map of Venezuela (1:500,000)
  Ministry of Mining and Petroleum (1976)
- Tectonic Map of Venezuela (1:1,000,000)
  Ministry of Mining and Petroleum (1976)
- Geology of Venezuela and Sedimentary Basin of Petroleum (1980)
  (Geologia de Venezuela y de sus Cuencas Petroliferas) JONINVES (1980)

5.2.2 Distribution of Geological Formation

A geological map of the Basin is shown in Fig. 2.2.1 and geological correlation of stratigraphic sequence is shown in Table 5.2.1.

As already mentioned in the Chapter II, the central part of the Andes Mountains consists of Mesozoic and Paleozoic igneous rocks, sedimentary rocks and metamorphic rocks including basement of Precambrian metamorphic rocks. Precambrian metamorphic rocks mainly consist of hard schist and gneiss. These rocks are distributed in the Piedmont between the Socorro river and the Suripa river. The resistance to erosion of these rocks is very strong.

Mesozoic and Paleozoic sedimentary rocks and metamorphic rocks are distributed between the Sarare river and the Socorro river. Paleozoic formations consist of sandstone, shale, slate, and schist. Sandstone and shale are very hard and they have enough resistance to erosion.

Weak metamorphosed slates have a remarkable joint system in the same direction. In result, joint blocks fall along the joint wall and are rapidly broken to small pieces, and many slope failures occur in the slates areas. Strong metamorphosed schists contain secondary clay minerals by metamorphic effect. Thus, resistance of this rock is very weak to weathering. In result, landslides often occur in the schist area .

Mesozoic formations consist of the same rocks as the Paleozoic formations. Especially in this area, Juristic formation named La Quinta is widely distributed. The La Quinta formation consists of a reddish and oxidized conglomerate. The matrix of this conglomerate is not so consolidated. In result, slope failure often occurs by bank erosion.

In the upper reaches between the Socorro river and the Acarigua river, Precambrian Granites and Tertiary sedimentary rocks widely are distributed. Granite mainly consists of coarse rock forming minerals. As a result, these minerals are easily separated into fragments by weathering. Consequently, granite has a very weak resistance to weathering compared with other rocks. Thus, granite areas supply a lot of materials to rivers.

Tertiary formations consist of sandstone, mudstone and conglomerate. Consolidation of the Tertiary rocks generally is weak compared with old rocks apart from sandstone. These rocks also have a weak resistance to weathering and erosion the same as granite.

The Coastal Mountains consist of Paleozoic sedimentary rocks and Mesozoic Pyroclastic rocks, sedimentary rocks, and metamorphic rocks. In the upper reaches between the Cojedes river and San Carlos river, Mesozoic meta-sedimentary rocks and granites are distributed.

In the upper reaches between the San Carlos river and Pao river, Paleozoic sedimentary rocks are widely distributed in the basement of the Coastal Mountains. In its Piedmont, Tertiary formations are distributed.

In the upper reaches between the Pao river and Tiznados river, Mesozoic Pyroclastic rocks are widely distributed. In its Piedmont, Tertiary formations are distributed which extend southward as far as the upper Llanos. The pyroclastic rocks of this area are weakly metamorphosed by heat and pressure. In result, the matrix of these rocks is very strong for weathering and erosion like a volcanic rock.

In front of the Coastal Mountains, the El Baul Mountains are located in the upper Llanos. These mountains consist of Paleozoic schist and granite and Mesozoic volcanic rocks. In these mountains, shist and granite areas are already eroded and separated to form hills. Presently only hard volcanic rocks rise as mountains and are widely distributed.

Diluvium formations are distributed as fan and river terrace deposits at the Piedmont in front of the Andes Mountains and Coastal Mountains. These formations mainly consist of gravels, which are widely distributed in the upper Llanos and are filled up by Alluvium formations in the lower Llanos. The relation between the Diluvium formations and Alluvium formations observed near Route 5 is shown in Fig. 5.2.1.

In the Bocono river, fan deposits of Diluvium directly form the ground surface. These deposits are very consolidated and the matrixes are oxidized.

At the Portuguesa river, fan deposits of Diluvium are covered with sandy fan deposits of Alluvium. On the other hand, in the Acarigua river, fan deposits of Diluvium are covered with gravel fan deposits of Alluvium.

5.2.3 Geological Structure

Distribution of earthquakes and faults in the Basin is shown in Fig. 5.2.1. As already mentioned in Chapter II, along the Andes Mountains, the Bocono Fault runs in direction from southwest to northeast and along the Coastal Mountains, while the Caribe Fault runs in direction from west to east.

The north side area of the Andes Mountains and the Coastal Mountains is located in the Caribe Plate advancing to the east. The south side area is located in the South American Plate advancing to the west by the plate tectonics.

The Bocono-Caribe Faults are lateral-trans form faults formed in the contact zone of these two plates. Along these faults, many normal fault crossing or in parallel with them are in existence. The Caribe Plate is approaching the South American Plate.

In result, between the Paleozoic formations and the Mesozoic or the Tertiary formations many thrusts are formed. These two mountain ranges are lifted up by the movement of the plates and the upheaval movement of the mountain areas has occured from the Paleozoic to present. Presently, many earthquakes occur along the axes of these two mountain ranges.

As a result, the Orinoco and the Apure lowlands have become a subsidence zone. Under the influence of this movement, many river channels were formed. Subsidence of the mountains promotes erosion in the rivers. In result, thick Tertiary and Quaternary formations were deposited in the Apure lowland.

5.2.4 Erosion and Sedimentation

As already mentioned in section 5.2.2, rocks with weak resistance to erosion and weathering are widely distributed in the Andes Mountains and Coastal Mountains. As already mentioned in section 5.2.3, erosion is very active in the two mountain ranges because of upheaval movement.

Furthermore, as many active faults cut the mountain ranges, many slope failures occur in these fault zones. In result, a lot of materials are supplied to the river channels.

As already mentioned in section 5.1.3, the rivers flowing down from these two mountain ranges have many nick points in the upper reaches. This fact supports the existence of these active works. In these two mountain ranges, erosion is very active. However, among them, there is some difference concerning quantities of erosion materials corresponding to type of rock and geological structure.

Comparison of the maximum diameter of the river bed materials, with the exception of the Pao river, reveals that the largest diameter is found between the Santo Domingo river and the Socorro river including the Paguey river, the Canagua river, the Acequia river and the Bumbum river. The existience of large diameter materials means that the river bed materials are transported a long way to the lower reaches. In other words, the rivers which have a large diameter of materials supply a lot of materials to the lower reaches.

In the mountains in the upper reaches between the Santo Domingo river and the Socorro river, there is a wide granite area. It seems that materials in these rivers are supplied from this granite zone.

On the other hand, in the Coastal Mountains, the quantity of materials supplied to the rivers is less than that in the Andes Mountains. This is because hard pyroclastic rocks are widely distributed in the Coastal Mountains. The upper reaches of the Cojedes river are located where the Andes Mountains and Coastal Mountains cross. This area has been affected by complex tectonic movement. In result, the mountains were divided into many small blocks by erosion.

Furthermore, in the upper reaches of the Cojedes river, Yaracuy Graben and Barquisimeto basin exist. For that reason, the diameters of river bed materials in the Cojedes river are small. The Portuguesa river basin covers the area from the Andes Mountains to the north of the Masparro river to the Coastal Mountains.

The Basin covers the area located to the south of the Santo Domingo river in the Andes Mountains. Compared with the Portuguesa river, the quantity of materials in the Apure river is greater. This is proved by the fact that the mean diameter of the Apure river at San Fernando is larger than that of the Portuguesa river at Camaguan.

Bank erosion and sedimentation in the middle and lower reaches of the Basin is remarkable in the channel of the Apure river. A large meandering zone as a result of erosion and sedimentation of the river channel is in existence between Suripa and Bruzual in the Apure river. At Totumito and San Vicente in the Apure river, lateral erosion of the banks was observed. In this section, protections of the river banks has been carried out by use of concrete piles.

On the other hand, in the Portuguesa river, a meandering zone is in existence. This zone was formed during on active erosion age. Presently, vertical erosion is more active than lateral erosion and in result the channel of the Portuguesa river is stable.

The Guanare river has a steep river profile compared with the above two rivers and mainly flows on the surface of Alluvial fan. The direction of its channel changes freely according to the velocity and the amount of water. As a result, in this river, lateral erosion is stronger than deepening erosion. Thus, a large meandering zone has not been formed in the Guanare river.

5.2.5 Geological Profile

A geological profile made by the result of borehole drillings in the Apure river between Puente Remolino and Arichuna is shown in Fig. 5.2.2. Another geological profile in the Portuguesa river between El Baul and San Fernando is shown in Fig. 5.2.3.

In these figures, the distance from a drilling point to a neighboring drilling point is between 30 km and 120 km. Therefore, between this interval, it is possible to change the geological boundary. Thus, in these figures, only drilling logs are shown with no connection to geological boundary.

From the geological profile of the Apure river, in the section between Puente Remolino and San Vicente clay soils of N-value of 30 and over and sandy soils of N-value of 30 and under are distributed from 5 m to 20 m in depth. These surface soils which show relatively low N-values are distributed very thinly in the section between San Vicente and El Saman from 1 m to 4 m in depth. However, in the section between El Saman and Apurito, this soft zone consisting of thick sands reaches 20 m and over in depth. These soft layers seems to be Alluvial flood plain deposits.

Under the soft layers, hard clayey soils and sandy soils are distributed. The sandy soils show N-values of 30 and over and the clayey soils show N-Values of 20 and over. Especially, the clayey soils often show an N-value of over 50 . These clayey soils have yellowish brown or grayish brown colors and sometimes a band of yellow clay is inserted. By Tricot (1974), Diluvial old sand dunes are widely distributed. Michel Pouyllau (1985) mentioned these soils as inland dune in this geomorphological map (Fig. 2.1.2).

Furthermore, by the interpretation of satellite images, these sand dunes are clearly observed as a characteristic zone in the direction from southwest to northeast. Probably, these hard yellow clays may be Leoss and these hard sands may be of old sand dunes deposited during the last ice age. These soils are presently covered with Alluvial soils which are from 1 m to 20 m on thickness on the south bank of the Apure river.

A geological profile of the Portuguesa river is as follows. The banks of the Portuguesa river consist of alternating beds of sand and clay, except Camaguan. At Camaguan, the bank consists of upper clay which is 10 m in thickness and lower sand which is over 10 m in thickness. These soils of the bank of the Portuguesa river show high N-values except the surface soil which is between 2 m to 10 m in depth.

By Tricot (1962), Diluivial terrace deposits distributed in the piedmonts of the Andes Mountains and Coastal Mountains incline gently toward the upper Llanos and parts of them extend into the lower Llanos. In this section, they are irregularly covered with Alluvial soils. The results of borehole drillings prove this fact clearly.

At El Baul, Diluvial soils are directly distributed on the ground and form river terraces. At El socorro and Camaguan, Diluvial soils are covered with Alluvial soils which are between 3 m to 10 m thick. In this area, Diluvial soils are in existence as buried terraces. In contrast, at San Fernando on the Apure river, Alluvial soils which are 20 m and over in thickness form the river banks.

VI. DESIGN VALUE FOR DIKE

6.1 Design Value of Bearing Layer

The dike proposed in this study will be about 2 to 3 m high. As indicated by the results of borehole drillings along the main river channels, relatively soft Alluvial clays and sands are deposited with from 1 m to 20 m in thickness on hard Diluvial soils.

Alluvial clays in the depth of 1 to 2 m sometimes show N-values of under 10. However, under the depth of 2 m, the Alluvial clays show N-values between 10 and 20. Thus, it seems that the possibility of consolidation settlement by loading is low. The Alluvial sands show higher N-values than the Alluvial clays and thus this Alluvial sands have no problem in regard to consolidation settlement.

The N-values of soils, cohesions, angles of internal friction and unit weights of soils for the bearing layer for the planned dike are discussed below. Some methods are proposed to determine cohesion and angle of internal friction of soils by N-value. The well known Terzaghi and Peck method was used to determine the relationship between strength of soil and consistency of clay as shown below:

N-value (times/30 cm)	Consistency of Clay	Unconfined Compression Strength qu (kgf/cm^2)
2>	very soft	0.25>
2~4	soft	0.25~0.5
4~8	medium	0.5~1.0
8~15	stiff	1.0~2.0
15~30	very stiff	2.0~4.0
>30	hard	>4.0

The relationship between strength of soil and relative density of sand is shown below:

N-value (times/30 cm)	Relative Density of Sand	Angle of Internal Friction f (°)
0~4	very loose	28.5>
4~10	loose	28.5~30
10~30	medium	30~36
30~50	dense	36~41
>50	very dense	>41

The N-values of the top alluvial soils are as follows:

Item	Alluvial Clay	Alluvial Sand
Maximum Value	40	46
Minimum Value	1	2
Mean Value	12.5	18

The mean N-value of alluvial clay is 12.5. The qu-value of this clay is between 1.0 and 2.0. Then, the mean qu-value is about 1.5 kgf/cm^2. The relationship between cohesion (C) and qu-value is as follows:

$$c = \frac{1}{2} qu \quad (f = 0)$$

In result, the cohesion of alluvial clay is as follows:

$$c = \frac{1}{2} x\ 1.5 = 0.75 \text{ kgf/cm}^2$$

The mean N-value of Alluvial sandy soil is 18. The angle of internal friction is between 30° and 36°. Thus, the mean f-value is about 33°. The cohesion of sand is assumed to be zero.

The wet unit weight of clay is generally between 1.2 g/cm^3 and 1.8 g/cm^3 and the wet unit weight of sand is generally between 1.6 g/cm^3 and 2.0 g/cm^3. If the moisture content falls, the wet unit weight increases.

The mean moisture content of the Alluvial clay in the investigation area is 21 % and the Alluvial sand is 18 %. These values are very low compared with the general value. Thus, the wet unit weight of the soils in the investigation area seem to be close to the maximum values of each soil.

The estimated values of the wet unit weights are as follows:

Alluvial clay	rt = 1.8 g/cm^3
Alluvial sand	rt = 1.9 g/cm^3

The design values of the bearing layer are as follows.

Item	Alluvial Clay	Alluvial Sand
Cohesion (C) (kgf/cm^2)	0.74	0
Angle of Internal Friction f (°)	0	33
Unit weight (rt) (g/cm^3)	1.8	1.9

6.2 Design Value of Embankment Material

The desirable qualities of the embankment material are as follows:

- Stable soil in regard to slope failure,
- Low permeability soil,
- Easy treatment soil for digging, transporting, and compaction, and
- Stable soil for changes in moisture content.

It is very difficult to obtain a soil which satisfies the above conditions. To the contrary, it is desirable to avoid the following characteristics:

- In case of clay
  - Soil of N-value under 3
  - Soil of qu-value under 0.6 kg/cm^2
  - Soil of moisture content over 40 % .

- In case of sand
  - Soil of N-value under 10
  - Poorly graded soil

The compaction tests were carried out on the embankment material obtained by test pitting. Results of the compaction tests are shown in Fig. 6.1.1 and Table 6.1.1, which show that the maximum dry densities are between 1,560 g/cm^3 and 1,820 g/cm^3. With the exception of samples from TP-4 (1,560 g/cm^3), these values are relatively high and these soils are suitable for embankment material.

Optimum moisture contents corresponding to maximum dry densities are between 12.2 % and 20.6 %. These samples satisfy conditions for embankment material already mentioned above with exception of samples of TP-4. The samples of TP-4 are poorly graded sand and the maximum dry density is low. It seems that this sample is not proper for embankment material.

Construction work should be carried out under control of optimum moisture content corresponding to maximum dry density. However, an increase of moisture content is allowed until the moisture content corresponding to 90 % of the maximum dry density is increased. In this case, the moisture contents should be between 18.0 % and 33.6 % and not over 40 %. Natural moisture contents of all samples are relatively low and thus it is not necessary to lower the moisture content by stock piling soils. As mentioned above, it seems that these soils are relatively good for embankment material with exception of the samples of TP-4.

TABLES

Table 3.1.1 LIST OF MATERIAL INVESTIGATION SITES

Site		River Bed Materials	Bore Hole Drilling	Test Pit
1)	Apure River :			
a)	Puente Remolino(Sarare river)	M-1	P-1	TP-1
b)	Totumito	M-2	P-2	TP-2
c)	Palmarito	M-3	P-3	TP-3
d)	Suripa	M-4	P-4	TP-4
e)	San Vicente	M-5	P-5	TP-5
f)	Bruzual	M-6	P-6	TP-6
g)	El Saman	M-7	P-7	TP-7
h)	Apurito	M-8	P-8	TP-8
i)	San Fernando	M-9	P-9	TP-9
j)	Arichuna	M-10	P-10	TP-10
	(Sub-total)	(10)	(10)	(10)
2)	Portuguesa River :			
a)	Paso la Portuguesa	M-11	-	-
b)	El Baul (Cojedes river)	M-12	P-11	TP-11
c)	Guadarrama	M-13	-	-
d)	Socorro	-	P-12	TP-12
e)	La Union	M-14	-	-
f)	Camaguan	M-15	P-13	TP-13
g)	Arismendi (Guanare river)	M-16	-	-
	(Sub-total)	(6)	(3)	(3)
3)	Tributaries at Crossing of Main Road Route-13 and Route-5:			
a)	Verde river	M-17	-	-
b)	Pao river	M-18	-	-
c)	Tinaco river	M-19	-	-
d)	San Carlos river	M-20	-	-
e)	Cojedes river	M-21	-	-
f)	Acarigua river	M-22	-	-
g)	Portuguesa river	M-23	-	-
h)	Guanare river	M-24	-	-
i)	Tucupido river	M-25	-	-
j)	Bocono river	M-26	-	-
k)	Masparo river	M-27	-	-
l)	Santo Domingo river	M-28	-	-
m)	Santo Domingo river (El Real)	M-28A		
n)	Santo Domingo river (El Real)	M-28B		
o)	Paguey river	M-29	-	-
p)	Canagua river	M-30	-	-
q)	Acequia river	M-31	-	-
r)	Bumbum river	M-32	-	-
s)	Socopo river	M-33	-	-
t)	Caparo river	M-34	-	-
u)	Uribante river (Chorrosquero)	M-35	-	-
	(Sub-total)	(21)	(0)	(0)
4)	Orinoco River			
a)	Puerto Ordaz (1)	M-36	-	-
b)	Puerto Ordaz (2)	M-37	-	-
	(Sub-total)	(2)	(0)	(0)
Total number. of sites		(39)	(13)	(13)

Table 3.2.1 RELATION BETWEEN GEOLOGICAL FORMATION AND N-VALUE

Formation	N-value			Number of SPT	Geological Age
	Maximum	Minimum	Mean		
First Clay	40	1	13	39	HOLOCENE (Alluvium)
Second Clay	14	6	10	2	
Third Clay	7	5	6	2	
First Sand	46	2	18	76	
First Clay	76	10	41	73	PLEISTOCENE (Diluvium)
Second Clay	36	34	35	2	
First Sand	48	9	34	7	
Second Sand	77	17	35	67	

Note : SPT - Standard Penetration Test

Table 3.4.1 GEOMORPHOLOGY AND GEOLOGY OF THE MATERIAL INVESTIGATION SITES

Site No.	Site	River	Geomorphology ( )*		Geology	Flood
M-1 (P-1)	Puente Remolino	Sarare R.	Flood Plain	(2m)	Clay, Sand	Yes (+1.0m)
M-2 (P-2)	Totumito	Apure R	Flood Plain	(3m)	Clay, Sand	Yes (+0.2m)
M-3 (P-3)	Palmarito	"	Flood Plain	(3.5m)	Sand, Clay	Yes (+0.5m)
M-4 (P-4)	Suripa	"	Flood Plain	(4~6m)	Mainly Sand	Yes (+1~2m)
M-5 (P-5)	San Vicente	"	Natural Levee	(6m)	Clay, Sand	Yes (not clear)
M-6 (P-6)	Bruzual	"	Natural Levee	(7~8m)	Clay, Sand	Left No Right, Yes(+1.0m)
M-7 (P-7)	El Saman	"	Natural Levee	(8m)	Clay, Sand	Yes (not clear)
M-8 (P-8)	Apurito	"	Natural Levee	(8m)	Mainly Sand	No
M-9 (P-9)	San Fernand	"	Natural Levee	(8m)	Mainly Sand	No
M-10 (P-10)	Arichuna	"	Natural Levee	(6m)	Clay, Sand	No
M-11	Paso La Portuguesa	Portuguesa R.	Terrace	(8m)	Clay, Sand	No
M-12 (P-11)	El Baul	Cojedes R.	Terrace	(8m)	Clay, Sand	No
M-13	Guadarrama	Portuguesa R	Terrace	(10m)	Sand	No
(P-12)	El Socorro	"	Terrace	(10m)	Sand, Clay	No
M-14	La Union	"	Terrace	(8m)	Clay	No
M-15 (P-13)	Camaguan	"	Natural Levee	(6m)	Clay, Sand	No
M-16	Arismendi	Guanare R.	Natural Levee	(4m)	Sand	No
M-17	Rio Verde	Tiznados R.	Flood Plain	(2m)	Sand	Yes
M-18	El Pao	Pao R.	Flood Plain	(3m)	Sand	Yes
M-19	Tinaco	Tinaco R.	Left, Flood Plain Right, Terrace	(3m) (5m)	Gravel Gravel, Rock	Left, Yes Right, No
M-20	San Carlos	San Carlos R.	Flood Plain	(2.5m)	Gravel	Yes
M-21	San Rafoel de Onoto	Cojedes R.	Terrace	(5m)	Gravel	Yes
M-22	Acarigua	Acarigua R.	Flood Plain	(3~4m)	Gravel	Yes
M-23	Guanare	Portuguesa R.	Flood Plain	(3.5m)	Sand, Gravel	Yes
M-24	Guanare	Guanare R.	Flood Plain	(2m)	Gravel	Yes
M-25	Tucupido	Tucupido R.	Flood Plain	(3.5m)	Gravel	Yes
M-26	Boconito	Bocono R.	Flood Plain	(1.5m)	Gravel	Yes
M-27	Barrancas	Maspapro R.	Terrace	(5m)	Gravel	Yes
M-28	Barinas	St. Domingo R.	Terrace	(5m)	Gravel	Yes
M-29	El corozo	Paguey R.	Terrace	(8m)	Gravel	Yes
M-30	Ciudad Bolivia	Canagua R.	Terrace	(8m)	Gravel	Yes
M-31	Ciudad Bolivia	Acequia R.	Terrace	(5m)	Gravel	Yes
M-32	La Esmeralda	Bumbum R.	Terrace	(5m)	Gravel	Yes
M-33	La Esmeralda	Socopo R.	Terrace	(8m)	Gravel	Yes
M-34	Punta de Piedra	Caparo R.	Terrace	(10m)	Gravel, Base Rock	Yes
M-35	Chorros quero	Uribante R.	Flood Plain	(4m)	Clay	Yes
M-36	Pto. Ordaz	Orinoco R.	Point Bar		Sand	Yes
M-37	Pto. Ordaz	Orinoco R.	Point Bar		Sand	Yes

Note : ( )* Height of banks from the river beds

Table 4.2.1 SUMMARY OF EXECUTED EXPLORATORY AND LABORATORY TESTS

Test Item	River Bed Material	Borehole	Test Pit	Total
1) Drilling or Digging (sites)	39	260 m long	13	-
2) Standard Penetration Test (nos)	-	260	-	260
3) Specific Gravity Test (nos)	39	262	13	314
4) Moisture Content Test (nos)	39	262	13	314
5) Grain Size Analysis (nos)	39	262	13	314
6) Liquid and Plastic Limits Test (nos)	11	47	11	69
7) Standard Compaction Test (nos)	-	-	13	13

Table 5.1.1 LIST OF SATELLITE IMAGE (FALSE COLOR, S = 1:250,000) (1/3)

NO.	AREA CODE	AREA	SATELLITE NO.	TYPE OF CENSOR	RECEIVING DATE	SEASON	CONDITION OF IMAGE
1	006-054	North bank of the Apure river, west area	L3	MSS	81/12/01	DRY	BAD
2	"	"	L5	"	86/07/01	RAINY	BAD
3	005-054	North bank of the Apure river, central area	L3	"	81/11/12	"	NO GOOD
4	"	"	L5	"	85/05/20	DRY	BAD
5	"	"	"	TM	86/03/20	"	GOOD
6	"	"	"	MSS	86/05/07	"	NO GOOD
7	"	"	"	"	86/08/27	RAINY	BAD
8	"	"	"	TM	86/11/15	"	BAD
9	"	"	"	"	86/12/17	DRY	GOOD
10	"	"	L4	"	87/11/26	RAINY	GOOD
11	004-054	North bank of the Apure river, east area	L5	"	87/01/11	DRY	GOOD
12	"	"	L4	"	88/05/13	"	GOOD
13	"	"	"	"	89/10/23	RAINY	GOOD
14	006-055	South bank of the Apure river, west are	L3	MSS	80/12/01	DRY	NO GOOD
15	"	"	L5	"	86/07/01	RAINY	GOOD
16	005-055	South bank of the Apure river, central area	"	TM	86/01/31	DRY	GOOD
17	"	"	"	"	86/12/17	"	GOOD
18	004-055	South bank of the Apure river, east area	"	"	87/01/11	DRY	GOOD
19	003-054	North bank of the Orinoco river	"	"	87/01/20	DRY	NO GOOD
20	003-055	South bank of the Orinoco river	"	"	87/02/21	"	GOOD

NOTE : DRY SEASON (DECEMBER - MAY), RAINY SEASON (JUNE - NOVEMBER)

Table 5.1.1 LIST OF SATELLITE IMAGE (MONO COLOR, S = 1:1,000,000) (2/3)

NO.	AREA CODE	AREA	SATELLITE NO.	TYPE OF CENSOR	RECEIVING DATE	SEASON	CONDITION OF IMAGE
1	006-054	North bank of the Apure river, west area	L3	MSS	78/04/27	DRY	BAD
2	"	"	"	"	78/07/08	RAINY	BAD
3	"	"	"	"	78/09/09	"	GOOD
4	005-054	North bank of the Apure river, central area	"	"	78/04/26	DRY	BAD
5	"	"	"	"	78/07/07	RAINY	BAD
6	"	"	L2	"	78/09/08	"	NO GOOD
7	"	"	"	"	78/10/14	"	NO GOOD
8	"	"	"	"	75/03/28	DRY	GOOD
9	004-054	North bank of the Apure river, east area	L1	"	72/10/17	RAINY	BAD
10	"	"	L3	"	79/02/25	DRY	GOOD
11	"	"	"	"	78/04/25	"	BAD
12	"	"	"	"	78/06/18	RAINY	BAD
13	"	"	L2	"	78/09/07	"	NO GOOD
14	"	"	"	"	78/10/31	"	NO GOOD
15	"	"	L1	"	73/03/10	DRY	BAD
16	"	"	L3	"	78/04/07	"	NO GOOD
17	006-055	South bank of the Apure river, west area	L1	"	73/02/22	"	BAD
18	"	"	L3	"	78/04/27	"	NO GOOD
19	"	"	"	"	79/02/09	"	GOOD
20	"	"	L1	"	72/10/19	RAINY	GOOD

Table 5.1.1 LIST OF SATELLITE IMAGE (MONO COLOR, S = 1:1,000,000) (3/3)

NO.	AREA CODE	AREA	SATELLITE NO.	TYPE OF CENSOR	RECEIVING DATE	SEASON	CONDITION OF IMAGE
21	006-055	South bank of the Apure river, west area	L2	MSS	78/09/09	RAINY	NO GOOD
22	"	"	"	"	78/09/27	"	BAD
23	005-055	South bank of the Apure river, central area	L1	"	73/01/16	DRY	GOOD
24	"	"	L2	"	78/09/08	RAINY	BAD
25	"	"	"	"	79/01/30	DRY	GOOD
26	004-055	South bank of the Apure river, east area	L1	"	73/03/10	"	GOOD
27	"	"	L3	"	79/02/25	"	GOOD
28	003-054	North bank of the Orinoco river	L1	"	73/03/27	"	BAD
29	"	"	L3	"	79/02/24	"	GOOD
30	003-055	South bank of the Orinoco river	L1	"	73/03/09	"	NO GOOD
31	"	"	L3	"	78/04/06	"	NO GOOD
32	"	"	"	"	78/07/23	RAINY	BAD
33	"	"	"	"	79/02/24	DRY	GOOD