1.3.1 Pattern of Sediment Flow of the Rivers

Patterns of the sediment flow are generally divided into following five patterns.

a) Debris flow

Debris flow is the flow mixed with mud, sand, cobbles, stones and water with high density. At the most downstream portion of the debris flow, concentration of big size of stones with several meters of their diameter can often be observed. The velocity of debris flow is generally very high. Debris flow generally happens in the place with slope of more than 15 degree (1/3.7) and stops flowing in the place with slope of 3 degree to 4 degree (1/14.3 to 1/19.1).

b) Transition flow between debris flow and bed load

Transition flow is the flow between the debris flow and the bed material load described in c). Transition flow is the sediment flow in which the some thickness of sand and cobbles of the river bed moves with water. This movement is not the saltation but not the condensed flow like debris flow. Transition flow generally can be observed in the river with the bed slope of 4 degree to 10 degree (1/14.3 to 1/5.7).

c) Bed load

Bed load is one of the sediment flow of the bed material load which is the sediment flow composed of the sand and cobbles existing in the river bed. Each sand and cobbles on the surface of the river bed ,which is smaller than the limitation size for movement, is lifted up by the current and is transported and deposited on the river bed again. This movement is called saltation and the distance of the saltation is very short. Bed load can be observed downstream reach of the transition flow.

d) Suspended load

Suspended load is also one on the sediment flow of bed material load. The suspended load can be generally observed in the river reach with the bed material including high percentage of fine sand. The movement of the suspended load is the saltation with longer transportation distance than the bed load. In the downstream reach, suspended load and bed load generally can be observed in a same place.

b) Wash load

Wash load is the sediment flow composed of very fine materials which cannot be found in the river bed. These materials are supposed to be carried from the upstream reaches. The floating materials of the wash load are not deposited in the river course during they are transported.

The sediment flow patterns which are important for the quantity of sediment discharge for the rivers in the Study area are debris flow, transition flow, bed load and suspended load.

1) The Rio Choloma

According to the site investigation and analysis of aerophotographs, the river reaches of the sediment flow patterns of debris flow, transition flow and bed load can be approximately identified as shown in *Fig*. E.1.2.

The most downstream of the deposition of debris flow of the hurricane "Fifi" in 1974 can be observed up to about 1.0 km upstream of the junction of the Rio Majaine with the Rio Ocotillo for the Rio Majaine. As for the Rio Ocotillo, debris flow reached up to the junction of the Rio Majaine with the Rio Ocotillo in the "Fifi". As for the Rio La Jutosa, debris flow reached up to the Old Jutosa Village which locates about 1.0 km upstream of the junction of the Rio Choloma with the Rio La Jutosa in the "Fifi".

As for the transition flow in the Rio Majaine, it does not occurs in the downstream reach of the debris flow reach. As for the Rio La Jutosa, transition flow occurs in the most downstream reach (distance about 1.0 km).

Bed load occurs in the downstream reach of the debris flow reach of the Rio Majaine (distance about 3.5 km). As for the Rio Choloma, bed load occurs in the midstream and downstream reaches which is the downstream reaches from the junction of the Rio Majaine/Rio La Jutosa with the Rio Choloma.

Suspended load seems to occur in the downstream reach of the Rio Choloma. But, the reach of its occurrence cannot be identified clearly.

2) The Rio Blanco

The river reaches of the sediment flow patterns of debris flow, transition flow and bed load can be approximately identified as shown in *Fig*.E.1.2.

Debris flow reached up to about 3.0 km upstream of the junction of the Rio del Zapotal with the Rio de Armenta for the Rio del Zapotal in the "Fifi". As for the Rio Armenta, debris flow reached upto about 2.5 km upstream of the junction of the Rio del Zapotal with the Rio de Armenta .

Transition flow of the Rio del Zapotal occurs in the most downstream reach (distance about 3.0 km). As for the Rio de Armenta , transition flow seems not to occur in the most downstream reach(distance 2.5 km).

Bed load seems to occur in the most downstream reach of the Rio de Armenta (distance about 2.5 km). As for the Rio Blanco of the downstream reach from the junction of the Rio del Zapotal/Rio de Armenta with the Rio Blanco, bed load occurs.

Suspended load seems to occur in the downstream reach of the Rio Blanco. But, the reach of its occurrence cannot be identified clearly.

3) The Rio El Sauce

The river reaches of the sediment flow patterns of debris flow, transition flow and bed load can be approximately identified as shown in *Fig*. E.1.2.

Though the reaches of the debris flow of the Rio Santa Ana/Rio Bermejo and the Rio Piedras are not clear, these reaches are supposed to locate in the upstream from the beginning of the alluvial fan of the Rio Santa Ana/Rio Bermejo and the Rio Piedras.

Transition flow of the Rio Santa Ana/Rio Bermejo occurs in the reach between about 4.0 km and 6.0 km upstream from the junction of the Rio Piedras with the Rio Santa Ana/ Rio Bermejo. As for the Rio Piedras, transition flow occurs in the reach between about 4.0 km and 6.5 km upstream from the junction of the Rio Piedras with the Rio Santa Ana/Rio Bermejo.

Bed load occurs in the downstream reach of the Rio Santa Ana/Rio Bermejo(distance about 4.0 km), downstream reach of the Rio Piedras(distance about 4.0 km) and the whole reach of the Rio El Sauce between the junction of the Rio El Sauce with the Rio Chamelecon and the junction with the Rio El Sauce with the Rio Bermejo/Rio Santa Ana (distance 14.6 km).

As the bed material of the midstream and downstream reach of the Rio El Sauce includes fine sands, suspended load seems to occur in these reaches.

1.3.2 River Bed Materials of the Rivers

In this Study, bed materials investigation for the Rio Choloma, the Rio Blanco and the Rio El Sauce was conducted to obtain the bed material data for assessment of the quantities of the sediment discharges of these rivers and planning of the channel with dynamic stability.

1) Sampling Sites of the River Bed Materials

Sampling sites of the river bed materials are shown in *Fig*.E.1.3. Total sampling sites are 9 sites composed of every 3 sites for the Rio Choloma, the Rio Blanco and the Rio El Sauce. In the each river, samples were taken in the downstream reach, midstream reach and upstream reach with every 3 samples from the right side, center and left side of the river. Therefore, total numbers of the sampling are 27.

At some sampling points in the midstream and upstream reaches of these rivers, the surfaces of the river bed are covered with bigger sand and cobbles than the river bed materials below the surface. This is called armour coat. Average diameters of these armour coats were also measured.

2) Characteristics of the River Bed Materials

For the every sample, laboratory tests composed of particle size analysis and specific gravity analysis were conducted. *Fig* E.1.4 shows the results of the particle size analysis and the average diameter, 90 % diameter and the average specific gravity of the river bed materials at the downstream, midstream and the upstream sites of the Rio Choloma, the Rio Blanco and the Rio El Sauce. In this figure, average diameter of the armour coat is also shown.

Fig E.1.5 shows the longitudinal variation of diameter and longitudinal average of the specific gravity of the Rio Choloma, the Rio Blanco and the Rio El Sauce. The longitudinal variation of the average diameter, 90 % diameter, average diameter of armour coat and specific gravity of the Rio Choloma, the Rio Blanco and the Rio El Sauce are summarized as follows;

(1) The Rio Choloma

Sampling Site	Acc. Distance (km)	Average Diameter dm(mm)	90 % Diameter d90 (mm)	Aver. Dia.of Armour Coat da (mm)	Specific Gravity
A-1(Downstream)	13.5	1.37	3.28	-	2.76
A-2(Midstream)	19.1	20.47	60.33	-	2.74
A-3(Upstream)	24.1	24.41	65.83	78.00	2.78
				Average	2.76

(2) The Rio Blanco

Sampling Site	Acc. Distance (km)	Average Diameter dm(mm)	90 % Diameter d90 (mm)	Aver. Dia.of Armour Coat da (mm)	Specific Gravity
B-1(Downstream)	20.9	0.70	1.38	-	2.68
B-2(Midstream)	23.8	0.94	2.83	-	2.68
B-3(Upstream)	25.9	23.44	60.75	85.60	2.68
				Average	2.68

(3) The Rio El Sauce

Sampling Site	Acc. Distance (km)	Average Diameter dm(mm)	90 % Diameter d90 (mm)	Aver. Dia.of Armour Coat da (mm)	Specific Gravity
C-1(Downstream)	4.50	0.48	1.03	-	2.68
C-2(Midstream)	13.00	0.40	0.97	-	2.70
C-3(Upstream)	19.20	21.46	56.70	81.40	2.71
				Average	2.70

As for the longitudinal variations of the diameter of river bed materials of the Rio Choloma, the Rio Blanco and the Rio El Sauce, they have a common characteristic of abrupt change of the diameter in the midstream reach from cobbles in the upstream to sand in the midstream. The reason of this abrupt change is the abrupt reduction of the tractive force of the river due to the abrupt reduction of the slope of the river bed in the midstream reaches.

1.4 Balance of Sediment Discharges of the Rivers

For the stabilization of river channel, it is necessary to keep the longitudinal balance of the sediment discharge. This is called dynamic equilibrium condition. In this section, longitudinal sediment discharges of the Rio Choloma, Rio Blanco and Rio El Sauce were simulated for the both cases of without projects (without flood control and without erosion and sediment control) and with projects (with flood control and with erosion and sediment control). By using these longitudinal sediment discharges, balance of sediment discharges and tendency of aggradation or degradation of river bed of these rivers were checked.

1.4.1 Procedure of Simulation of Sediment Discharge and River Bed Variation

Procedure of simulation of longitudinal sediment discharge and river bed variation of the Rio Choloma, Rio Blanco and the Rio El Sauce is as follows;

(1) The simulation is conducted for the reaches of the bed load of these rivers.

(2) Hydraulic calculation including water level and velocity are conducted by non-uniform calculation for the design hydrograph of 50 year floods by using the river cross section data of about 1.0 km interval.

(3) Sediment discharge is calculated as bed load for the design hydrograph of 50 year floods by Ashida-Michiue's method by using the river cross section data of about 1.0 km interval.

(4) The hydraulic calculation and sediment discharge calculation are conducted by using the river cross section data with fixed river bed elevation in the duration of the design hydrograph. Hence the river bed variations with short time sequence in the duration of the design hydrograph are not calculated.

(5) Longitudinal balance of sediment discharge, deposition and erosion of sediment and aggradation and degradation of river bed are calculated by using the above sediment discharge.

(6) Balance of sediment discharge of the upstream reaches of debris flow reaches and transition flow reaches between the sediment discharge of the bed load reaches is checked by using the results of Supporting Report D "Sediment Yield and Sediment Control Study" and the sediment discharge of (5).

Simulation cases are as follows ;

1) Rio Choloma

Case 1-1 Without flood control and without erosion and sediment control
Case 1-2 With flood control and with erosion and sediment control (ref. to ***Fig.*** E.1.6)

2) Rio Blanco

Case 2-1 Without flood control and without erosion and sediment control
Case 2-2 With flood control along the original river course and with erosion and sediment control (ref. to *Fig.* E.1.7)

3) Rio El Sauce

Case 3-1 Without flood control and without erosion and sediment control
Case 3-2 With flood control and with erosion and sediment control (ref. to ***Fig.*** E.1.8)

4) Diversion Plan of the Rio Blanco with River Improvement of the Rio El Sauce

Case 4-1 Flood control by the diversion channel of the Rio Blanco to the Rio El Sauce with river improvement of the Rio El Sauce and erosion and sediment control of Rio Blanco basin and Rio El sauce basin (ref. to *Fig.* E.1.9)

1.4.2 Method of Bed Load Calculation

For the bed load calculation, Ashida-Michiue's Method was adopted.

Ashida-Michiue's Method

Discharge of bed load per unit width is as follows;

$$q_B=17t_{*e}\cdot(1-t_{*c}/t_*)(1-u_{*c}/u_*)\cdot u_{*e}\cdot d_m$$

where,

q_B	:	discharge of bed load per unit width (cm^3/sec)
dm	:	average diameter of river bed material
u_*	:	shear velocity (cm/sec)
u_{*c}	:	critical shear velocity of d_m calculated by Iwagaki's method by using s/w
s/w	:	specific gravity of river bed material
t_*	:	non-dimensional tractive force corresponding to u_*
t_{*c}	:	non-dimensional critical tractive force corresponding to u_{*c}
u_{*e}	:	effective shear velocity that is a function of velocity, water depth, and t_*
t_{*e}	:	non-dimensional effective tractive force corresponding to u_{*e}

The discharge of bed load per unit width was calculated for the shear velocity which is bigger than the critical shear velocity of armour coat. The bed load discharge of a river cross section (Q_B) is calculated by using q_B and river bed width. The sediment discharge volume transported by the design flood is the sum of the Q_B for the duration of the flood hydrograph. Furthermore, the sediment discharge volume was calculated as a bulk volume including void ratio of 40 %.

1.4.3 The Rio Choloma

Simulation of sediment discharge and river bed variation for the Rio Choloma is conducted for the river reach from the junction with the Rio Choloma with the Canal San Roque to the National Road Bridge(11.25 km - 19.08 km).

1) Case 1-1 Without Flood Control and Without Erosion and Sediment Control

Fig. E.1.10 shows the results of simulation. In this figure, the longitudinal variation of the sediment volume, deposition and erosion of the sediment and aggradation and degradation depth of the river bed of low water channel are shown.

Following characteristics in terms of sediment balance and tendency of aggradation and degradation of the river bed can be got from the figure;

(1) There is an unbalance of the longitudinal sediment discharge volume. The sediment discharge volume is relatively smaller in the reaches near the junction with the Canal San Roque, in the middle reach and near the National Road Bridge.

(2) By the unbalance of sediment discharge volume, deposition of sediment is estimated to be occurred in the upstream reach of the junction with the Canal San Roque and the middle reach. The aggradation depth of the river bed in the most downstream reach is estimated to be as much as 120 cm by the 50 year floods. But the aggradation depth for these reaches except the most downstream reach is within 20 cm.

(3) This unstable sediment condition causes aggradation problem in this reach.

(4) Balance of sediment discharge volume of the upstream reaches of debris flow reaches and transition flow reaches between the sediment discharge volume of the bed load reach is evaluated at the National Road Bridge which is the design control point of the erosion and sediment control.

a) Design sediment discharge	:	1,428,000 m^3
b) Sediment discharge volume of bed load	:	6,400 m^3
Difference	:	1,421,600 m^3

The above difference volume is assumed to be mainly deposited within the downstream reach between the junction of the Canal San Roque and the National Road Bridge of about 7.8 km. If the average width of the deposition is supposed to be about 250 m which is the same width of the deepest deposition area of "Fifi", the deposition depth can be estimated to be about 75 cm. This deposition depth almost coincides with the deposition of sediment caused by Hurricane Fifi in 1974.

2) Case 1-2 With Flood Control and With Erosion and Sediment Control

In relation to the flood control, river improvement with compound section of 60 m width of low water channel and 148 m width of high water channel is planned for the reach between the junction of the Canal San Roque and the National Road Bridge. By the erosion and sediment control, check dams and consolidation dams etc. are planned to be installed in the upstream reaches from the National Road Bridge.

Fig. E.1.11 shows the results of the simulation.

(1) The unbalance of sediment discharge of Case 1-1 will be much improved by the river improvement.

(2) Deposition and erosion volume of the sediment as well as aggradation and degradation depth of the river bed will be very small in this reach.

(3) Therefore, this reach will be almost in the dynamic stability condition.

(5) Balance of sediment discharge volume of the upstream reaches from the National Road Bridge between the downstream reach is evaluated at the National Road Bridge.

a) Design allowable sediment discharge	:	142,800 m^3
b) Sediment discharge volume of bed load	:	4,900 m^3
Difference	:	137,900 m^3

The above difference volume is assumed to be mainly deposited within the downstream channel from the National Road Bridge of about 7.8 km. If the deposition of sediment is supposed to be occurred within the low water channel, the average deposition depth is calculated to be about 30 cm which is less than the design allowable height for the embankment of 1.0 m. Therefore the influence of this deposition will be small.

1.4.4 The Rio Blanco

Simulation of sediment discharge and river bed variation for the Rio Blanco is conducted for the river reach from the inlet of Laguna El Carmen to the National Road Bridge (20.50 km - 23.90 km).

1) Case 2-1 Without Flood Control and Without Erosion and Sediment Control

The results of the simulation are shown in *Fig*. E.1.12. The characteristics of the sediment balance and tendency of aggradation and degradation of the river bed are as follows;

(1) There is an unbalance of longitudinal sediment discharge volume.

(2) Aggradation and degradation of the river bed is estimated to be occurred by the above unbalance. But their depth are less than 20 cm only.

(3) Therefore the river channel can be said to be in almost dynamic equilibrium condition from the view point of sediment simulation.

(4) From the local view point, aggradation of the river bed is assumed to be occurred around the National Road Bridge from the results of the sediment simulation. But in really, the degradation of more than 2.0 m is observed at the National Road Bridge and the foundation piers of the bridge are exposed above the river bed.

(5) Hence, artificial unbalance of the sediment discharge is caused by excessive sand taking. This excessive sand taking should be restricted for the stability of the river bed and protection of the bridge piers is necessary to be provided.

(6) Balance of sediment discharge volume of the upstream reaches of debris flow reaches and transition flow reaches between the sediment discharge volume of the bed load reach is evaluated at the National Road Bridge which is the design control point of the erosion and sediment control.

a) Design sediment discharge	:	801,000 m^3
b) Sediment discharge volume of bed load	:	13,400 m^3

Difference : 787,600 m^3

The above difference volume is assumed to be mainly deposited within the downstream channel from the National Road Bridge with about 3.4 km. If the width for the sediment deposition is supposed to be same as the existing river width, the total deposition area between the inlet of Laguna El Carmen and the National Road Bridge becomes about 480,000 m^2. And the average deposition depth is estimated to be about 1.65 m. This deposition depth coincides with the deposition of sediment caused by Hurricane Fifi in 1974.

2) Case 2-2 With Flood Control and With Erosion and Sediment Control

In relation to the flood control, Canal San Roque will be improved with compound section and some embankment will be provided for the downstream reach around the inlet of Laguna El Carmen. The upstream reach from Laguna El Carmen will be remained as without river improvement. By the erosion and sediment control, check dams and training levee etc. are planned to be installed for the upstream reaches from the National Road Bridge.

(1) The sediment balance and the tendency of aggradation and degradation are same as Case 2-1.

(2) Balance of sediment discharge volume of the upstream reaches from the National Road Bridge between the downstream reach is evaluated as follows;

a) Design allowable sediment discharge	:	80,100 m^3
b) Sediment discharge volume of bed load	:	13,400 m^3
Difference	:	66,700 m^3

The above difference volume is assumed to be mainly deposited within the downstream reaches of from the National Road Bridge with 480,000 m^2. The deposition depth is estimated to be only about 15 cm. The influence of this deposition will be small.

3) Annual Inflow Sediment Volume into Laguna El Carmen from the Rio Blanco

The Rio Blanco had originally flowed through the present river course of Rio El Sauce and partly flowed into Laguna El Carmen until 1974. By the Hurricane Fifi of 1974, the main river course of the Rio Blanco was made to be shifted to the present river course by the natural blockade of river cross section caused by sediment deposition around the diverging point of the main river. After 1974, considering this natural shifting of the river course, the river course was changed permanently to the present river course by river improvement including closing of the original river course by the embankment.

Since the completion of the above river improvement, 100 % of the sediment discharge of the Rio Blanco has been flowed into Laguna El Carmen. By this sediment inflow, sediment deposition around the most upstream area of Laguna El Carmen has been accelerated.

In this sub-section, annual sediment inflow volume into Laguna El Carmen from the Rio Blanco is estimated. The estimation was conducted by using the daily rainfall data between 1982 and 1991. Daily sediment discharges volume for these daily rainfall were calculated. The annual sediment discharge volume are as follows ;

Year	Annual Sediment Discharge Vol. (m3)	Year	Annual Sediment Discharge Vol. (m3)
1982	19,600	1987	21,200
1983	17,300	1988	32,000
1984	21,300	1989	20,000
1985	14,100	1990	21,900
1986	18,100	1991	21,200
		Average	21,700

The above annual average sediment discharge of 21,700 m^3 is the quantity which can move a sand bar of 150 m width and 1.5 m height about 100 m per year to the downstream direction. By this sediment inflow and the deposition of the sediment, the river bed slope of the most downstream reach of the Rio Blanco will be made gentle. This will decrease the discharge capacity at the most downstream reach of the Rio Blanco. Before 1974, this kind of sediment unbalance around the inlet portion of Laguna El Carmen had not been occurred.

1.4.5 The Rio El Sauce

Simulation of sediment discharge and river bed variation of the Rio El Sauce as well as the Rio Bermejo/Santa Ana and the Rio Piedras is conducted for the river reach from the junction with the Rio Chamelecon to the upstream (Rio El Sauce : 0.0 km - 14.6 km, Rio Bermejo/Santa Ana : 14.85 km - 16.50 km, Rio Piedras: 14.85 km - 16.85 km).

1) Case 3-1 Without Flood Control and Without Erosion and Sediment Control

Fig. E.1.13 to*Fig*. E.1.15 shows the results of simulation. Characteristics of sediment balance and tendency of aggradation and degradation of the river bed are as follows ;

(1) There is an unbalance of sediment discharge volume in the Rio El Sauce, Rio Bermejo/Santa Ana and Rio Piedras.

(2) As for the Rio El Sauce, sediment discharge volume between 0.0 km and 8.0 km is less than that of upstream. Hence, there is a tendency of sediment deposition in the downstream reach.

(3) Balance of sediment discharge volume of the upstream reaches of debris flow reaches and transition flow reaches between the sediment discharge of bed load reach is evaluated at the National Road Bridges of the Rio Bermejo/Santa Ana and the Rio Piedras which are the design control points of the erosion and sediment control.

Rio Bermejo

a) Design sediment discharge	:	406,000 m^3
b) Sediment discharge volume of bed load	:	100 m^3
Difference	:	405,900 m^3

<u>Rio Piedras</u>

a) Design sediment discharge	:	331,000 m^3
b) Sediment discharge volume of bed load	:	900 m^3
Difference	:	330,100 m^3

The above difference volume (total 736,000 m^3) is assumed to be mainly deposited within the downstream channel from the National Road Bridges with distances of about 14.6 km for the Rio El Sauce, 1.7 km for the Rio Bermejo/Santa Ana and 2.0 km for the Rio Piedras. The deposition area is about 3,708,000 m^2. The average deposition depth is estimated to be about 0.2 m.

2) Case 3-2 With Flood Control and With Erosion and Sediment Control

In relation to the flood control without diversion from the Rio Blanco, river improvement with compound section with 40 m width of low water channel and 148 m width of high water channel will be conducted from 0.0 km to 9.75 km. Upstream from 9.75 km of the Rio El Sauce, Rio Bermejo/Santa Ana and Rio Piedras will be remained as without river improvement. By the erosion and sediment control, check dams etc. are planned to be installed for the upstream reaches from the both National Road Bridges.

Fig. E.1.16 to *Fig*.E.1.18 show the results of simulation. Sediment balance and tendency of river bed variation are as follows ;

(1) Although the sediment discharge volume in the downstream reach from 8.00 km will be improved, there is still an longitudinal unbalance of sediment discharge volume.

(2) There will be an tendency of deposition of sediment in the above downstream reach. But, the depth of deposition is only less than 20 cm.

(3) Hence, periodical cross sectional survey and river bed maintenance including dredging will be necessary to keep the design river cross section.

(4) Balance of sediment discharge volume between the upstream reach from the National Road Bridges and the downstream reaches will be as follows;

<u>Rio Santa Ana/Bermejo</u>

a) Design allowable sediment discharge	:	40,600 m^3
b) Sediment discharge volume of bed load	:	200 m^3
Difference	:	40,400 m^3

Rio Piedras

a) Design allowable sediment discharge	:	33,100 m^3
b) Sediment discharge volume of bed load	:	1,200 m^3
Difference	:	31,900 m^3

The above difference volume (total 72,300 m^3) is assumed to be mainly deposited within the downstream reaches from the National Road Bridges with 1,180,000 m^2. The deposition depth is estimated to be only about 6 cm. The influence of this deposition will be small.

1.4.6 Case 4-1 Diversion Plan of the Rio Blanco with the River Improvement of the Rio El Sauce

Simulation of sediment discharge and river bed variation for the flood control plan of the Rio Blanco and the Rio El Sauce by changing the river course of the Rio Blanco to the Rio El Sauce(junction at 12.60 km) with river improvement of the Rio El Sauce between 0.00 km and 9.75 km.

Fig. E.1.19 to *Fig*. E.1.22 shows the results of the simulation.

1) The Rio Blanco

Characteristics of the sediment balance and river bed variation of the Rio Blanco including the diversion channel are as follows;

(1) There will be an longitudinal unbalance of sediment discharge. Especially, the sediment discharge volume is small around the upstream of the junction of the diversion channel with the Rio El sauce.

(2) By this sediment unbalance, sediment deposition will be occurred around the upstream of the above junction and the deposition depth will be about 25 cm.

(3) Hence, periodical cross sectional survey and river bed maintenance for the diversion channel will be necessary.

(4) Excessive sand taking will be necessary to be restricted for the channel of the Rio Blanco including the diversion channel.

(5) Balance of sediment from the upstream basin and the sediment discharge of the channel of the Rio Blanco is same as described in Case 2-1.

2) The Rio El Sauce

Characteristics of the sediment balance and river bed variation of the Rio El Sauce are as follows;

(1) There will be still an longitudinal unbalance of the sediment discharge volume.

(2) There will be a tendency of sediment deposition in the downstream from the junction of the diversion channel of the Rio Blanco. But the deposition depth will be less than 20 cm.

(3) It will be necessary to conduct periodical river cross sectional survey and river bed maintenance.

(4) Sediment balance between the sediment discharge from the upstream basin and the sediment discharge volume of the Rio Bermejo/Santa Ana and the Rio Piedras will be almost same as described in Case 3-2.

1.5 Summary of the Simulation Results and Recommendation

1) The Rio Choloma

(1) There is an unbalance of sediment discharge volume for the condition of without flood control and erosion and sediment control. Especially, notable tendency of deposition and aggradation of the river bed is estimated to occur in the most downstream reach.

(2) Above tendency will be much improved in the condition of with flood control and erosion and sediment control and the river channel will be almost in the dynamic stability condition.

(3) Difference between the design allowable sediment and the sediment discharge capacity of the channel of the with flood control and sediment control projects will be mainly deposited in the downstream reaches from the National Road Bridge. As this deposition depth will be small, its influence to the channel will be small.

2) The Rio Blanco

(1) Although there is some unbalance of sediment discharge volume for the condition of without flood control and erosion and sediment control, the river channel is almost in the dynamic stability condition.

(2) But, due to the excessive sand taking, artificial degradation of the river bed is occurred. This excessive sand taking should be restricted.

(3) Sediment deposition will happen around the inlet portion of the Laguna El Carmen. The river bed slope of this portion will be made gentle by this sediment deposition.

(4) Difference between the design allowable sediment and the sediment discharge capacity of the channel of the with flood control and erosion and sediment control projects will be mainly deposited in the downstream reaches from the National Road Bridge. The deposition depth and its influence to the channel will be small.

3) The Rio El Sauce

(1) There is an unbalance of sediment discharge volume for the condition of without flood control and erosion and sediment control.

(2) Although above unbalance will be improved in some extent in the with flood control and erosion and sediment control projects, this tendency will be still remained.

(3) Hence, periodical maintenance of the channel will be necessary.

(4) Difference between the design allowable sediment and the sediment discharge capacity of the channel will be mainly deposited in the downstream reaches from the both National Road Bridges of the Rio Santa Ana/Bermejo and the Rio Piedras. The deposition depth and its influence to the channel will be small.

4) The Diversion Plan of the Rio Blanco with the River Improvement of the Rio El Sauce

(1) Sediment deposition will occur around the junction with the Rio El Sauce for the diversion of the Rio Blanco. But the deposition depth is small.

(2) Longitudinal unbalance of the sediment discharge is estimated to occur for the Rio El Sauce.

(3) Hence, periodical maintenance of the channels will be necessary.

(4) Difference between the design allowable sediment and the sediment discharge capacity of the channel will be mainly deposited in the downstream reaches from the both National Road Bridges of the Rio Santa Ana/Bermejo, the Rio Piedras and the Rio Blanco. The deposition depth and its influence to the channel will be small.

2. SEDIMENTOLOGICAL STUDY IN THE FEASIBILITY STUDY STAGE

2.1 General

As the results of the Master Plan Study, the Rio Choloma from the junction with the Canal San Roque to the junction with the Rio La Jutosa, the Rio La Jutosa and the Rio Majaine were selected for the river reaches of the feasibility study for flood control and erosion and sediment control.

In the feasibility study, supplemental river cross sectional survey, hydrological study and flood damage survey etc. were conducted. Based on these upgraded data, the above master plan for the flood control and the erosion and sediment control for the Rio Choloma was upgraded. And the long term flood control and erosion and sediment control projects and the urgent projects of those were formulated as described in the

Supporting Report D " Sediment Yield and Sediment Control Study" and the Supporting Report F "Flood Mitigation Study".

In this chapter, sediment discharge and tendency of aggradation or degradation of the river bed of the Rio Choloma were simulated by using the above upgraded data. By using the results of the above simulations, sediment balance and tendency of aggradation or degradation of the river bed were evaluated.

2.2 Simulation of Sediment Discharge and River Bed Variation

The simulations of sediment discharge of bed load and river bed variation for the Rio Choloma were conducted for the river reaches between the junction with the Canal San Roque and the proposed consolidation dam of about 700 m upstream from the National Road Bridge in this Study (refer to the Supporting Report D " Sediment Yield and Sediment Control Study").

Furthermore, the above simulations were conducted for the design flood hydrograph of 50 year return period. Hydraulic parameters for the bed load calculation were obtained by the non-uniform calculation for the design hydrograph. The river bed materials for the simulation were same as the simulation of the Master Plan Study. The river cross section data of 1993 survey by the JICA Study with about 200 m distance interval were used for the simulations.

The simulation cases are as follows;

Case 1	:	without flood control and erosion and sediment control projects
Case 2	:	with long term flood control and erosion and sediment control projects
Case 3	:	with urgent flood control and erosion and sediment control projects

2.2.1 Case 1 Without Flood Control and Erosion and Sediment Control Project

1) *Fig.* E.2.1 shows the results of the simulation of the Case 1. A tendency of deposition of sediment and aggradation of the river bed can be estimated in the downstream reach near the junction with the Canal San Roque and the middle reach. The aggradation depth of the above downstream reach is estimated to be about 100 cm as the maximum.

This tendency coincides with the sediment simulation conducted in the Master Plan Stage (refer to *Fig*.E.1.10).

Futhermore, a notable tendency of erosion can be estimated around the existing National Road Bridge. The estimated degradation depth of these bridges are about 20 cm to 60 cm. As the existing lowest river bed elevation at the National Road Bridge is almost same as the top of the footing of the existing bridge, river bed protection of the piers of the existing bridge and those of the under constructed bridge is necessary to be provided against the erosion of the river bed.

2) The balance of sediment discharge volume of the upstream reach of debris flow reach and transition flow reaches between the sediment volume of the bed load reach is evaluated at the proposed consolidation dam site (existing accumulative distance 19.780 km).

a) Design sediment discharge	:	1,428,000 m^3
b) Sediment discharge volume of bed load	:	1,300 m^3
Difference	:	1,426,700 m^3

The above difference of the sediment volume will be mainly deposited within the downstream reaches from the proposed consolidation dam. If the average width of the deposition will be about 250 m which is the same width of the deepest deposition area of "Fifi", the average deposition depth will be about 70 cm. This deposition depth is almost same as the deposition depth observed in "Fifi". Considering that the deposition depth of the upstream reach around the proposed consolidation dam will be higher than that of the downstream reach around the junction with the Canal San Roque, the deposition depth will be possible to reach up to 140 cm around the proposed consolidation dam. This 140 cm is almost same deposition depth observed after "Fifi" around the proposed consolidation dam site.

2.2.2 Case 2 With Long Term Flood Control and Erosion and Sediment Control Project

By the long term flood control and erosion and sediment control plan, following facilities will be provided for the Rio Choloma (between the junction with the Canal San Roque and the junction with the Rio La Jutosa), the Rio La Jutosa and the Rio Majaine.

Flood Control Facilities :

River improvement with compound section are planned for the long term plan by the "Flood Mitigation Study" for the river reaches between the junction with the Canal San Roque and the proposed consolidation dam located at 700 m upstream from the National Road Bridge (existing accumulative distance 11.250 km to 19.780 km and the future accumulative distance 11.250 km to 18.885 km). The size of the typical design sections are as follows;

11.250 km - 18.185 km (future accumulative distance) :

Low water channel	: 50 m to 40 m width and 2.0 m to 2.5 m height (to the upstream)
High water channel	: 45 m to 40 m width (to the upstream)
Total width	: 148 m to 130 m (to the upstream)

18.185 km - 18.885 km (future accumulative distance) :

Low water channel	: 40 m width and 2.5 m height
High water channel	: 40 m to 70 m width (to the upstream)
Total width	: 130 m to 300 m (to the upstream)

Erosion and Sediment Control Facilities :

For the erosion and sediment control, 10 check dams, 17 consolidation dams and 1 training levee are proposed for the long term plan by the "Sediment Yield and Sediment Control Study". The numbers of the facilities for the each river are as follows;

Check dam	: total 10 numbers	
	the Rio Majaine	7 numbers
	the Rio La Jutosa	3 numbers
Consolidation dam	: total 17 numbers	
	the Rio Choloma	7 numbers
	the Rio Majaine	2 numbers
	the Rio La Jutosa	8 numbers

Training levee : total 1 number
the Rio Choloma 1 number

1) *Fig.* E.2.2 shows the results of the simulation of Case 2. The notable tendency of deposition of sediment and the aggradation of the river bed of the Case 1 will be much improved and the river course will have a good sediment balance. But, some local tendency of deposition and aggradation of the river bed will be remained in the downstream reach near the junction with the Canal San Roque(11.25 km - 12.00 km), middle reach (13.50 km - 15.50 km) and upstream reach (17.00 km - 17.50 km).

The above tendency of the downstream reach is caused by lack of discharge capacity of the existing Canal San Roque-Cuabanos and the Canal Copen-Higuero-Cuabanos as well as the backwater effect of the flood water level of the Rio Chamelecon. This tendency will not be able to be improved without the river improvement of the above canals and the Rio Chamelecon. Although the estimated aggradation depth is less than 30 cm, periodical maintenance of the channel by dredging will be necessary for this reach.

The above tendency of the middle reach and the upstream reach are the effect of changing of the design river cross sections. But, the aggradation depth will be less than 25 cm and this effect will be small.

Furthermore, although the notable tendency of erosion and degradation around the National Road Bridge will be improved by the river improvement in some extent, this tendency will be remained. The degradation depth will be about 50 cm. Hence, it will be necessary to provide the river bed protection around the National Road Bridge.

2) The balance of sediment discharge volume of the upstream reach of debris flow reach and transition flow reaches between the sediment volume of the bed load reach is evaluated at the proposed consolidation dam site (future accumulative distance 18.885 km).

a) Design allowable sediment discharge	:	142,800 m^3
b) Sediment discharge volume of bed load	:	4,900 m^3
Difference	:	137.900 m^3

The above difference of the sediment volume will be mainly deposited between the proposed consolidation dam and the junction with the Canal San Roque of 7.64 km of the future distance. Supposing that the sediment deposition will occur within the low water channel with the width of 50 m to 40 m, the deposition area will be about 329,200 m^2. Then the average deposition depth will be 40 cm which is less than the design allowable height for the embankment of 1.0 m.

Considering that the deposition depth of the upstream reach around the proposed consolidation dam will be higher than that of the downstream reach around the junction with the Canal San Roque, the deposition depth will be possible to reach up to 80 cm around the proposed consolidation dam. But this maximum deposition depth will be also within the design allowable height of the embankment and the deposition is assumed to occur within the low water channel.

Hence, the influence of this deposition will be small.

2.2.3 Case 3 With Urgent Flood Control and Erosion and Sediment Control Project

By the urgent flood control and erosion and sediment control plan, following facilities will be provided for the Rio Choloma (between 15.610 km of existing accumulative distance and the junction with the Rio La Jutosa), the Rio La Jutosa and the Rio Majaine.

Flood Control Facilities :

River improvement with compound section are planned for urgent plan by the "Flood Mitigation Study" for the river reaches between the middle reach and the proposed consolidation dam (existing accumulative distance 15.610 km to 19.780 km and the provisional accumulative distance of the urgent projects of 15.610 km to 19.105 km). From the junction with the Canal San Roque to 15.610 km, existing channel will be remained. The size of the typical design sections are as follows;

15.610 km - 18.405 km (provisional accumulative distance) :

Low water channel : 40 m width and 2.5 m height
High water channel : 40 m width

Total width : 130 m

18.405 km - 19.105 km (provisional accumulative distance) :

Low water channel : 40 m width and 2.5 m height
High water channel : 15 m to 70 m width (to the upstream)
Total width : 90 m to 300 m (to the upstream)
(At the National Road Bridge, existing width of 90 m will not be changed.)

Erosion and Sediment Control Facilities :

For the erosion and sediment control, 2 check dams, 2 consolidation dams and 1 training levee are proposed for the urgent plan by the "Sediment Yield and Sediment Control Study". The numbers of the facilities for the each river are as follows;

Check dam	: total 2 numbers	
	The Rio Majaine	1 numbers
	The Rio La Jutosa	1 numbers
Consolidation dam	: total 2 numbers	
	The Rio Choloma	2 numbers
Training levee	: total 1 number	
	The Rio Choloma	1 number

1) *Fig*. E.2.3 shows the results of the simulation of Case 3. The notable tendency of deposition of sediment and the aggradation of the river bed in the downstream reach of the existing channel reaches will be remained. Some tendency of deposition can be estimated to occur near the most downstream reach of the river improvement (15.610 km) due to the backwater effect from the existing channel in the downstream which has small discharge capacity. Although the estimated deposition depth of this reach will be only about 30 cm, periodical maintenance by dredging will be necessary to be provided to keep the improved river channel.

Furthermore, as the tendency of erosion and degradation around the National Road Bridge will be remained, river bed protection around the National Road Bridge will be also necessary to be provided..

2) The balance of sediment discharge volume of the upstream reach of debris flow reach and transition flow reaches between the sediment volume of the bed load reach is evaluated at the proposed consolidation dam site (provisional accumulative distance 19.105 km).

By the urgent erosion and sediment control facilities, the design discharge of 1,428,000 m^3 will be controlled and about 985,200 m^3 will be flowed down through the proposed consolidation dam (at 19.105 km).

a) Sediment discharge from the consolidation dam	:	985,200 m^3
b) Sediment discharge volume of bed load	:	5,300 m^3
Difference	:	979.900 m^3

The above difference of the sediment volume will be mainly deposited between the proposed consolidation dam and the junction with the Canal San Roque of 7.86 km of the provisional distance. Supposing that the sediment deposition of the improved channel will occur within the low water channel with the width of 40 m, and sediment deposition for the existing channel will occur within the flood plain with the width of 250m, the average deposition depth will be about 80 cm which is less than the design allowable height for the embankment of 1.0 m.

Considering that the deposition depth of the upstream reach around the proposed consolidation dam will be higher than that of the downstream reach around the junction with the Canal San Roque, even though the deposition is assumed to occur within the low water channel, there will be some possibility that the deposition depth will reach the design allowable height of embankment of 1.0 m in some places of the upstream reach. Hence, it will be necessary to continue the step by step construction of the erosion and sediment control facilities aiming the facilities of the long term plan.

2.3 Summary of the Simulation Results and Recommendation

The results of the sediment discharge and river bed variation for the river reaches of the Rio Choloma between the junction with the Canal San Roque and the proposed consolidation dam are summarized as follows;

1) Without Flood Control and Erosion and Sediment Control Project

(1) There is an unbalance of sediment discharge volume. There is a notable tendency of deposition of sediment and aggradation of the river bed in the most downstream reach near the junction with the Canal San Roque.

(2) At the existing National Road Bridge, notable tendency of erosion can be estimated. Hence, river bed protection against this erosion is necessary to be provided around the National Road Bridge.

2) With Long Term Flood Control and Erosion and Sediment Control Project

(1) The above unbalance will be much improved and the river course will have good sediment balance.

(2) But, some local tendency of deposition and erosion of sediment such as the deposition of the most downstream reach and the erosion around the National Road Bridge will be remained even though their depth will be smaller than the without projects condition.

(3) Hence, periodical maintenance of the river channel in the most downstream reach and the river bed protection around the National Road Bridge will be indispensable.

(4) The difference of the design allowable sediment and the sediment discharge capacity of the channel will be mainly deposited in the river channel downstream from the proposed consolidation dam and this effect to the river channel will be small.

3) With Urgent Flood Control and Erosion and Sediment Control Project

(1) The unbalance of sediment discharge of 1) will be much improved in the improved river channel reach.

(2) But, some local tendency of deposition and erosion of sediment such as the deposition of the most downstream reach of the river improvement and the

erosion around the National Road Bridge will be remained even though their depth will be smaller than the without projects condition.

(3) Hence, periodical maintenance of the river channel in the most downstream reach and the river bed protection around the National Road Bridge will be also indispensable.

(4) The difference of the design allowable sediment and the sediment discharge capacity of the channel will be mainly deposited in the river channel downstream from the proposed consolidation dam. As the deposition depth will be more than twice of the long term plan, it will be necessary to continue the step by step construction of the erosion and sediment control facilities of the long term plan to reduce the sediment discharge from the upstream basin.

FIGURES

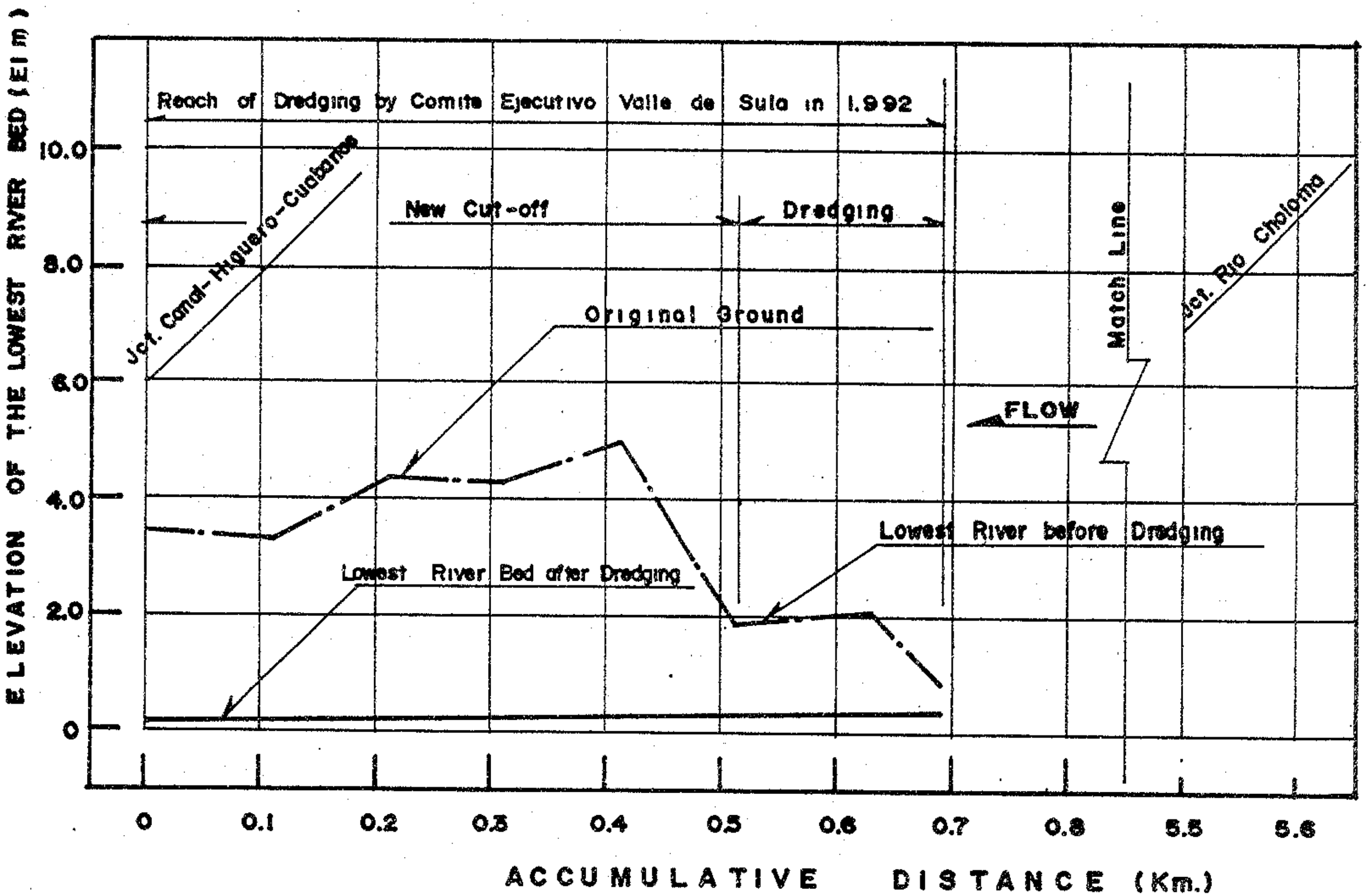


FIG. E.1.1 DEPOSITION OF SEDIMENT IN THE MOST DOWNSTREAM REACH OF THE CANAL SAN ROQUE-CUABANOS IN 1992

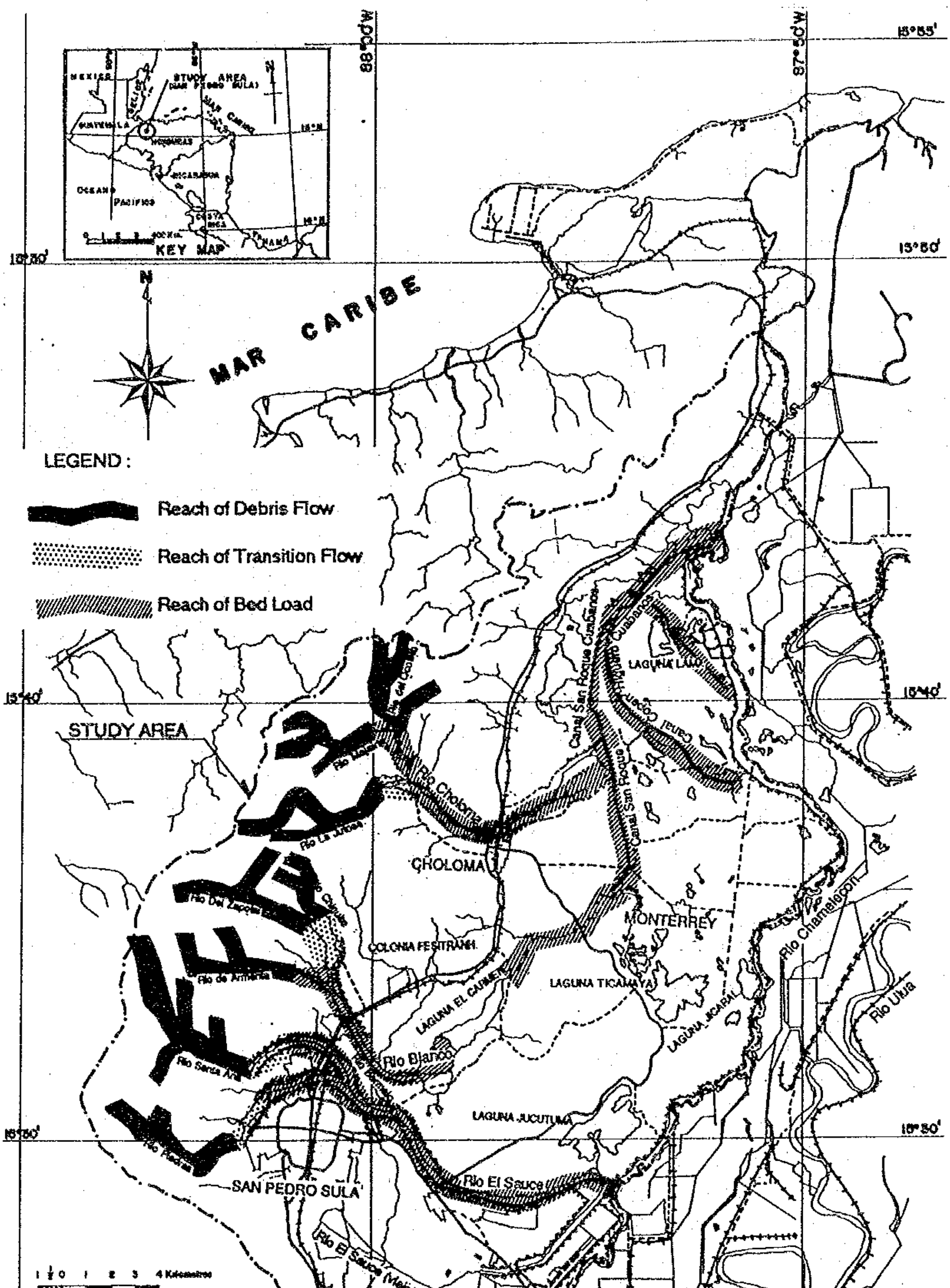


FIG. E.1.2 **PATTERNS OF THE SEDIMENT FLOW OF THE RIO CHOLOMA, THE RIO BLANCO AND THE RIO EL SAUCE**

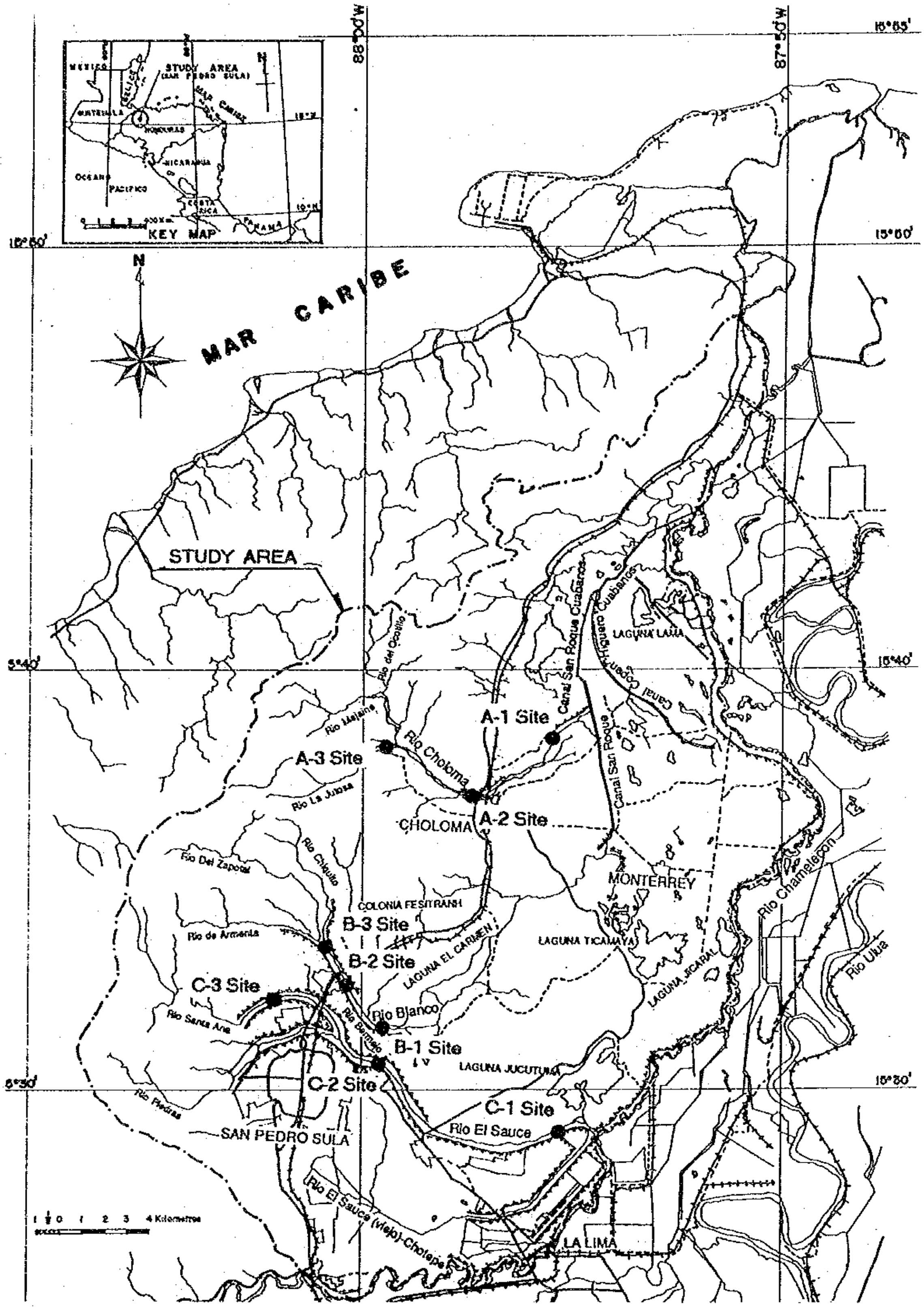
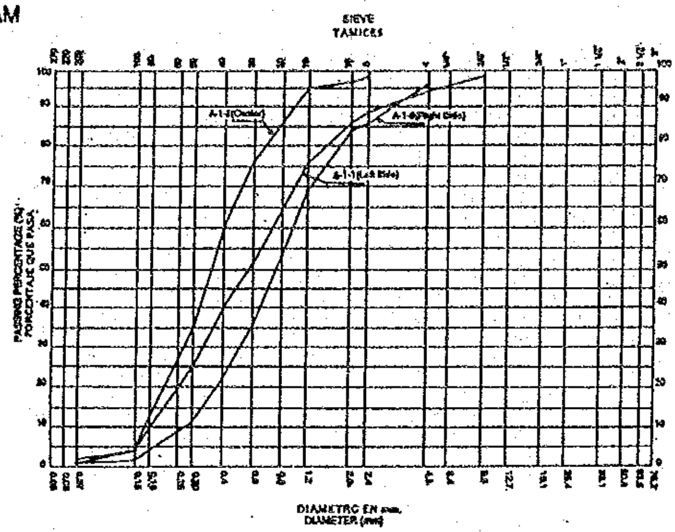


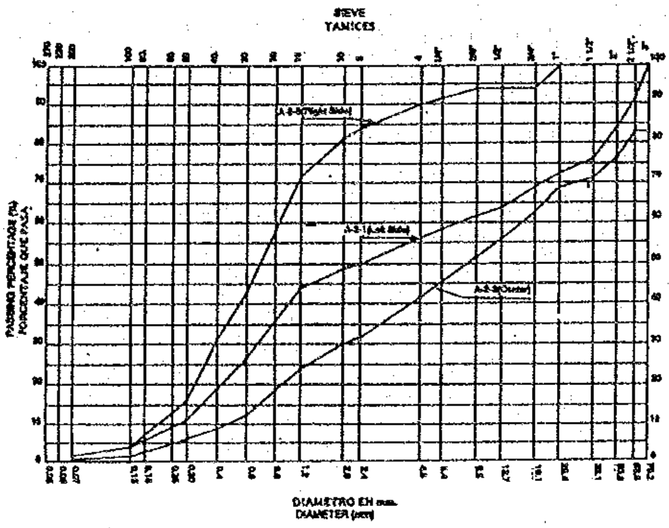
FIG. E.1.3 **SAMPLING SITES OF THE RIVER BED MATERIALS INVESTIGATIONS FOR THE RIO CHOLOMA, RIO BLANCO AND RIO EL SAUCE**

A-1 SITE : DOWNSTREAM
(Acc. Distance =13.5 km)



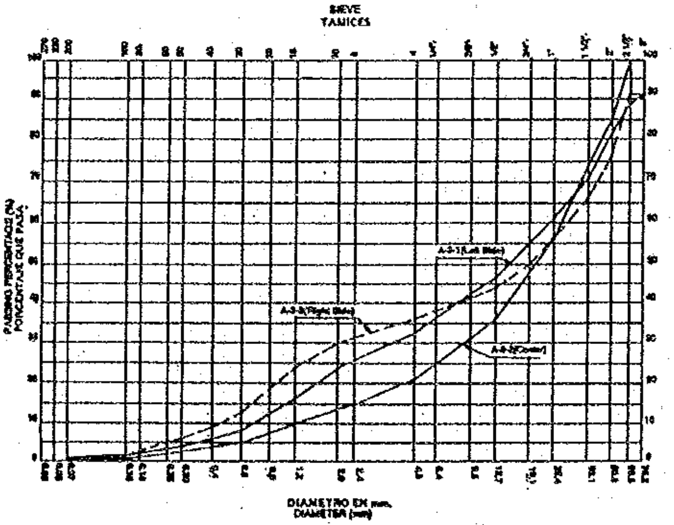
SITE	A-1-1	A-1-2	A-1-3	Average
dm(mm)	1.97	0.54	1.86	1.97
d90(mm)	8.20	1.04	3.96	3.28
ds(mm)	-	-	-	-
s/w	2.79	2.79	2.71	2.76

A-2 SITE : MIDSTREAM
(Acc. Distance = 19.1 km)



SITE	A-2-1	A-2-2	A-2-3	Average
dm(mm)	17.17	23.78	2.97	20.47
d90(mm)	80.33	-	4.80	80.33
ds(mm)	-	87.20	-	-
s/w	2.72	2.73	2.78	2.74

A-3 SITE : UPSTREAM
(Acc.Distance = 24.1 km)

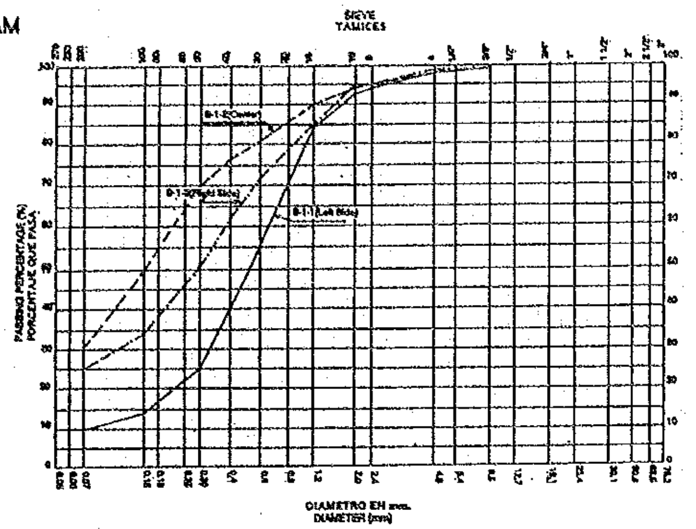


SITE	A-3-1	A-3-2	A-3-3	Average
dm(mm)	24.07	23.77	25.38	24.41
d90(mm)	69.95	-	51.81	65.93
ds(mm)	78.70	77.30	-	78.00
s/w	2.79	2.78	2.78	2.78

Legend :
dm : average diameter
d90 : 90 % diameter
ds : diameter of armour coat
s/w : specific gravity

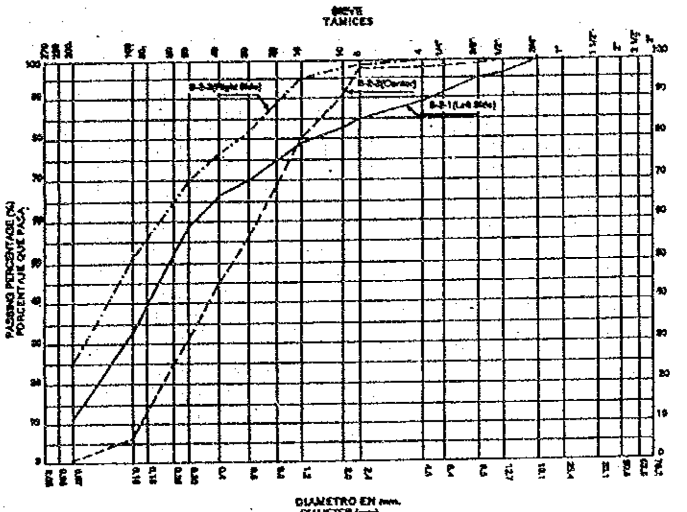
FIG. E.1.4 **RESULTS OF PARTICLE SIZE ANALYSIS OF THE RIVER BED MATERIALS AT THE SAMPLING SITES (1/3) - THE RIO CHOLOMA**

B-1 SITE : DOWNSTREAM
(Acc. Distance =14.5 km)



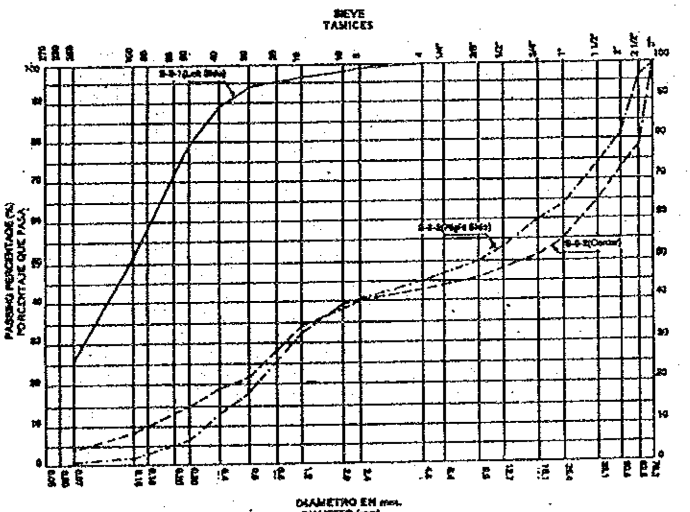
SITE	B-1-1	B-1-2	B-1-3	Average
dm(mm)	0.91	0.58	0.61	0.70
d90(mm)	1.78	1.20	1.20	1.39
ds(mm)	-	-	-	-
s/w	2.67	2.68	2.68	2.68

B-2 SITE : MIDSTREAM
(Acc. Distance = 17.4 km)



SITE	B-2-1	B-2-2	B-2-3	Average
dm(mm)	1.59	0.88	0.36	0.94
d90(mm)	5.58	1.93	0.97	2.83
ds(mm)	-	-	-	-
s/w	2.66	2.69	2.69	2.68

B-3 SITE : UPSTREAM
(Acc.Distance = 19.5 km)

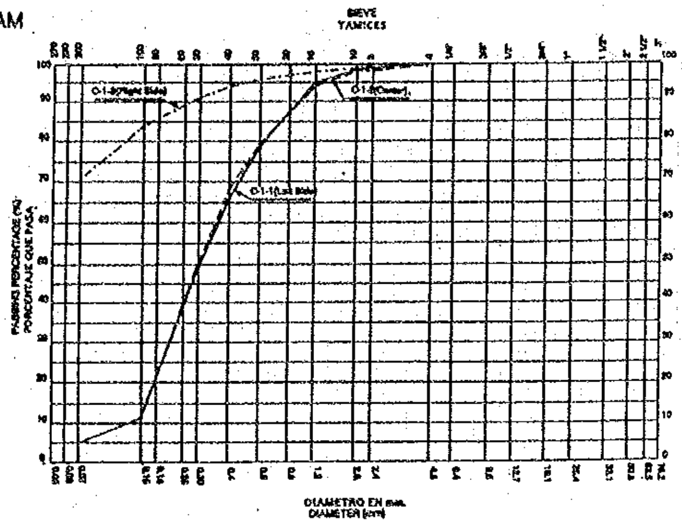


SITE	B-3-1	B-3-2	B-3-3	Average
dm(mm)	0.28	26.62	20.28	23.44
d90(mm)	0.44	70.69	50.81	60.75
ds(mm)	-	87.90	83.20	85.60
s/w	2.61	2.69	2.67	2.68

Legend :
dm : average diameter
d90 : 90 % diameter
ds : diameter of armour coat
s/w : specific gravity

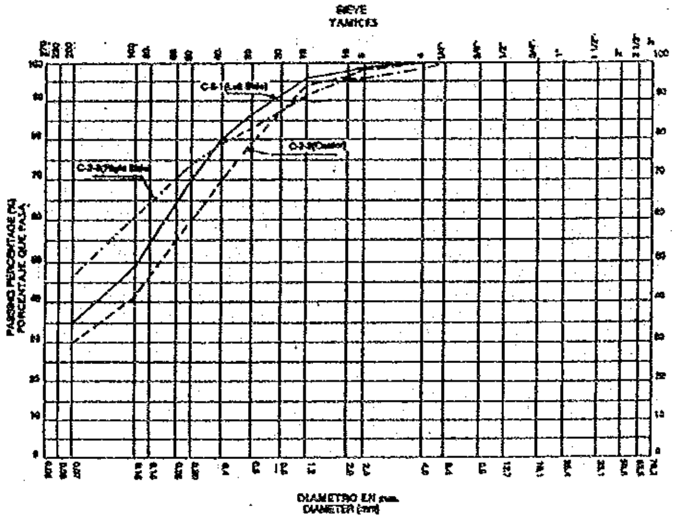
FIG. E.1.4 **RESULTS OF PARTICLE SIZE ANALYSIS OF THE RIVER BED MATERIALS AT THE SAMPLING SITES (2/3) - THE RIO BLANCO**

C-1 SITE : DOWNSTREAM
(Acc. Distance =4.5 km)



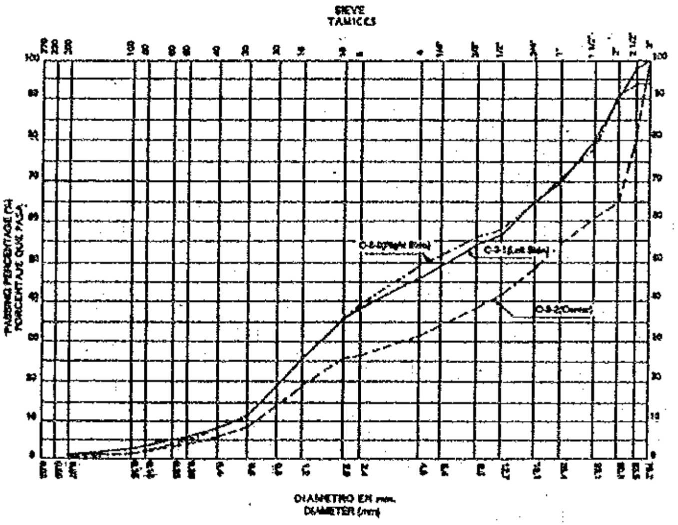
SITE	C-1-1	C-1-2	C-1-3	Average
dm(mm)	0.47	0.49	0.15	0.68
d90(mm)	1.02	1.04	0.28	1.03
da(mm)	-	-	-	-
s/w	2.69	2.71	2.66	2.68

C-2 SITE : MIDSTREAM
(Acc. Distance = 13.0 km)



SITE	C-2-1	C-2-2	C-2-3	Average
dm(mm)	0.82	0.42	0.48	0.40
d90(mm)	0.80	1.04	1.07	0.87
da(mm)	-	-	-	-
s/w	2.72	2.74	2.64	2.70

C-3 SITE : UPSTREAM
(Acc.Distance = 19.2 km)



SITE	C-3-1	C-3-2	C-3-3	Average
dm(mm)	17.03	29.67	17.47	21.49
d90(mm)	60.80	89.85	49.44	66.70
da(mm)	60.30	61.10	62.90	61.40
s/w	2.69	2.71	2.73	2.71

Legend :
dm : average diameter
d90 : 90 % diameter
da : diameter of armour coat
s/w : specific gravity

FIG. E.1.4 **RESULTS OF PARTICLE SIZE ANALYSIS OF THE RIVER BED MATERIALS AT THE SAMPLING SITES (3/3) - THE RIO EL SAUCE**

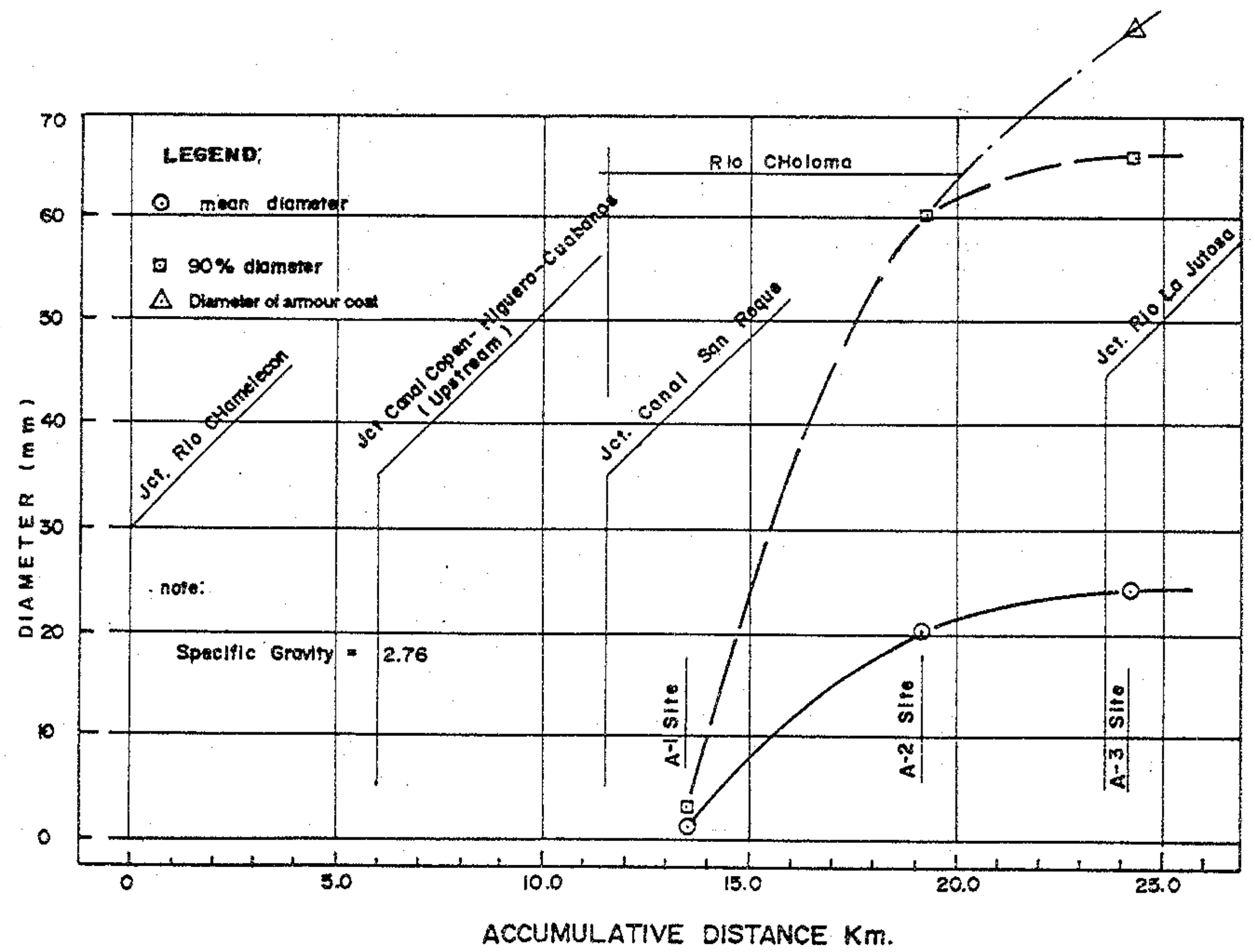


FIG. E.1.5 LONGITUDINAL VARIATION OF THE DIAMETER OF RIVER BED MATERIALS (1/3)
- THE RIO CHOLOMA

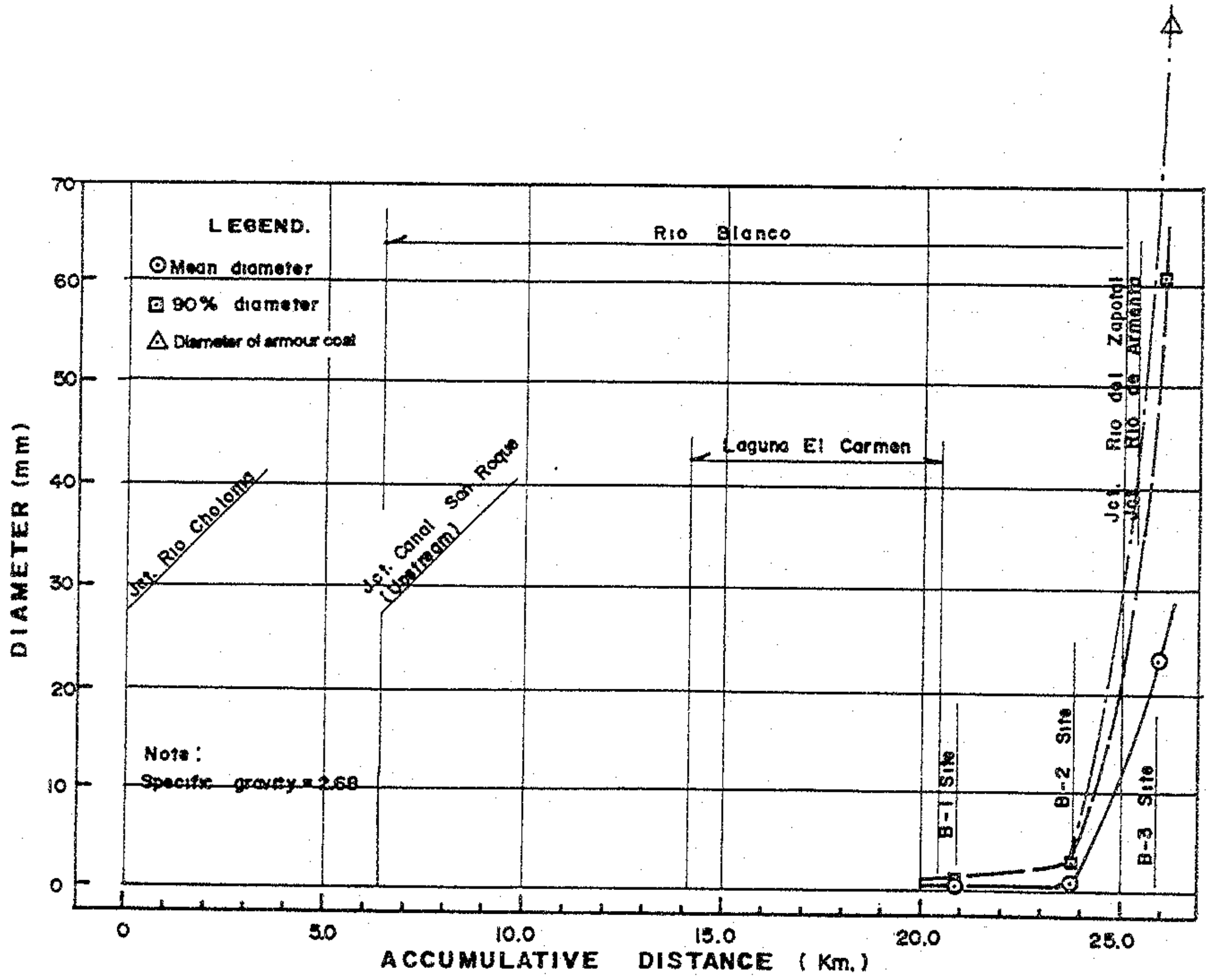


FIG. E.1.5 LONGITUDINAL VARIATION OF THE DIAMETER OF RIVER BED MATERIALS (2/3)
- THE RIO BLANCO

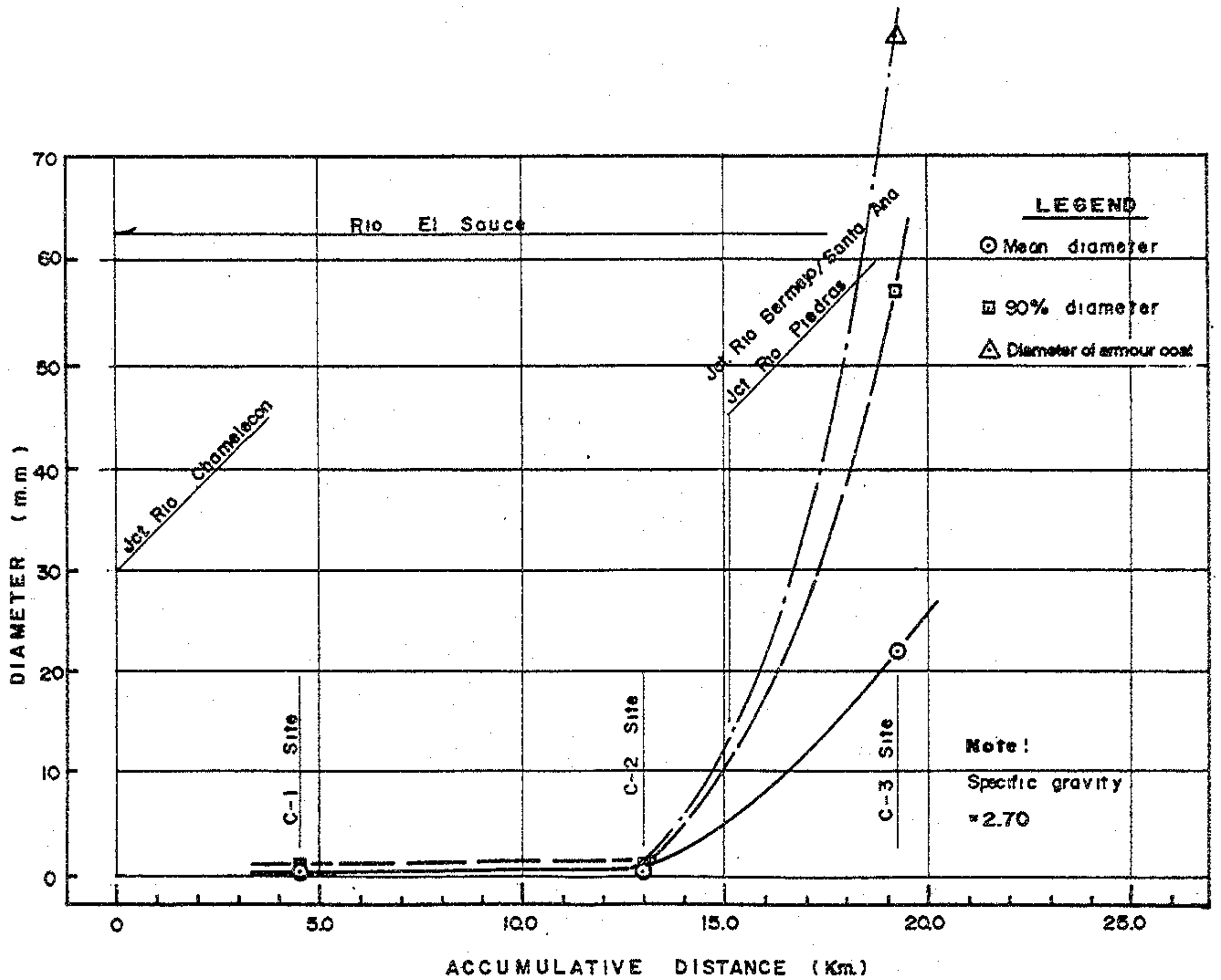
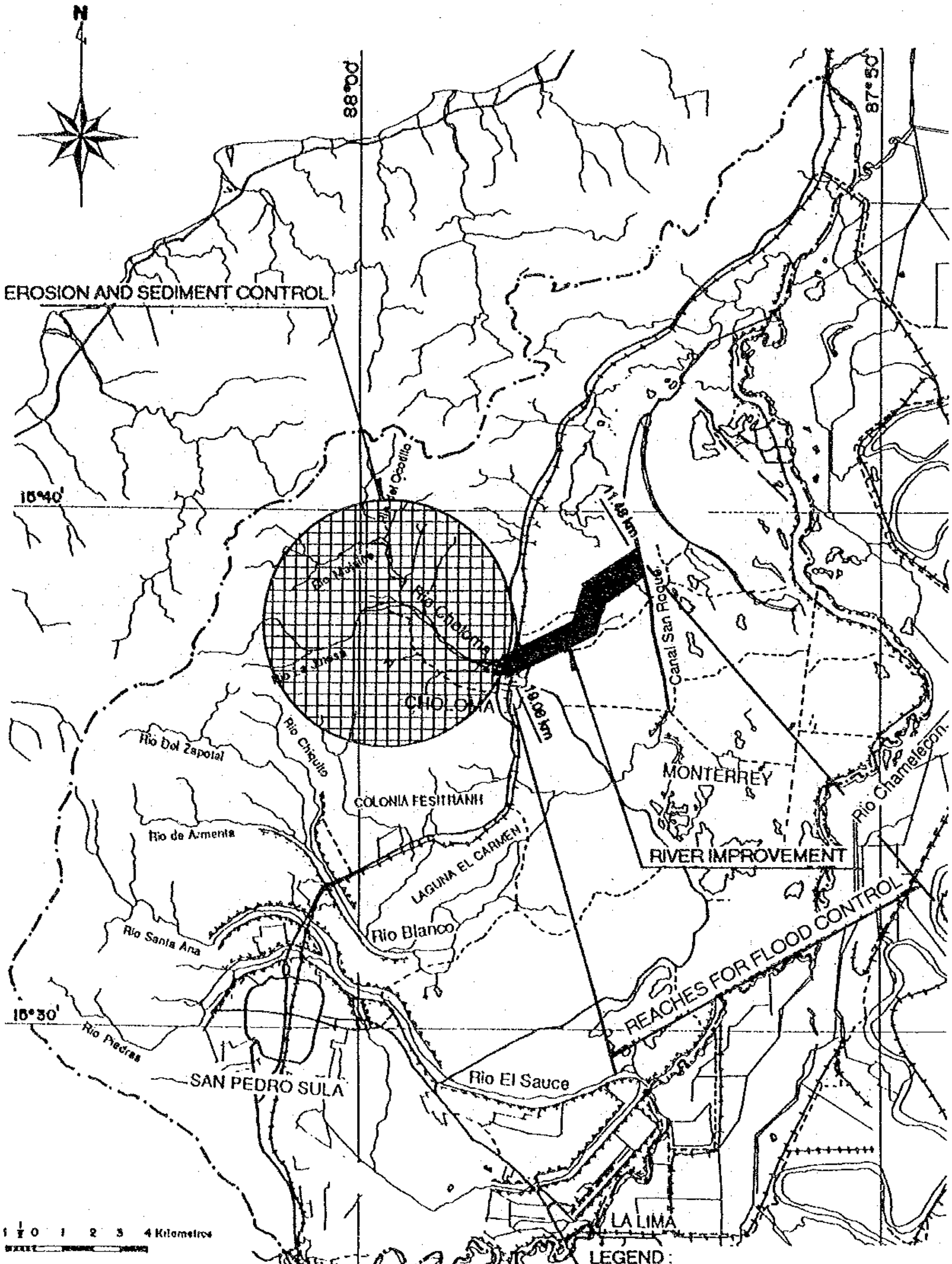


FIG. E.1.5 LONGITUDINAL VARIATION OF THE DIAMETER OF RIVER BED MATERIALS (3/3)
- THE RIO EL SAUCE



LEGEND :

△ CONTROL POINT FOR EROSION AND SEDIMENT CONTROL

FIG. E.1.6 **COMBINATION OF RIVER IMPROVEMENT AND EROSION AND SEDIMENT CONTROL FOR CASE 1-2 - RIO CHOLOMA (WITH PROJECT)**

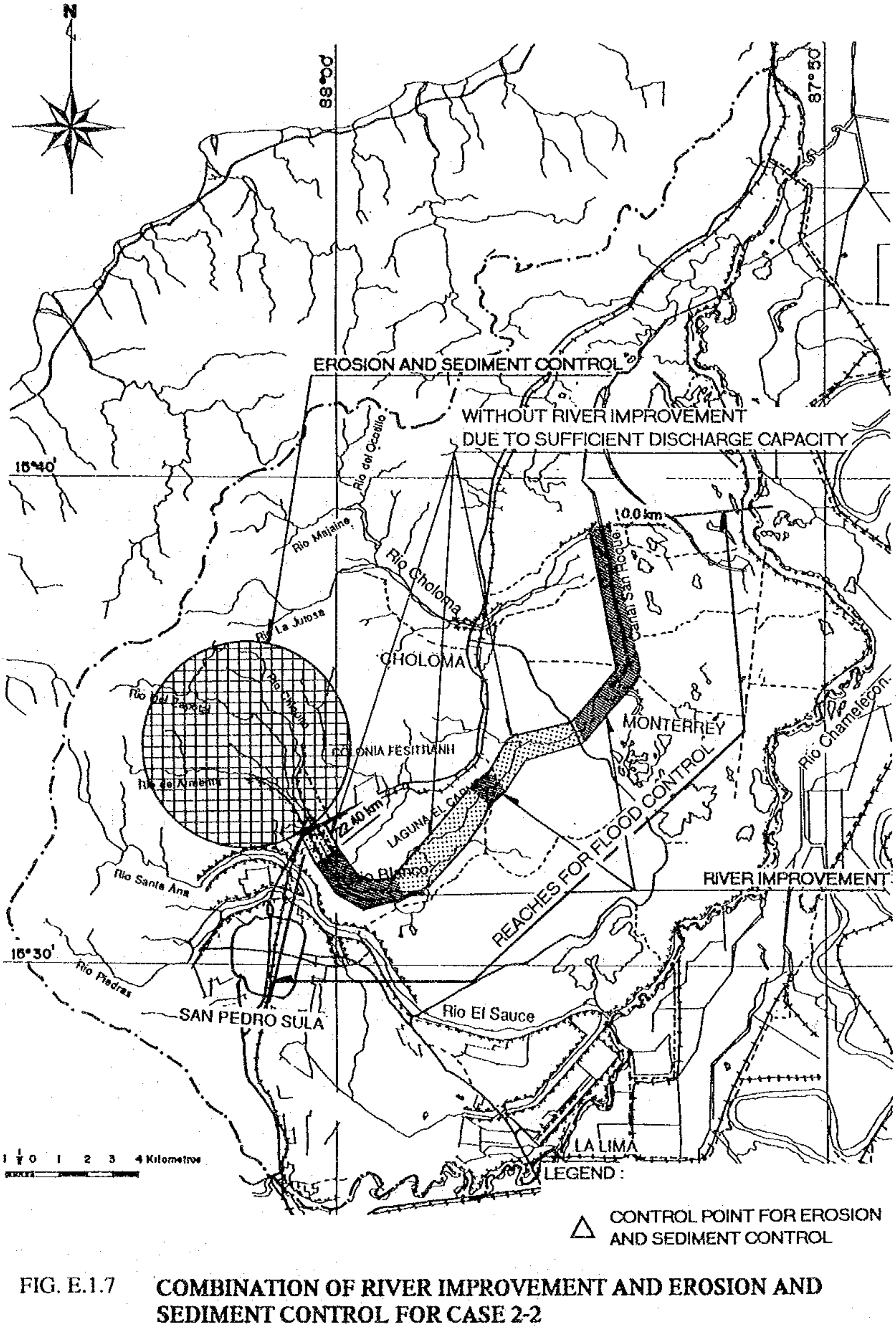


FIG. E.1.7 **COMBINATION OF RIVER IMPROVEMENT AND EROSION AND SEDIMENT CONTROL FOR CASE 2-2 - RIO BLANCO (WITH PROJECT)**

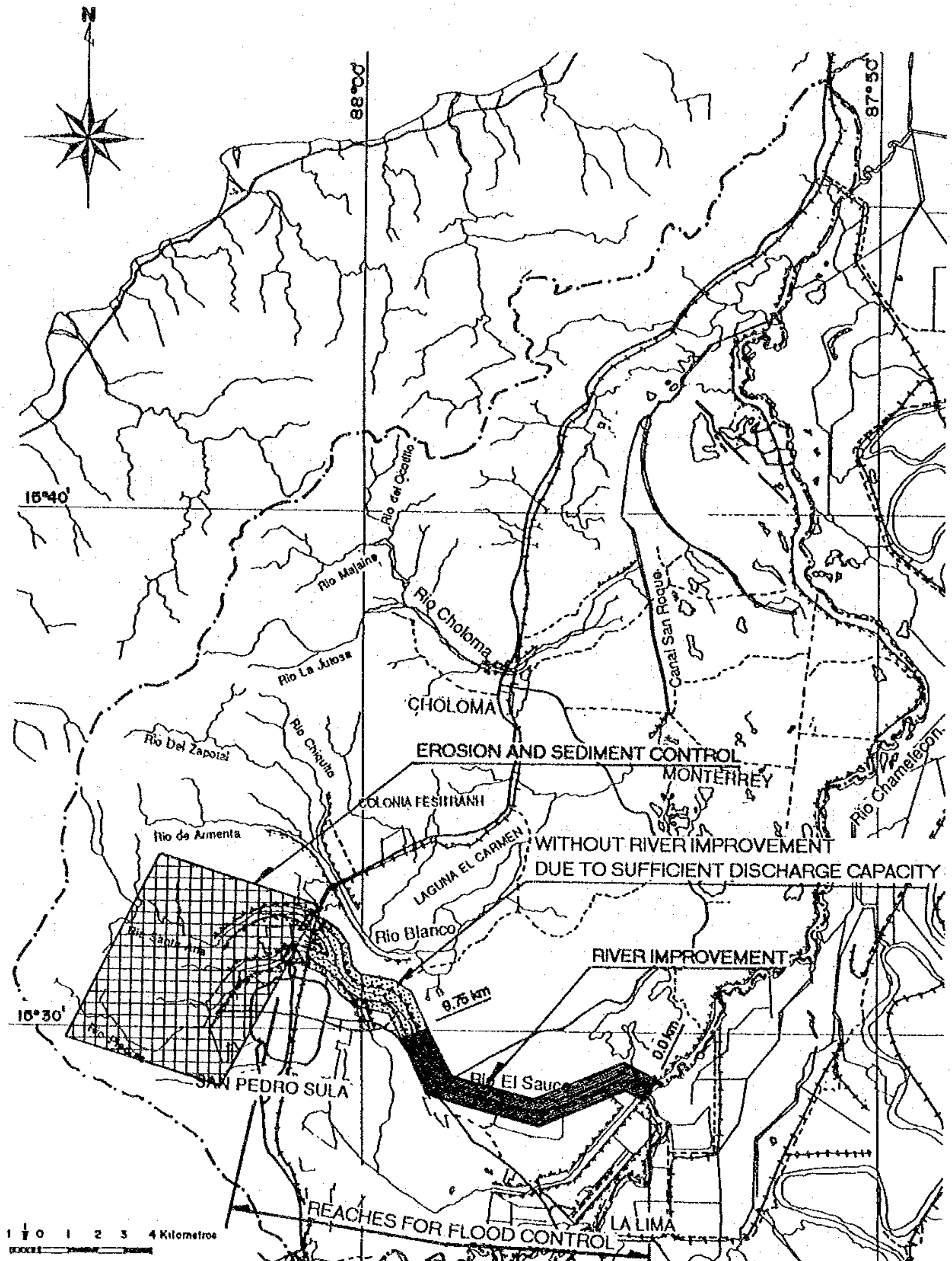


FIG. E.1.8 **COMBINATION OF RIVER IMPROVEMENT AND EROSION AND SEDIMENT CONTROL FOR CASE 3-2 - RIO EL SAUCE (WITH PROJECT)**

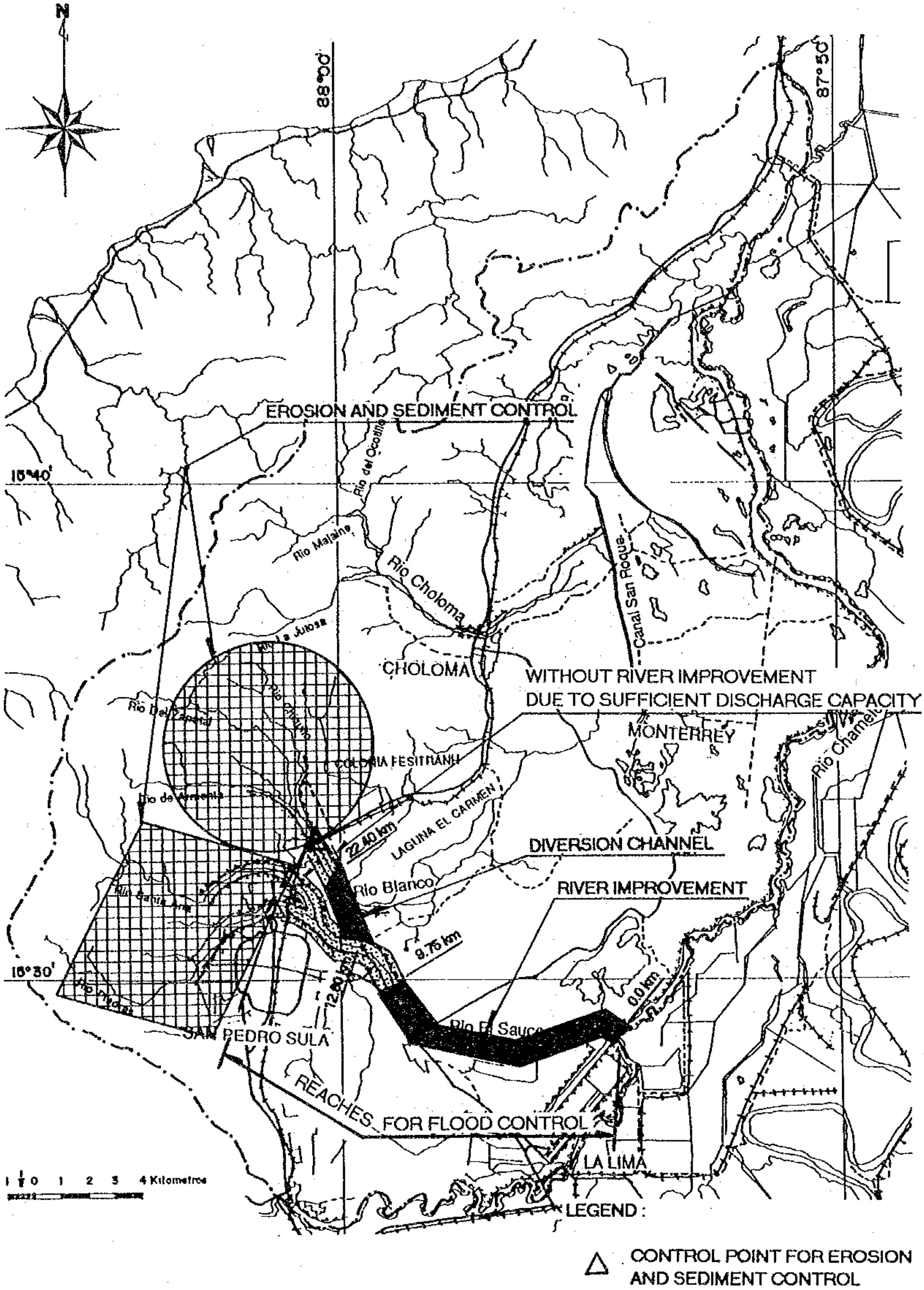


FIG. E.1.9 **COMBINATION OF RIVER IMPROVEMENT AND EROSION AND SEDIMENT CONTROL FOR CASE 4-1 - DIVERSION PLAN OF THE RIO BLANCO**

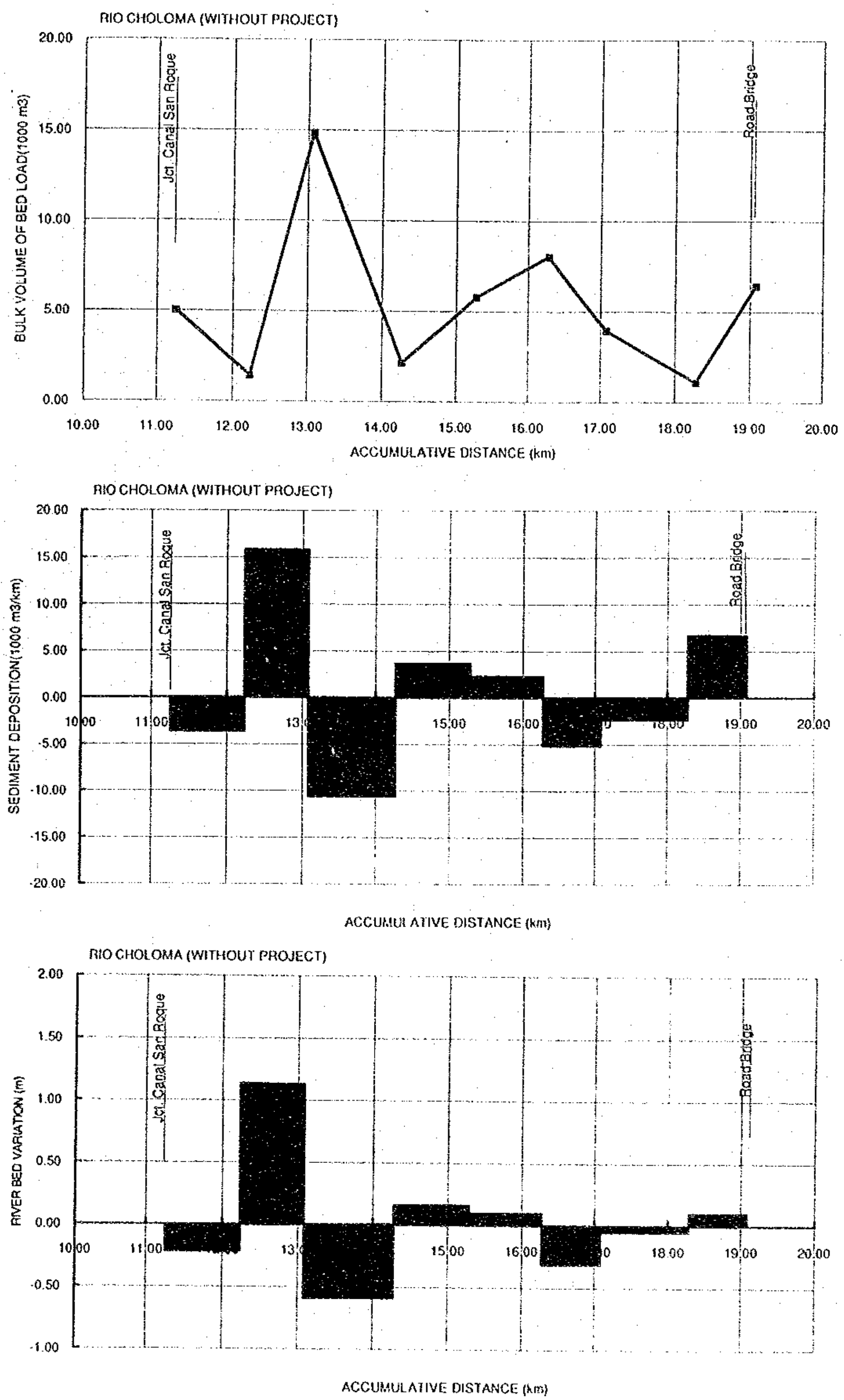


FIG. E.1.10 RESULTS OF SEDIMENT SIMULATION OF THE RIO CHOLOMA (CASE 1-1 WITHOUT PROJECT)

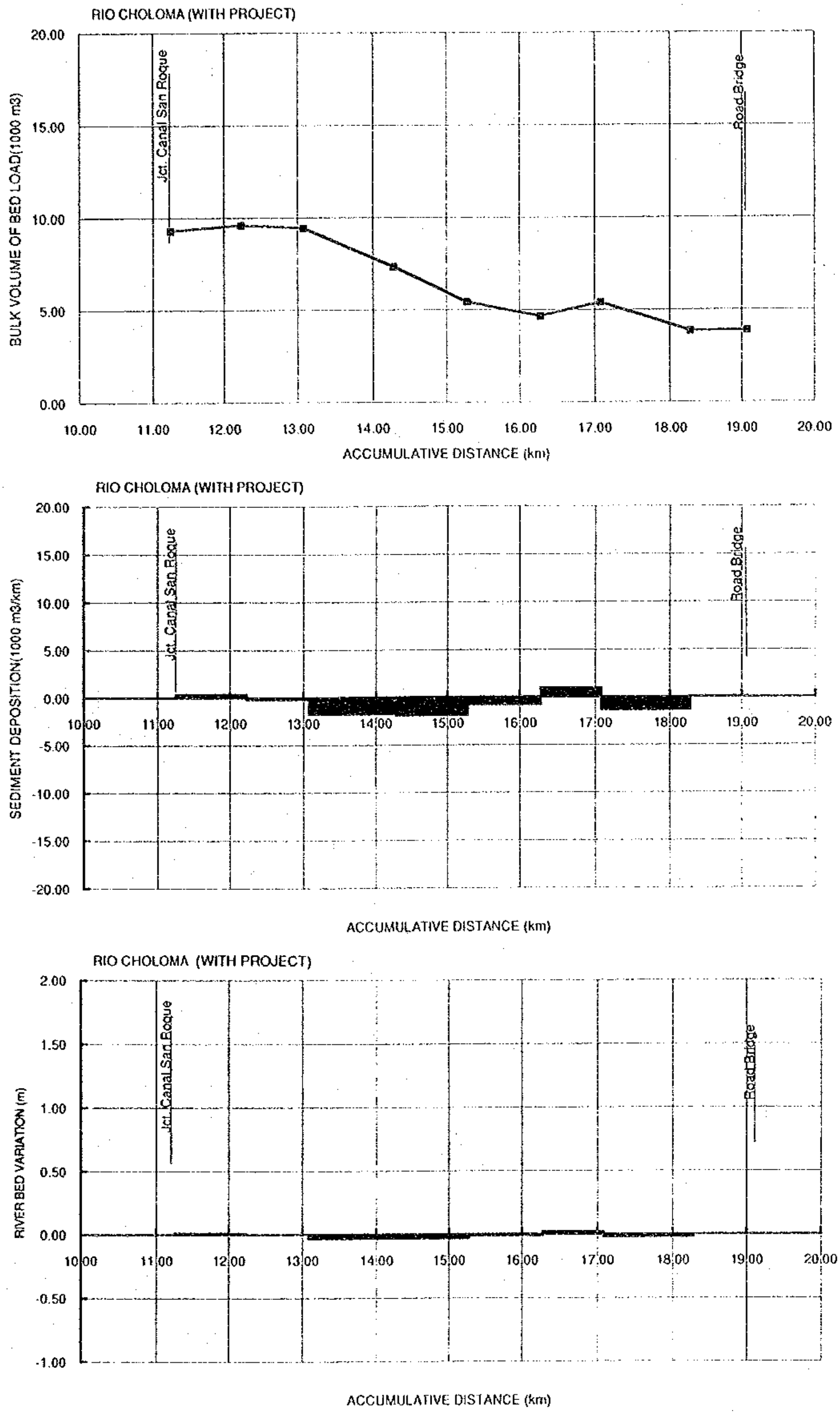


FIG. E.1.11 RESULTS OF SEDIMENT SIMULATION OF THE RIO CHOLOMA (CASE 1-2 WITH PROJECT)

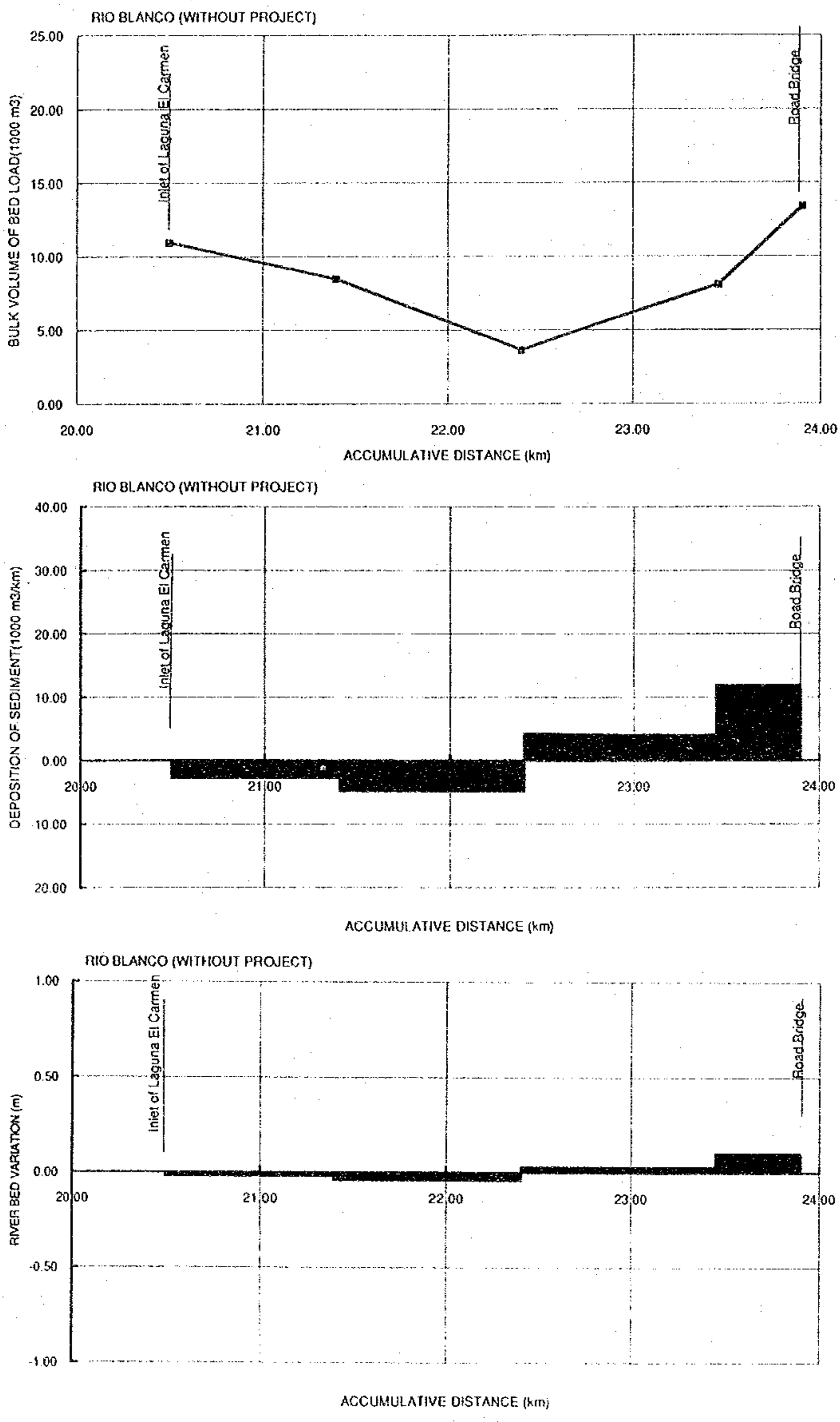


FIG. E.1.12 RESULTS OF SEDIMENT SIMULATION OF THE RIO BLANCO (CASE 2-1 WITHOUT PROJECT)

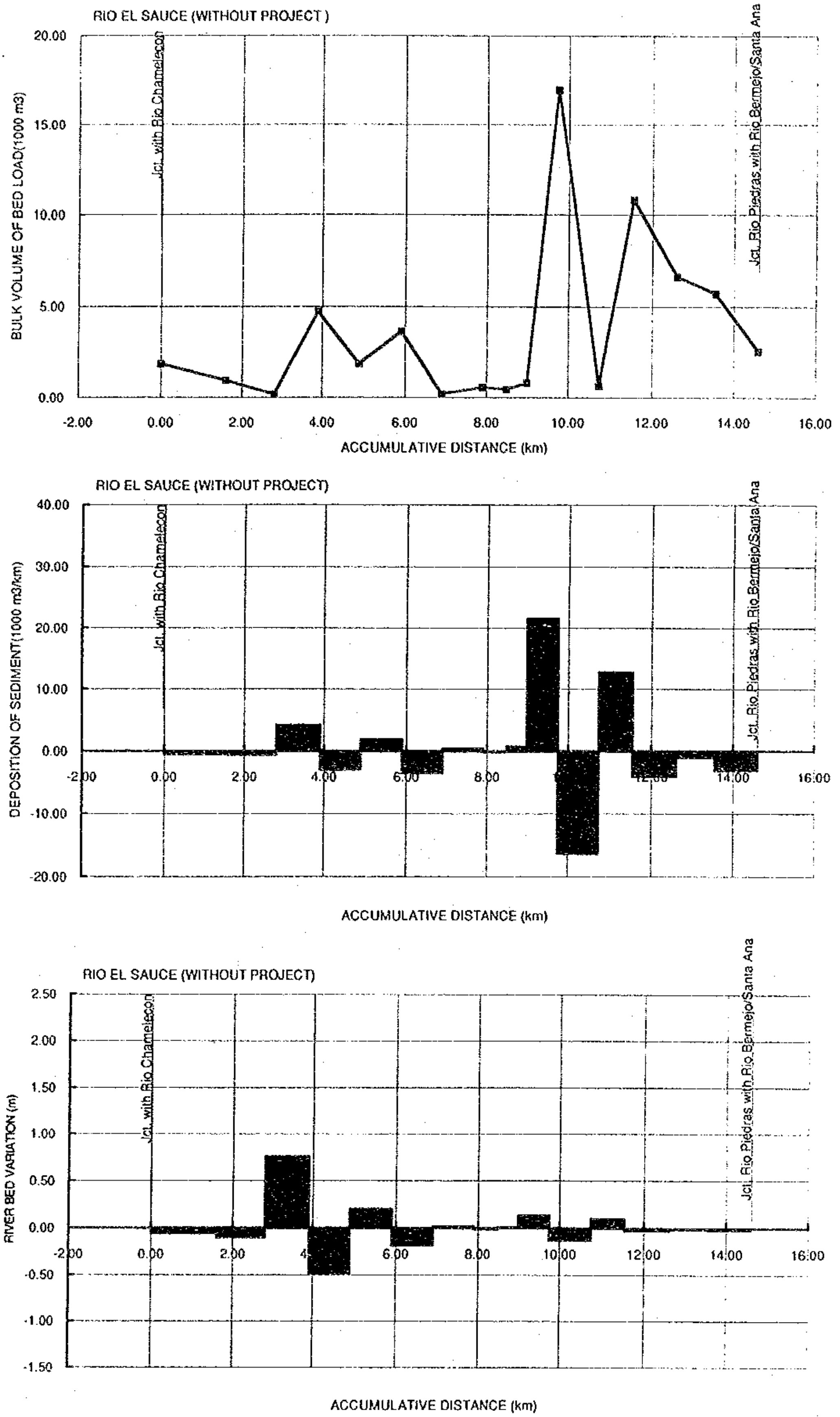
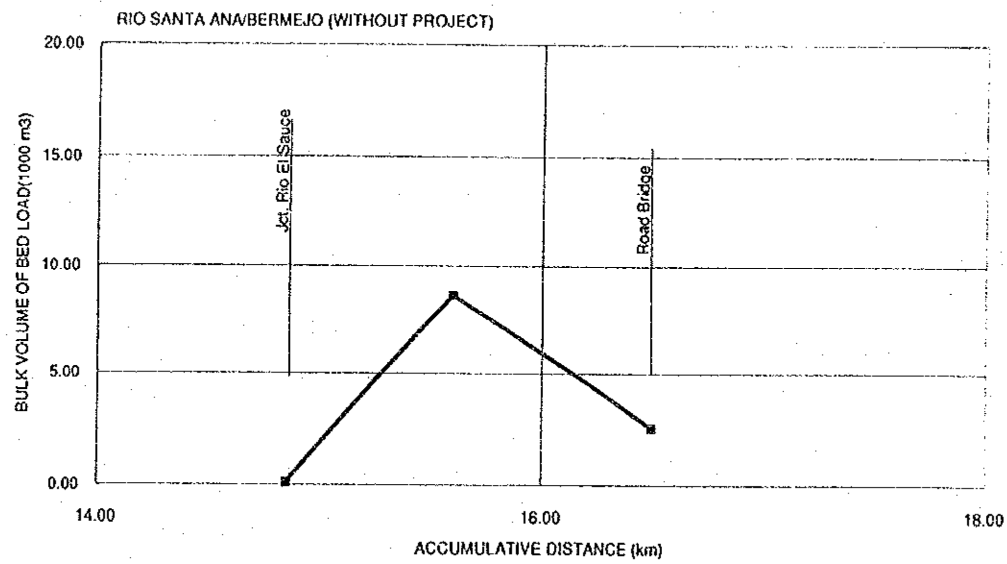
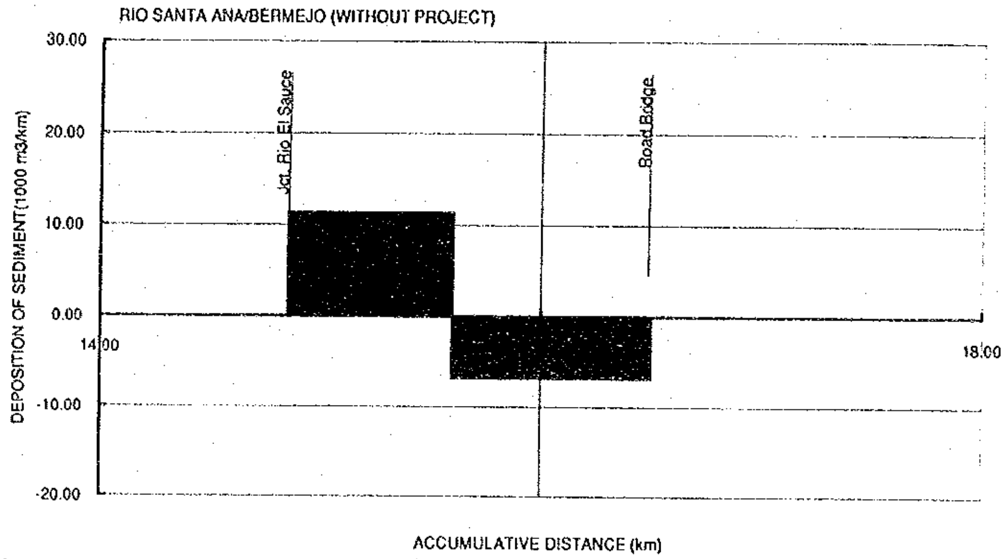


FIG. E.1.13 RESULTS OF SEDIMENT SIMULATION OF THE RIO EL SAUCE (CASE 3-1 WITHOUT PROJECT)





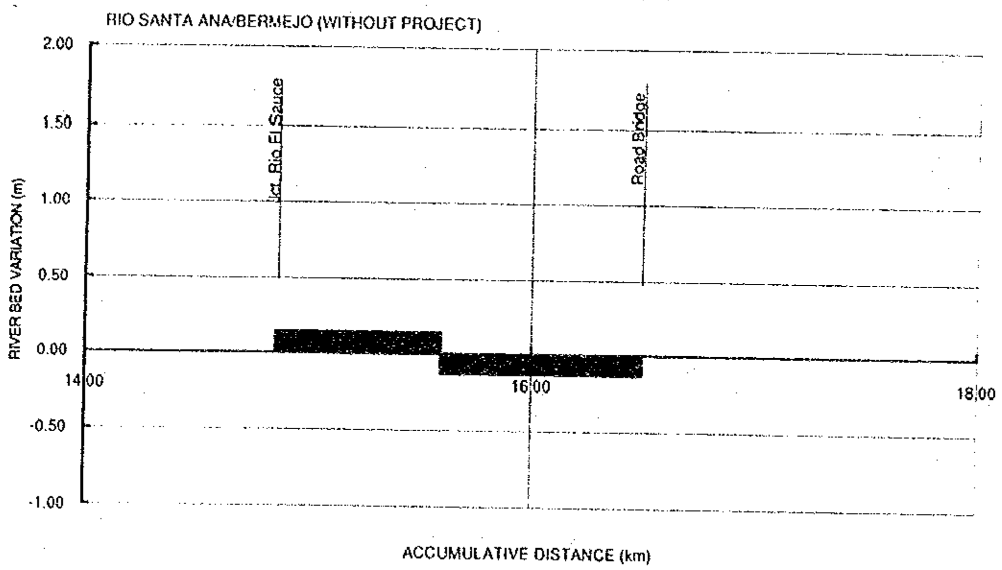


FIG. E.1.14 RESULTS OF SEDIMENT SIMULATION OF THE RIO SANTA ANA/BERMEJO (CASE 3-1 WITHOUT PROJECT)

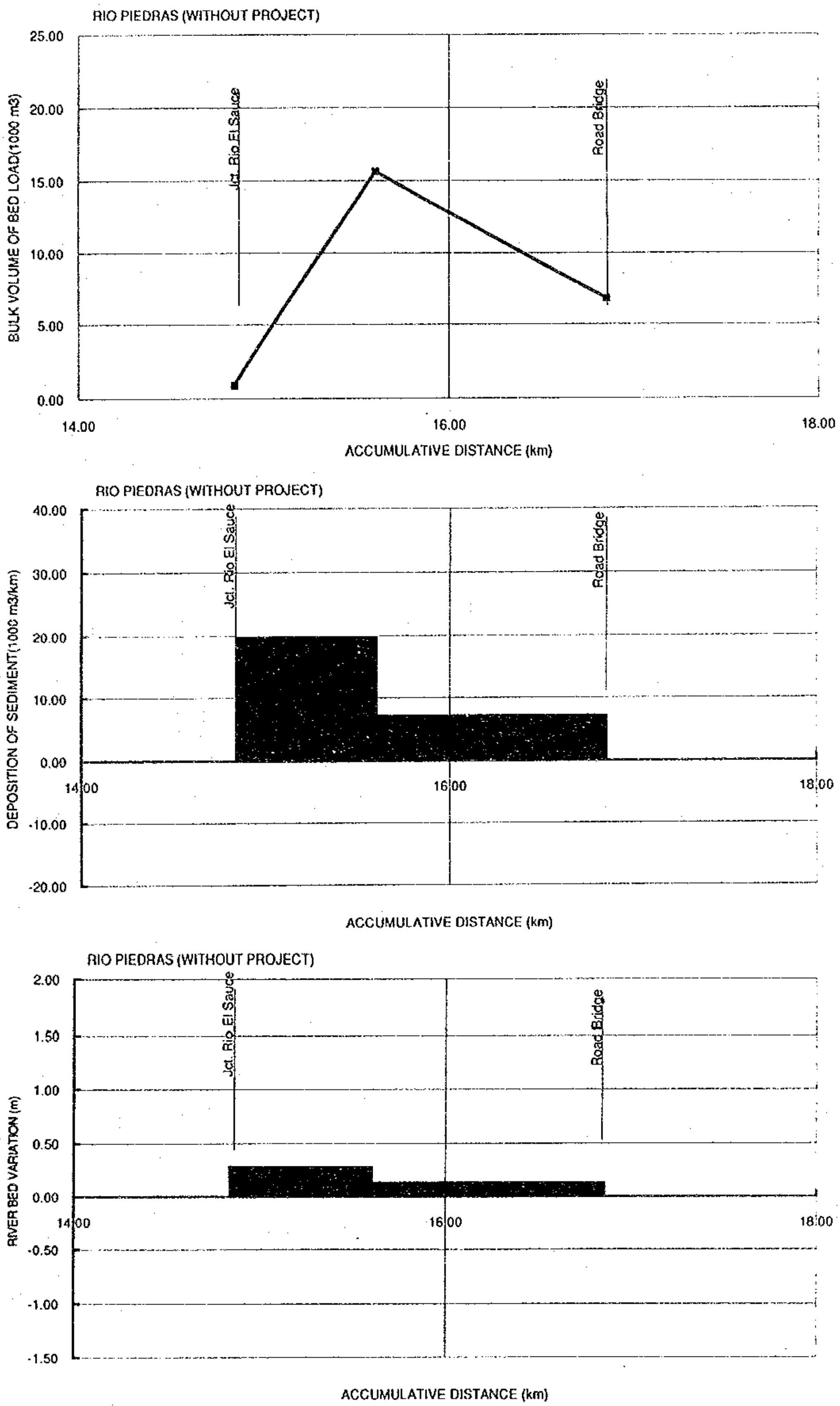


FIG. E.1.15 RESULTS OF SEDIMENT SIMULATION OF THE RIO PIEDRAS (CASE 3-1 WITHOUT PROJECT)

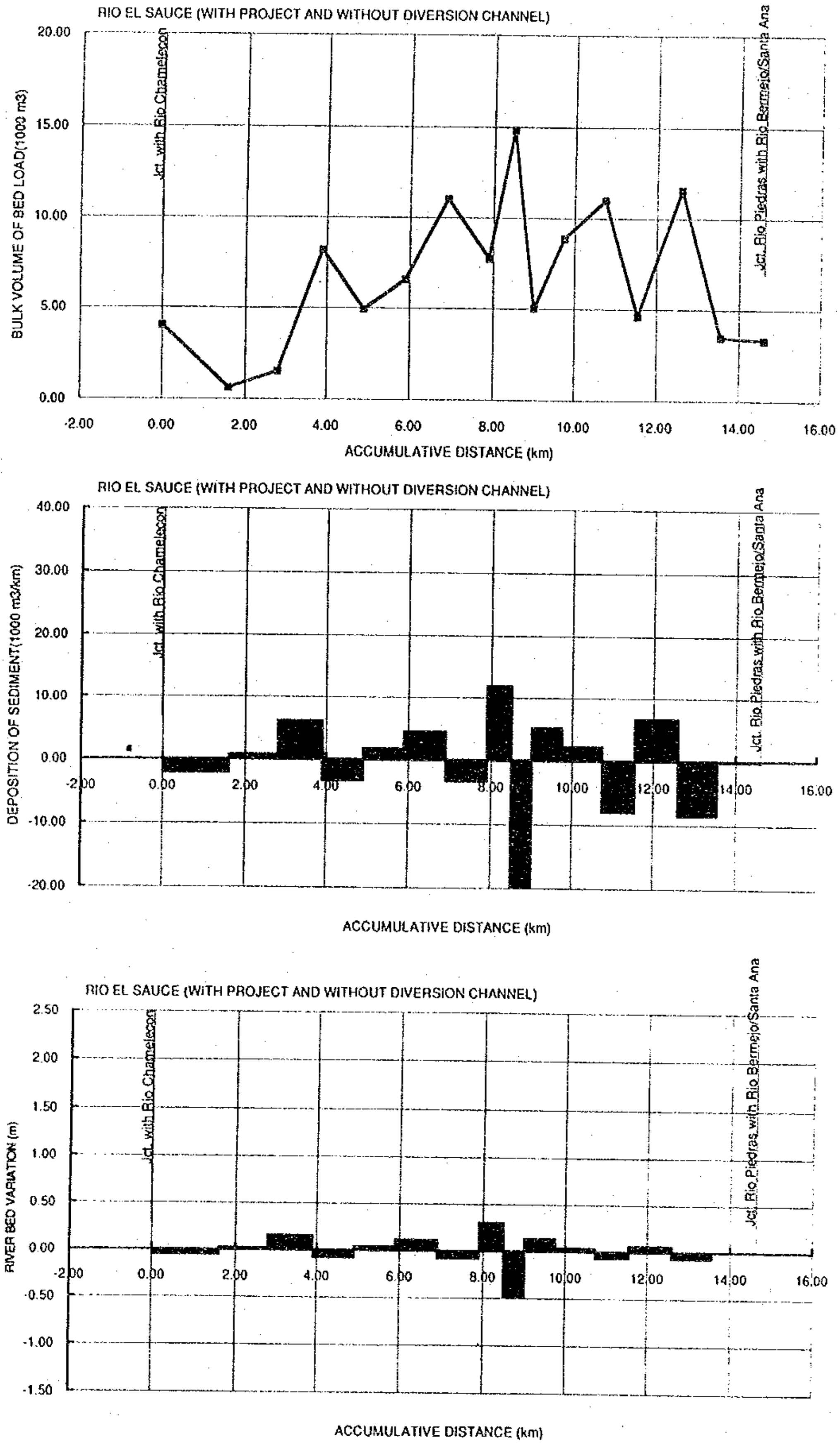


FIG. E.1.16 RESULTS OF SEDIMENT SIMULATION OF THE RIO EL SAUCE (CASE 3-2 WITH PROJECT)

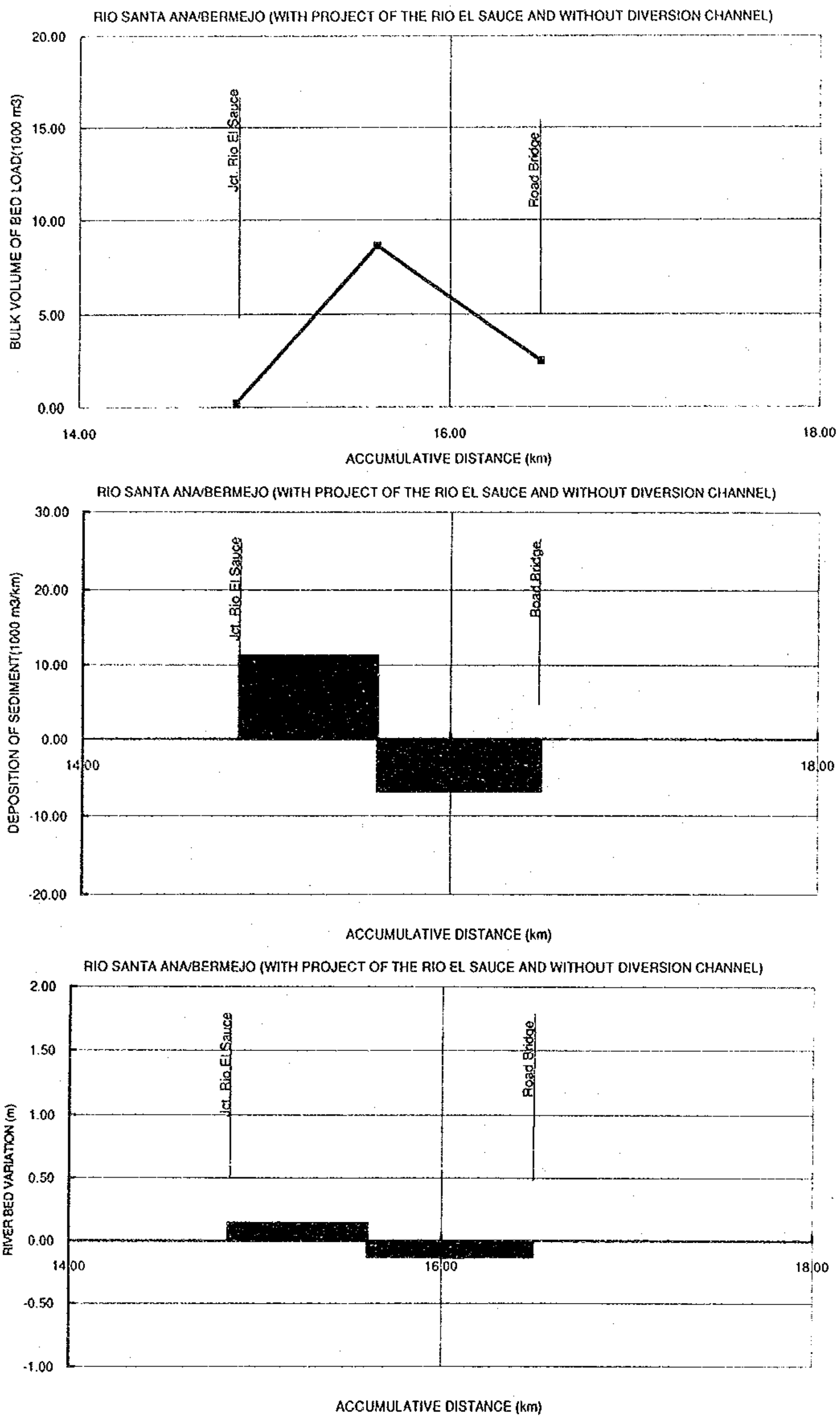
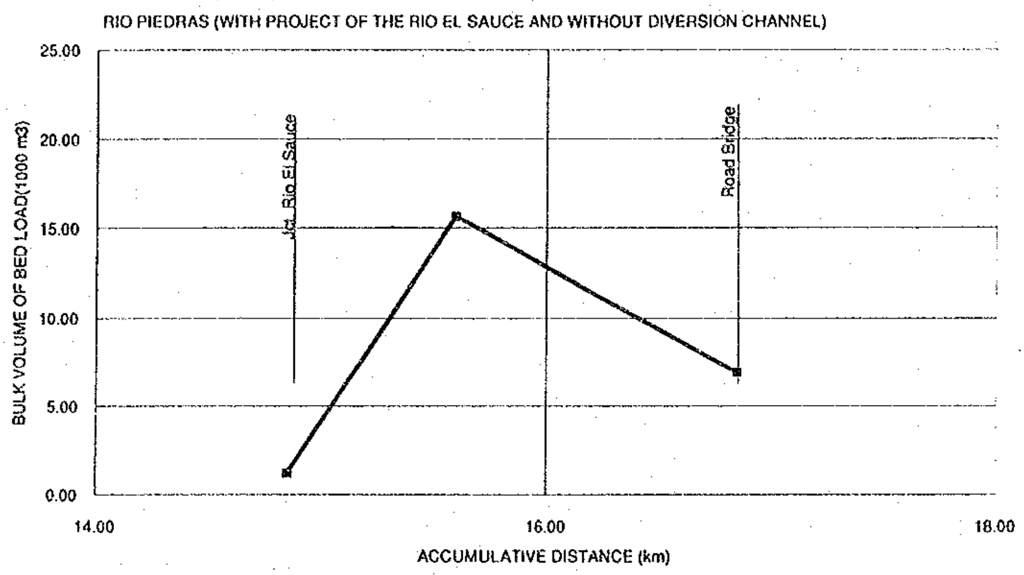
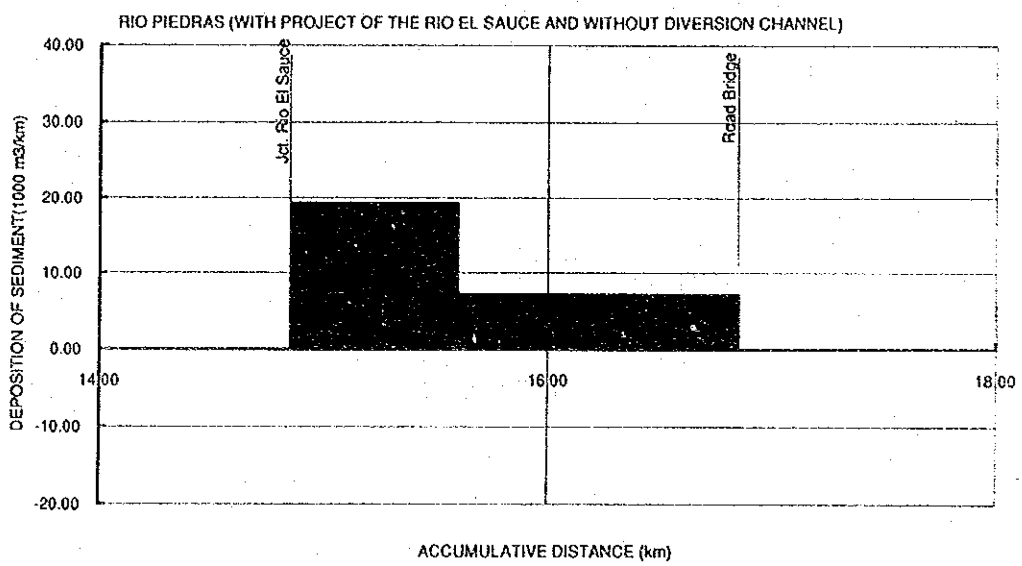


FIG. E.1.17 RESULTS OF SEDIMENT SIMULATION OF THE RIO SANTA ANA/BERMEJO (CASE 3-2 WITH PROJECT)





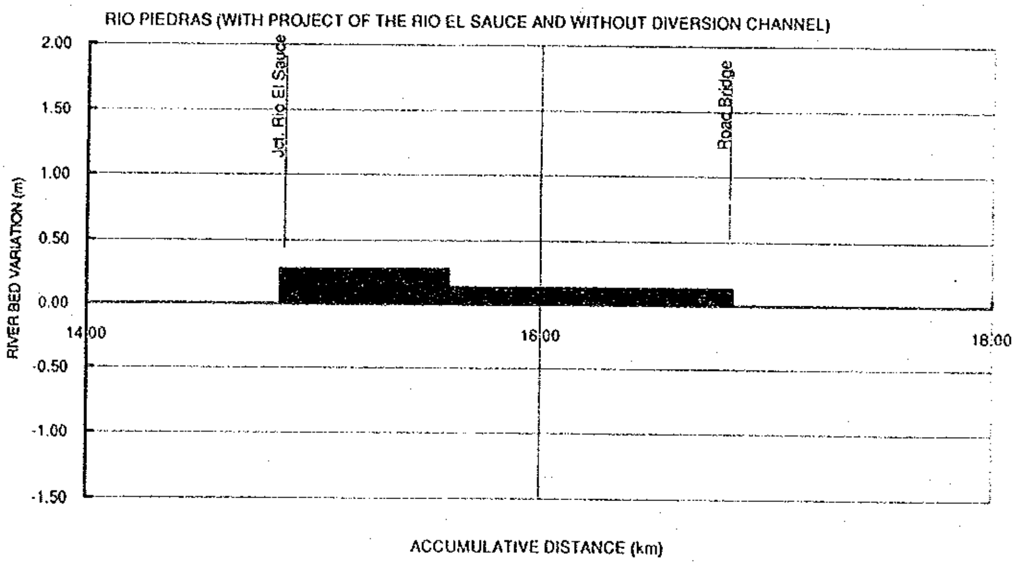


FIG. E.1.18 RESULTS OF SEDIMENT SIMULATION OF THE RIO PIEDRAS (CASE 3-2 WITH PROJECT)

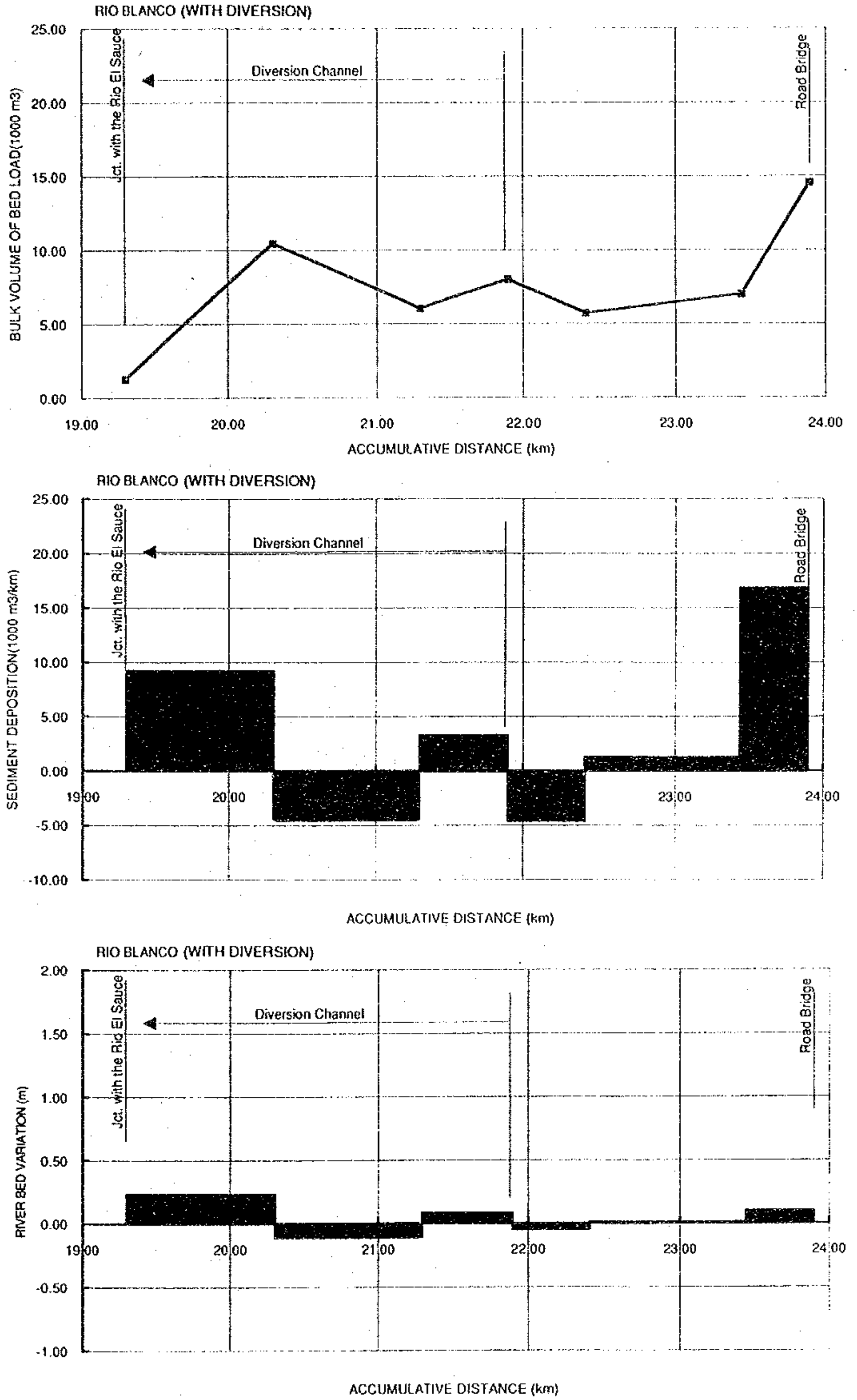


FIG. E.1.19 RESULTS OF SEDIMENT SIMULATION OF THE RIO BLANCO (CASE 4-1 WITH DIVERSION)

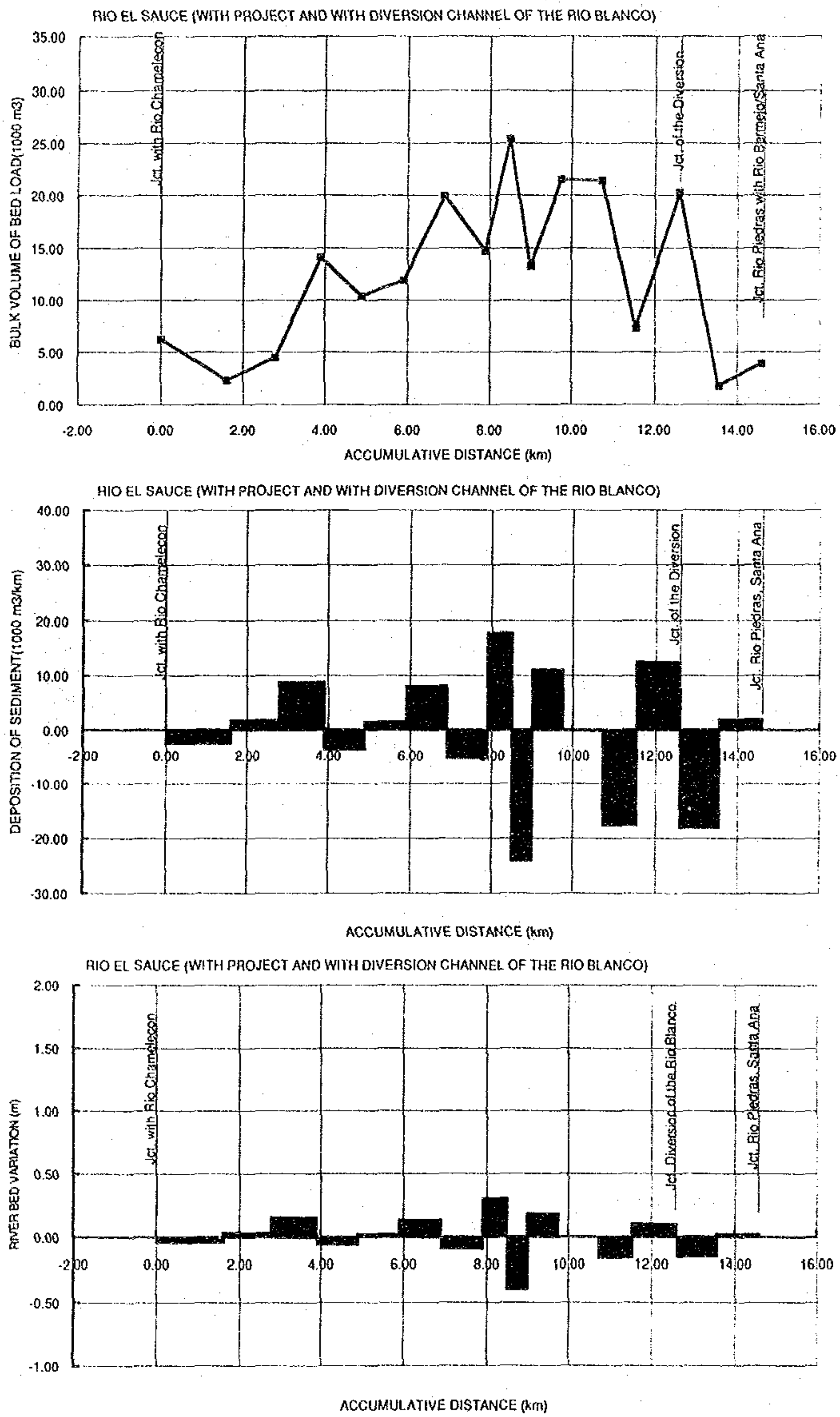


FIG. E.1.20 RESULTS OF SEDIMENT SIMULATION OF THE RIO EL SAUCE (CASE 4-1 WITH DIVERSION)

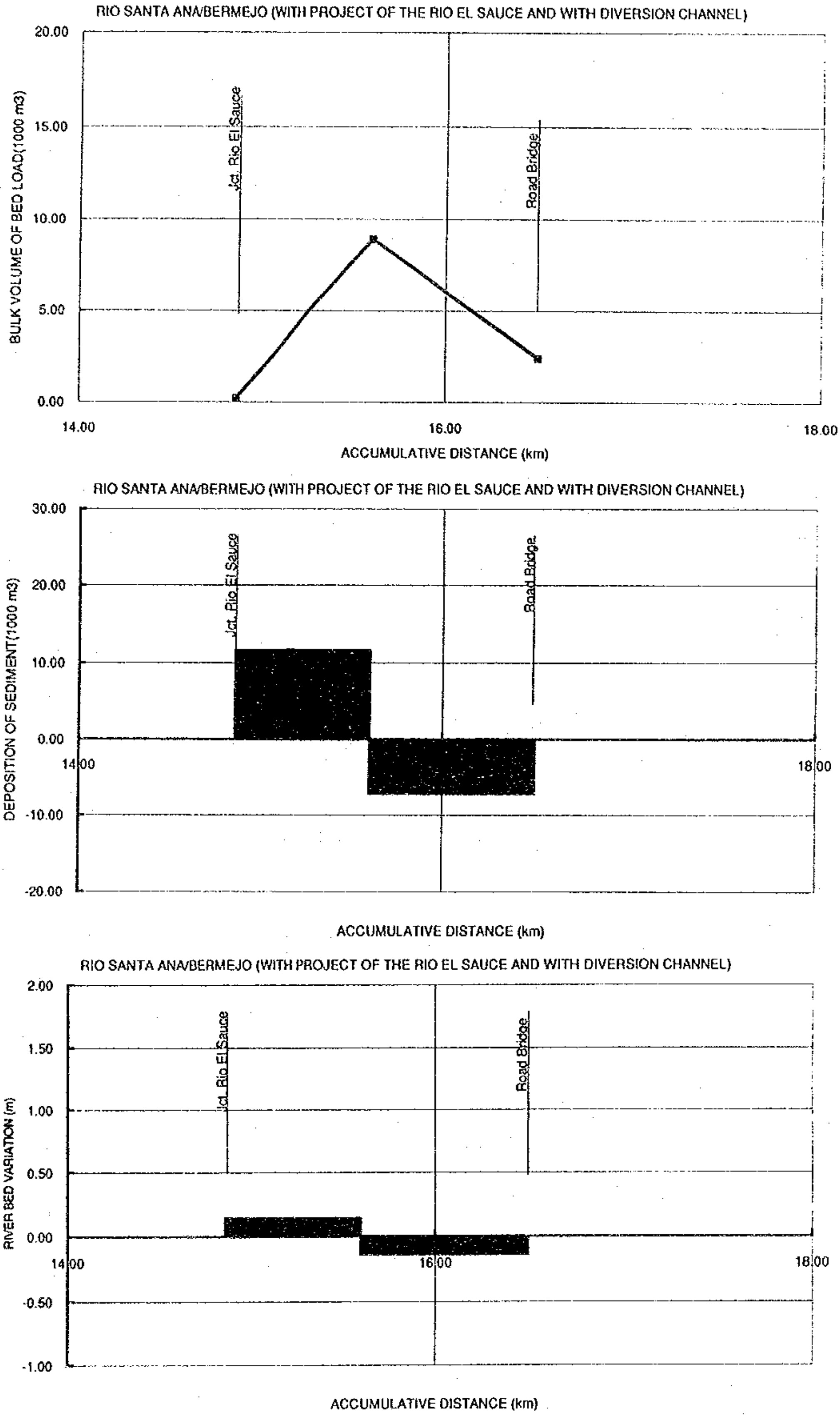


FIG. E.1.21 RESULTS OF SEDIMENT SIMULATION OF THE RIO SANTA ANA/BERMEJO (CASE 4-1 WITH DIVERSION)

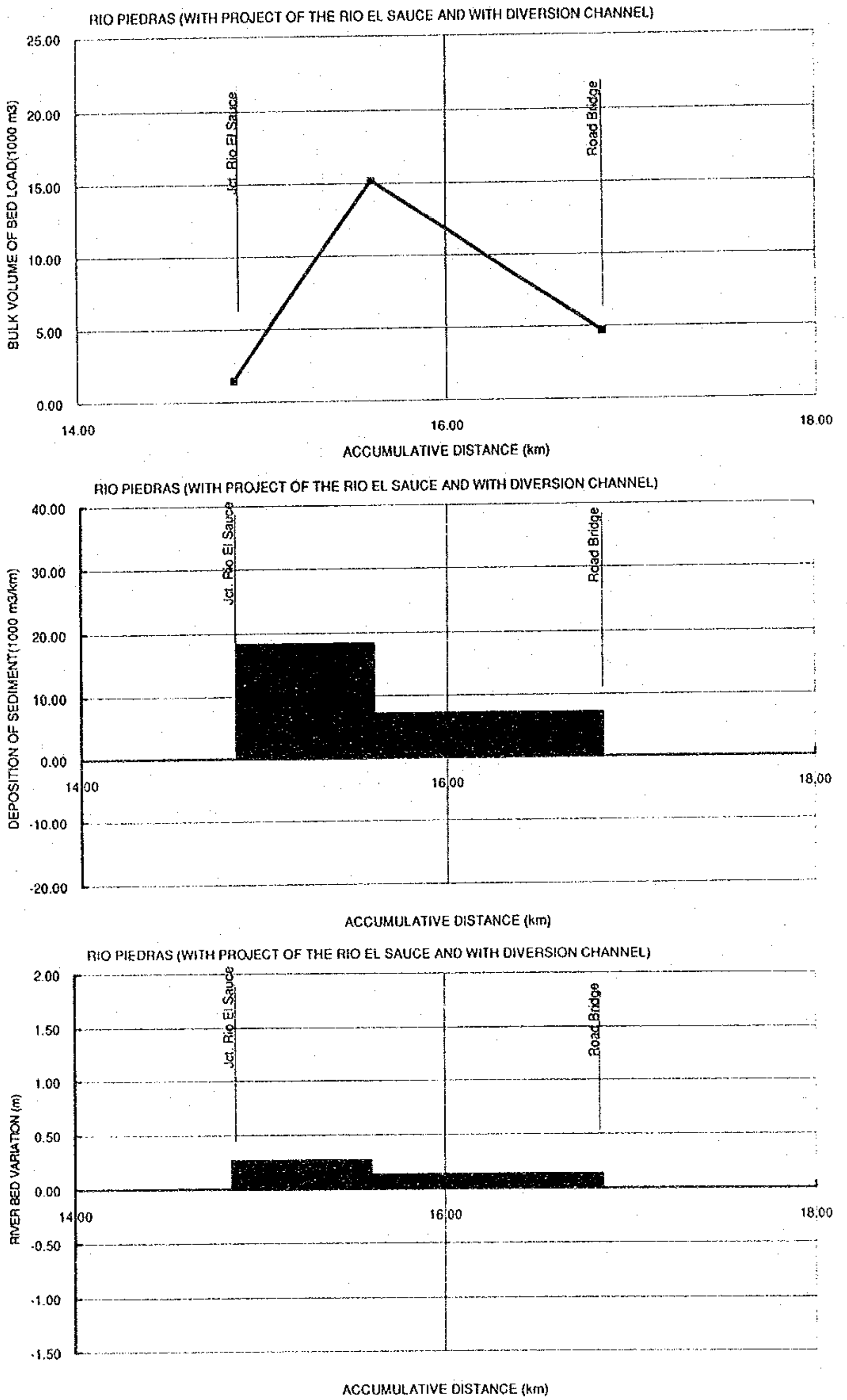


FIG. E.1.22 RESULTS OF SEDIMENT SIMULATION OF THE RIO PIEDRAS (CASE 4-1 WITH DIVERSION)

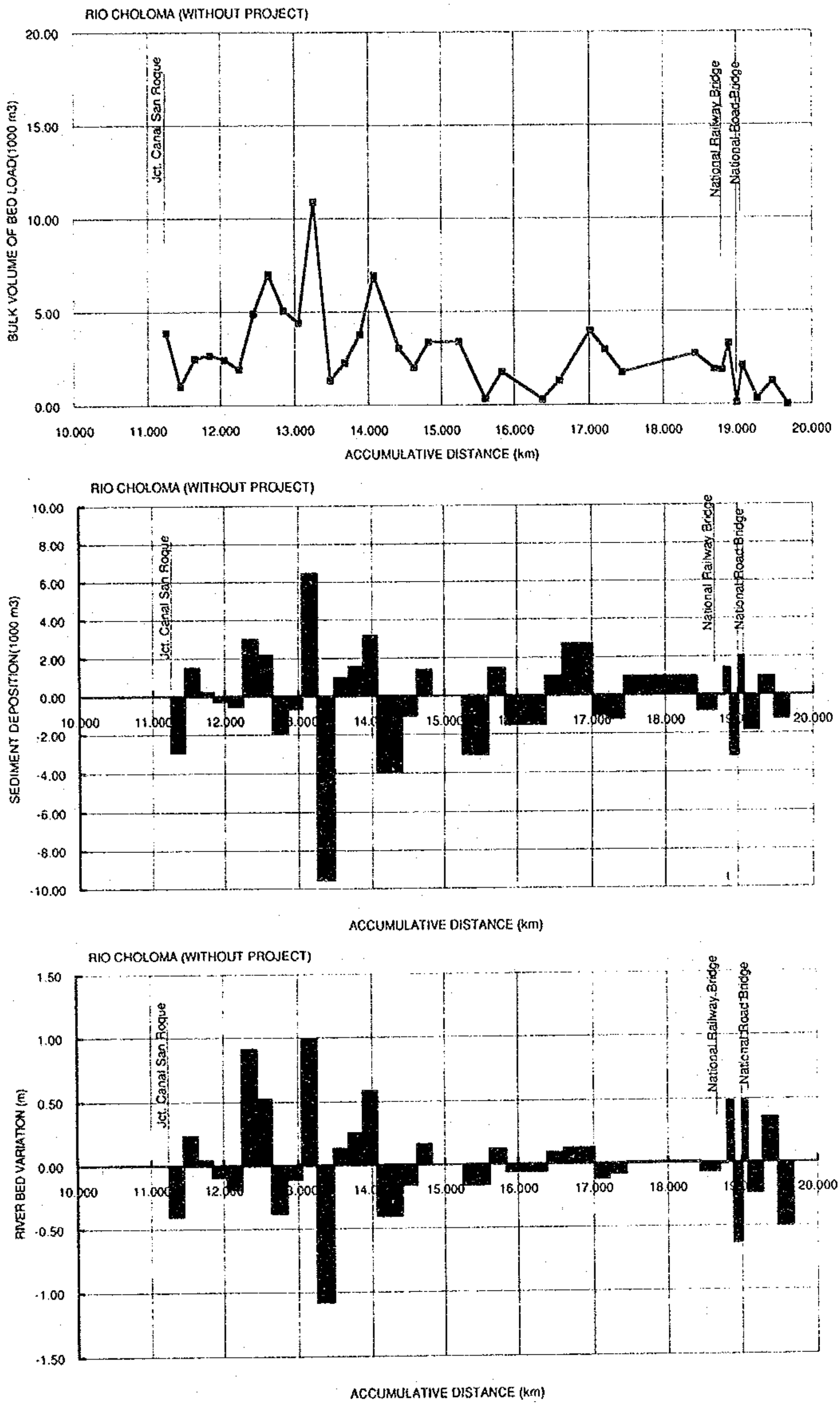


FIG. E.2.1 RESULTS OF SEDIMENT SIMULATION OF THE RIO CHOLOMA (F/S-CASE 1 WITHOUT PROJECT)

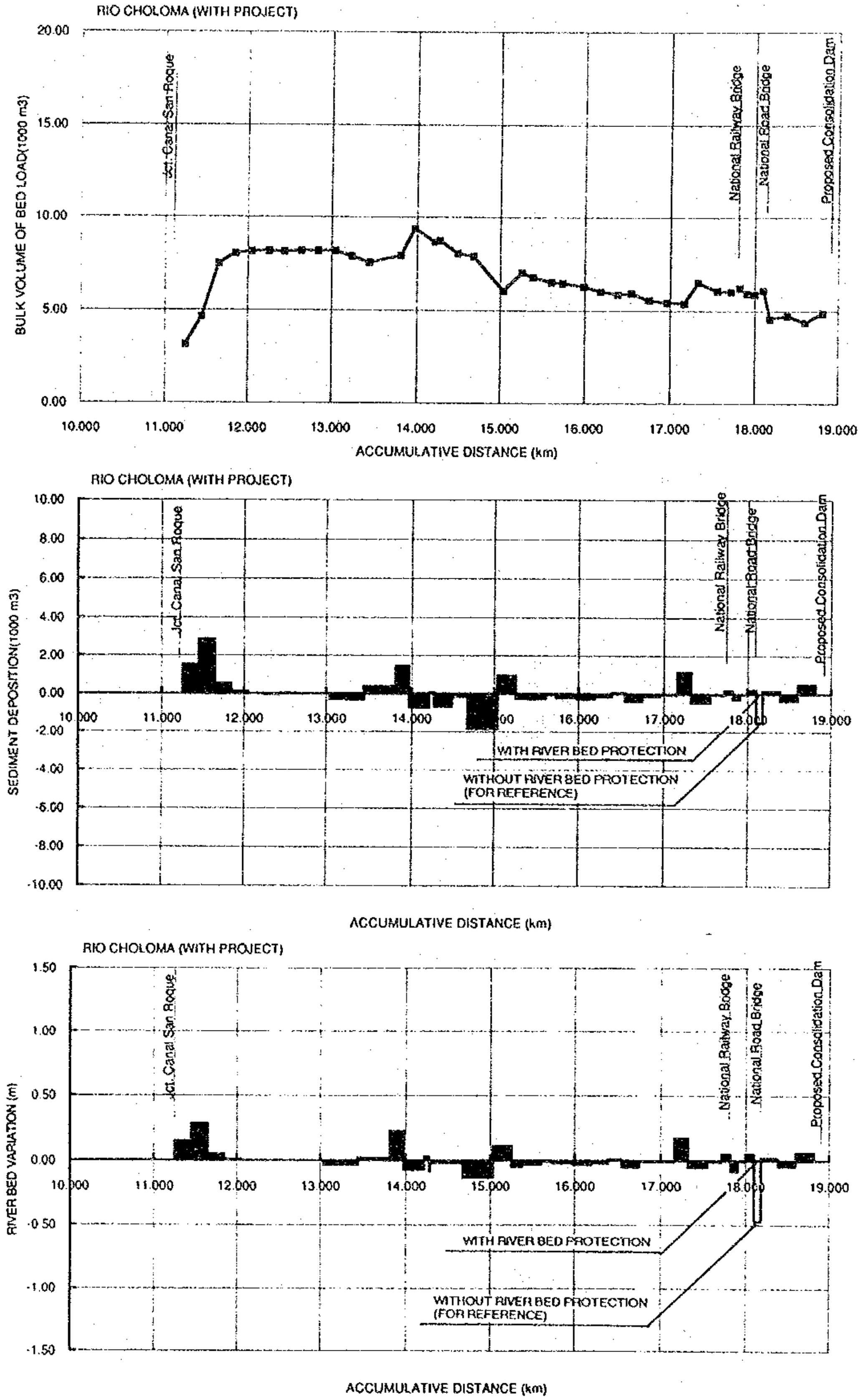


FIG. E.2.2 RESULTS OF SEDIMENT SIMULATION OF THE RIO CHOLOMA (F/S-CASE 2 WITH LONG TERM PROJECT)

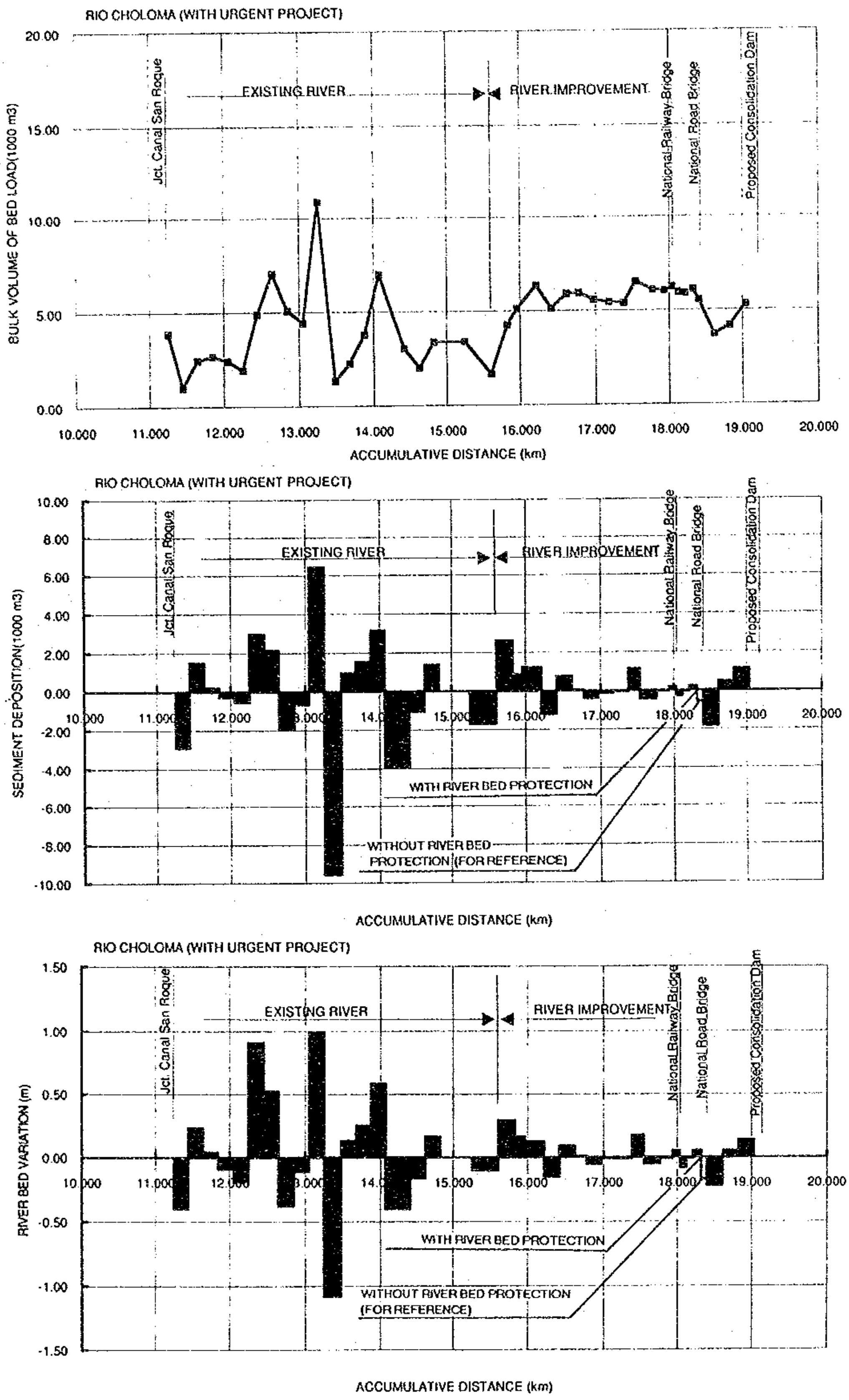


FIG. E.2.3 RESULTS OF SEDIMENT SIMULATION OF THE RIO CHOLOMA (F/S-CASE 3 WITH URGENT PROJECT)

SUPPORTING REPORT F
FLOOD MITIGATION STUDY

SUPPORTING REPORT F FLOOD MITIGATION STUDY

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SUPPORTING REPORT F FLOOD MITIGATION STUDY

1. GENERAL

The study area includes industrialized or being industrialized cities such as San Pedro Sula City, Choloma City and La Lima City. This area consists of central part of socio-economic activities of the Sula Valley which is the most important productive area of Honduras. Furthermore, the national road which is one of the most important life line of Honduras connecting Puerto Cortes, San Pedro Sula and Tegucigalpa goes through the study area.

In the study area, there are three major tributaries of the Rio Chamelecon. They are the Rio Choloma, the Rio Blanco and the Rio El Sauce. These rivers are called the pilot rivers in this study.

In spite of above socio-economic importance of the study area, this area has had severe problems caused by the floods and sediments of the pilot rivers as well as the floods of the Rio Chamelecon or the Rio Ulua in the lowland areas. Remarkable floods were reported in 1897, 1916, 1935, 1945, 1954, 1969, 1974, 1976, 1988 and 1990. Especially, in 1974, the hurricane "Fifi" caused the largest floods and sediments including debris flows in the record and caused the largest damages to the study area.

Although, since 1974 floods, several flood control studies and some flood control facilities such as the embankments have constructed for the Rio Blanco, Rio El Sauce, Rio Choloma and the Rio Chamelecon, many flood problems have been left in the study area.

In this report, the present river conditions such as existing river facilities, discharge capacities and related flood mitigation plans for the pilot basins of the Rio Choloma Basin, the Rio Blanco Basin and the Rio El Sauce Basin are examined and necessary flood mitigation measures are being proposed. In the Master Plan Study Stage, above assessments and proposals were done for the pilot rivers of the Rio Choloma, the Rio Blanco and the Rio El Sauce. In the Feasibility Study Stage, more detailed assessment and proposals were made for the Rio Choloma.

2. THE MASTER PLAN STUDY STAGE

2.1 Related and Existing Flood Mitigation Plans and Facilities

2.1.1 Related and Existing Flood Mitigation Plans

After the hurricane Fifi in 1974, several studies of flood control were conducted in the Sula Valley. There are two studies that are pertinent to the current situation. They are described below.

1) Obras de Protection Contra Inundaciones, by Sir William Halcrow & Partners in September 1975

In this study, detailed designs for the remedial works including enlargement and flood dikes of the channels with 100 year flood frequency and reconstruction of the bridges in the mid-stream reach of the Rio Blanco, the upstream to the mid-stream reaches of the Rio El Sauce and the mid-stream to the downstream reaches of the Rio Piedras and the Rio Santa Ana in San Pedro Sula were prepared. The recommended works are summarized in *Table* F.2.1 and *Fig*.F.2.1.

The Municipality of San Pedro Sula and SECOPT have constructed the enlargement and flood dikes of the Rio Blanco, the Rio El Sauce, the Rio Piedras and the Rio Santa Ana and the diversion work of the Rio Chiquito based on their recommendation. However, the other works have not been executed yet.

2) Informe del Plan Maestro para el Desarrollo Integral y Control de Inundaciones en el Valle de Sula, in March 1979 and Informe Resumido de Estudio de Factibilidad y Diseno de las Obras Hidraulicas Prioritarias para el Desarrollo Integral y Control Inundaciones en el Valle de Sula, by HARZA-CINSA, in November 1980.

In this study, a master plan of flood control plans of the Rio Ulua Basin and the Rio Chamelecon Basin were prepared to control inundation of the Sula Valley. In this study, several flood control dams in the upper basins of the Rio Ulua and the Rio Chamelecon and floodway of the Rio Ulua and the Rio Chamelecon were proposed aiming to control the floods with 50 year flood frequency. Furthermore, as for the downstream basin of the Rio Choloma and related lowland areas, some drainage canals were proposed with less than 20 year flood frequency. The proposed plans are shown in *Fig*.F.2.2 and *Fig*.F.2.3.

Among these proposals, El Cajon Dam was constructed as a multipurpose dam of flood control and electric power generation etc. in 1985. But, other flood control measures proposed in the master plan have not been implemented yet, except some part of the drainage improvement works. The drainage improvement works which have been or are being carried out are as follows;

- Canal Copen-Higuero-Cuabanos (14 km)
- Canal San Roque-Cuabanos (5.3 km)
- Canal San Roque (6.4 km)
- Canal Montanuela-San Roque

As the above drainage canals have much smaller cross section compared with the proposed plans of HARZA-CINSA, they are required remedial works in the future.

As described above, there have not been any comprehensive master plan of flood control for the pilot rivers of the study area yet.

2.1.2 Related and Existing Flood Mitigation Facilities

There are flood mitigation facilities such as embankments and embanked channels constructed along the pilot rivers of the Rio Choloma, Rio Blanco and the Rio El Sauce to control floods of these rivers. Furthermore, there are embankments along the left bank of the Rio Chamelecon to protect the lowland area of the study area against floods of the Rio Chamelecon and the Rio Ulua. Existing flood mitigation facilities are shown in *Table* F.2.2 , *Fig*.F.2.4 and *Fig*.F.2.5. They are explained below.

1) Embankment along the Pilot Tributaries

After the hurricane Fifi, embankments in combination with enlargement of channels of the Rio Blanco, the Rio El Sauce including the Rio Piedras and the Rio Santa Ana/Bermejo were constructed with 100 year flood frequency by the Municipality of San Pedro Sula and SECOPT as described in sub-section 2.1.1 1). And embankments of the mid-stream to the downstream reaches of the Rio Choloma were constructed by SECOPT. The river distances of the embanked channels are summarized as follows;

- the Rio Choloma	:	5.0 km
- the Rio Blanco and its tributaries	:	21.2 km
- the Rio El Sauce and its tributaries	:	44.1 km
- the Rio El Sauce(viejo)-Chotepe	:	12.7 km

The improved river reaches of the Rio Blanco and the Rio El Sauce seem to have sufficient flow capacities against the flood caused by the hurricane FiFi. But, the improved channels of the Rio Choloma does not seem to have enough flow capacity. Furthermore, the river reaches of the pilot tributaries which have not yet improved have had flood problems until now. Therefore, the river reaches with inadequate flow capacity will be clarified in this study and necessary flood mitigation measures will be proposed.

The ring levee (11.5 km) was also constructed by SECOPT to protect the Airport of La Lima from 1981 to 1990. However, the drainage pump station planned has not been constructed yet.

2) Embankment along the Rio Chamelecon

There are flood embankments (approximately 54.1 km) along the left bank of the Rio Chamelecon which have been constructed by different agencies i.e., Tela Railroad Company, Municipality of San Pedro Sula, SECOPT and Sula Valley Committee.

But, about 5.5 km of the left bank is still remaining without embankment. Furthermore, it is not clear whether the existing embankments are high and strong enough against some extent of flood scale, because flood water came into the study area from the Rio Chamelecon in 1990 floods.

In order to protect the lowland areas of the study area from the flood water of the Rio Chamelecon or the Rio Ulua, embankments along the left bank of the Rio Chamelecon are very important. Hence, the height as well as stability of the embankment should be checked out in detail and reinforced or rehabilitated, if necessary.

3) Other Facilities

There are two water intake weirs, eight river crossing roads in the pilot rivers. They have effect of consolidation for the river bed.

2.2 Existing River Conditions

2.2.1 Existing River System

The river system with their watersheds are shown in *Fig*.F.2.6. The river distance and longitudinal profile of the main channels are shown in *Fig*.F.2.7 and *Fig*.F.2.8 respectively. The study area (716.71 km^2) is divided into six (6) sub-catchments. They are 1). Rio Choloma (106.89 km^2), Rio Blanco - Canal San Roque (190.24 km^2), 3) Rio El Sauce (118.33 km^2), 4) Rio El Sauce (Viejo) - Canal Chotepe (97.37 km^2), 5) Canal Cuabanos (123.02 km^2) and 6) Rio Chamelecon and La Lima Airport (80.86 km^2).

The Rio Choloma and the Rio Blanco join at the upper reaches of the Canal San Roque-Cuabanos and flow into the Rio Chamelecon. The Rio El Sauce (viejo)-Chotepe flows into the most downstream of the Rio El Sauce and then the Rio El Sauce flows into the Rio Chamelecon. The river length and river bed slope between the confluence and the design control points of the sediment control plan (refer to Supporting Report D) are summarized for each pilot river as follows;

-	Rio Choloma	7.8 km	1/420 ~ 1/120
-	Rio Blanco	18.9 km	1/520 ~ 1/240
-	Rio El Sauce	14.6 km	1/1000 ~ 1/210

Before the hurricane Fifi in 1974, the Rio Blanco had mainly flowed into the Rio Chamelecon through the present river course of the Rio El Sauce and partly flowed into Laguna El Carmen. The Rio El Sauce had flowed through the river course of the Rio Chotepe. As the blockade of the river channel of the Rio Blanco around the distributing point was happened by sediment deposition caused by the Fifi, the river course of the Rio Blanco had been shifted to the present river course to Laguna El Carmen after 1974. The river course of the Rio El Sauce had been shifted to the present river course as well as the Rio Blanco.

2.2.2 Discharge Capacities of the Existing Rivers and Canals

Discharge capacities of the existing rivers and canals were checked by using the surveyed river cross sections by this study in the Master Plan Study Stage and the existing 1/2000 topographic maps. The hydraulic calculations were done by using Manning's Formula. The roughness coefficients were 0.035 for low water channel and

0.050 for high water channel. The river bed slopes of the rivers and canals are same as those shown in *Fig*.F.2.8.

The discharge capacities are as follows;

(1) Rio Choloma : 40 ~ 60 m^3/s (11.25 ~ 17.0 km)
: 100 ~ 170 m^3/s (17.0 ~ 18.7 km)
: 170 ~ 910 m^3/s (18.7 ~ 19.1 km)

The discharge capacity at the national railway bridge (18.70 km) is as small as 170 m^3/s. The discharge capacity between the national road bridge (19.08 km) and the national railway bridge decreases from 900 m^3/s to 170 m^3/s.

(2) Rio Blanco : 1600 ~ 3600 m^3/s (20.5 ~ 23.45 km)

The discharge capacity of the river reaches between the national road bridge and the inlet of Laguna El Carmen decreases from 3600 m^3/s to 1600 m^3/s. The river reaches between the outlet of Laguna El Carmen to the Canal San Roque (6.40 km ~ 23.45 km) is called the Qda. San Agustin. As the Qda. San Agustin flows down through mountainous area, discharge capacity of this river is more than 2000 m^3/s. But the most upstream reach of the Qda. San Agustin has only 460 m^3/s of discharge capacity.

(3) Rio El Sauce : 600 m^3/s (0.0 ~ 5.0 km)
: 1000 ~ 2000 m^3/s (5.0 ~ 14.6 km)

The discharge capacity of the downstream reach is smaller than those of mid-stream and upstream reaches. The discharge capacity of the Rio Piedras is about 1200 m^3/s. The discharge capacity of the Rio Santa Ana/Bermejo is about 900 ~ 1300 m^3/s.

Discharge capacities of canals are very small.

(4) Canal Copen-Higuero-Cuabanos : 60 ~ 100 m^3/s

(5) Canal San Roque-Cuabanos : 30 ~ 60 m^3/s

(6) Canal San Roque : 20 ~ 80 m^3/s

2.3 Simulation of the Probable Flood Stages and Inundation Area

Floods in the study area are caused not only by the tributaries of the Rio Chamelecon such as the Rio Choloma, the Rio Blanco and the Rio El Sauce but also by the Rio Chamelecon and the Rio Ulua. The flood conditions caused by these rivers were clarified by the flood damage survey of the 1974 floods and 1990 floods etc. conducted by this study.

In order to formulate the flood mitigation plans of the pilot rivers of the Rio Choloma, the Rio Blanco and the Rio El Sauce, it is necessary to clarify the inundation conditions by the floods of the pilot rivers separating those of the Chamelecon River and the Ulua River. Therefore, flood simulations with several flood scales were conducted for the pilot rivers referring the results of the flood damage survey. These results were used for assessment of the flood damages as well as formulating the facility plans of flood mitigation measures.

1) Methods of the Simulations

Methods of the flood simulations are as follows;

a)	Calculation method	:	non-uniform flow
b)	Manning's roughness coefficient	:	0.035 (low water channel) 0.050 (high water channel)
c)	River sections	:	surveyed sections (by JICA) or 1/2000 topographic maps
d)	Discharge	:	peak discharges of 2, 5, 30, 50 and 100 year flood frequency
e)	Downstream water levels	:	estimated flood water levels or back- water levels of the Rio Chamelecon

2) Results of the Simulation

The simulated flood water levels and the inundation areas are shown in *Table* F.2.3 and *Fig*.F.2.9 respectively.

Inundation areas with different flood scales were estimated from the calculated water stages referring the existing 1/2000 topographic maps, 1/20000 topographic maps and the results of the flood damage survey.

There are two kinds of inundations. They are the inundation with sediment and the inundation without sediment. As for the Rio Choloma, inundation will be with sediment. As for the Rio Blanco (upstream of Laguna El Carmen), inundation will be with sediment. As for the Canal San Roque, inundation will be without sediment. As for the Rio El Sauce, inundation will be without sediment in the downstream reaches and with sediment in the Rio Piedras and the Rio Santa Ana/Bermejo.

By the above simulated floods, it can be estimated that the big flood damages will be caused in the area around the Choloma City, areas between the Rio Piedras and the Rio Santa Ana/Bermejo, the downstream area of the Rio El Sauce and some areas of the Rio Blanco near the national road. The big flood damage will be caused by the concentration of properties such as houses and factories as well as the existence of infrastructures such as transportation. As the land uses of the other inundation areas are agricultural land ,pasture and swamp areas, flood damages of these areas will be small. Hence, there will be a high priority of providing flood mitigation measures for the areas with high flood damage potential.

2.4 Flood Mitigation Measures

2.4.1 Basic Concept

In the hurricane Fifi, most of the urban areas and agricultural lands in the study area were submerged by the flood water from the Rio Chamelecon and the pilot rivers. The hurricane Fifi gave severe damage not only to the people in the study area, but also to major infrastructures such as transportation and communication systems. After the hurricane Fifi, some flood mitigation measures such as embanked channels and embankments have been provided, but the study area is extremely vulnerable to floods as ever. And there are some areas with high flood damage potential in the study area as described in sub-section 2.3.

The study area is part of the Sula Valley which is one of the most important productive areas of the country. Currently, the importance of the area is increasing, developing several industrial parks in both San Pedro Sula and Choloma areas. Hence, the necessity of providing flood mitigation measures has been increasing in these days very much.

Furthermore, as the potentials of erosion and sediment of the pilot rivers are very large as described in Supporting Report D, it will be necessary to provide erosion and sediment control measures as well as flood mitigation measures. In this case, it is important to formulate the flood mitigation measures considering the erosion and sediment control measures and balance of sediment in the river channels.

Basic concepts of formulating of flood mitigation measures are as follows;

(1) Protecting the people, their assets and social properties from the floods of the pilot rivers by structural measures such as river improvement including embankment and by non-structural measures.

(2) Above structural measures are necessary to be formulated considering the erosion and sediment control measures and balance of sediment in the river channels.

2.4.2 Design Criteria

Design criteria for planning the flood mitigation facilities is as follows;

1) Design Flood

The past biggest flood in the record caused by the hurricane Fifi had the flood scale with 50 year return period for the peak discharge and more than 200 year return period for the erosion and sediment. Hence, it is better to formulate the flood mitigation plan with the design flood more than the flood scale of Fifi.

For a reference of determining the design flood, comparison of economic efficiency (EIRR) which is expressed as relation with construction cost and reduction of flood damage (benefit) was conducted for the Rio Choloma with flood frequency of 2-year, 5-year, 30-year, 50-year and 100-year. And 50-year flood had the slightly higher economic efficiency among them.

Therefore, the design flood for formulating the flood mitigation measures is selected to be the flood with 50 year return period.

The erosion and sediment control measures are formulated with the scale of erosion and sediment caused by the hurricane Fifi as described in Supporting Report D.

2) Design High Water Level

The design high water level (H.W.L.) is determined by referring to the results of the non-uniform calculation with the design flood.

3) Design Longitudinal Section

Design longitudinal sections of the pilot rivers are determined so that they have almost same river bed slope as the existing rivers. Furthermore, excessive excavation of the river bed will be avoided.

4) Design Cross Section

Compound section is applied in principle. The cross section of the low water channel is determined so that it has the discharge capacity of 2 to 3 year flood. The cross section of the high water channel is determined so that the water depth above the high water channel of the design flood will be less than the inundation water depth of the existing river conditions.

The design freeboard of the embankment is 1.0 m. The slope of the banks of the low water channel is 1 : 2. The embankment has the slope of 1 : 3 and the top width of 4.00 m.

2.4.3 Flood Mitigation Measures of the Rio Choloma

Flood mitigation measures of the Rio Choloma were formulated in the river reaches between the national road bridge (design control point of the erosion and sediment control) and the junction with the Canal San Roque.

Considering the flood condition of the Rio Choloma and the small discharge capacity of the existing river, it will be necessary to conduct river improvement with excavation and enlargement of the low water channel as well as embankment along the both banks of the channel. The proposed flood mitigation facilities are shown in *Fig*.F.2.10.

By this river improvement, the town of Choloma City which has the high flood damage potential will be protected from the floods. And highly development in the areas around the mid-stream and the downstream reaches of the Rio Choloma will be possible.

Although there is an unbalance of sediment in the Rio Choloma in the present, it will be much improved and the channels will be in a dynamic stability condition by this river improvement (refer to Supporting Report E). But periodical maintenance of the river bed will be indispensable especially around the junction of the Canal San Roque.

Detailed informations of the flood mitigation facilities are described below.

1) Design Discharge

The design discharge at major stations are as follows;

- Junction of the Canal San Roque (Sta. 11.25 km) : 790 m^3/s
- National road bridge (Sta. 19.08 km) : 620 m^3/s

2) Design Longitudinal Section

The design longitudinal section is determined to be I = 1/360 and I = 1/330 considering the existing river bed slope. This design longitudinal section will be stable as described in the Supporting Report E "Sedimentorology". The design longitudinal section is shown in *Fig*.F.2.11.

3) Design Cross Section

A compound cross section is planned by considering easy operation and maintenance. The low water channel is designed to have a flow capacity of once in 2 to 3-year flood frequency.

The design cross section is determined as follows;

- Width of low water channel (B1) : 60 m
- Height of low water channel (h1) : 2.0 m
- River width (B) : 140 m

The typical cross section is shown in *Fig*.F.2.11.

4) Design High Water Level

The design high water level at major points are as follows;

-	Junction of the Canal San Roque	:	El. 12.00 m
-	National road bridge	:	El. 32.26 m

Detailed information is presented in *Fig*.F.2.11.

5) Flood Mitigation Facilities and Their Work Quantities

Flood mitigation facilities and their work quantities are as follows;

-	Embankment	15.6 km	480,700 m^3
-	Channel Improvement (excavation)	7.8 km	1,102,000 m^3
-	Revetment (wet masonry)	4 places, 4.8 km	42,600 m^2
-	Sodding	15.6 km	237,700 m^2
-	Rehabilitation of bridges	2 places	
	a) National road bridge	: extension 41 m x 10 m x 2 no. foot protection by gabion 90 m x 40 m	
	b) National railway bridge	: reconstruction 160m x 5.0 m	
-	Land acquisition		91.0 ha

2.4.4 Flood Mitigation Measures of the Rio Blanco (Alternative 1)

The Rio Blanco had flowed down through the present river course of the Rio El Sauce until the floods of the hurricane Fifi in 1974. By the river improvement in 1979, the river course of the Rio Blanco was shifted to the Laguna El Carmen. Since that time, the flood water of the Rio Blanco has drained through Laguna El Carmen, the Qda. San Agustin, the Canal San Roque, Canal San Roque-Cuabanos and the Canal Copen-Higuero-Cuabanos. Furthermore, the river course of the Rio El Sauce had changed to be the present river course from the Rio El Sauce (viejo) corresponding to the above change of the river course of the Rio Blanco.

Although the inundation by the Rio Blanco near La Lima City may have prevented by the above river improvements, the flood discharge and the flood problems of the Canal San Roque has increased. Furthermore, as the sediment of the Rio Blanco has been made to flow into Laguna El Carmen, sediment deposition has been occurred in the most downstream reach of the Rio Blanco and Laguna El Carmen since that time.

Considering the above, following two alternative flood mitigation plans were studied (refer to *Fig*.F.2.12).

(a) Alternative 1

River improvement of the Rio Blanco and the Rio El Sauce will be done along the present river courses respectively. The river improvements of the Alternative 1 are those of the Rio Blanco includes the Canal San Roque etc. and the Rio El Sauce.

(b) Alternative 2

River improvement of the Rio Blanco will be done by making diversion channel from the upstream of Laguna El Carmen (Sta. 21.90 km) to the Rio El Sauce (Sta. 12.60 km).

By the Alternative 2, the river course of the Rio Blanco will be made to return to the river course until 1974 and the river flow to Laguna El Carmen will be stopped in principal. In this case, the Canal San Roque will drain the water of its own drainage basin. The river course of the Rio El Sauce will be remained as present condition.

The river improvement of the Alternative 2 are those of the Rio Blanco (upstream from Laguna El Carmen), the diversion channel and the Rio El Sauce.

In this sub-section, the river improvement of the Alternative 1 of the Rio Blanco is described.

<u>River Improvement of Alternative 1 of the Rio Blanco</u>

As the existing channel of the Rio Blanco has enough capacity for flowing 50 year floods except in some portions in the downstream reaches, partly river improvement in the downstream reaches with embankment will be necessary for preventing the inundation. As for the Canal San Roque, river improvement with embankment as well as enlargement will be necessary. The proposed flood mitigation facilities are shown in *Fig*.F.2.13.

By this river improvement, the inundations in the downstream reaches of the Rio Blanco, Canal San Roque and the outlet area of Laguna El Carmen will be prevented.

As the present land use condition of these areas are, almost pasture or natural swamp, the land use of these areas will be improved by this river improvement.

As for the sediment balance of the Rio Blanco, the river channel will have good sediment balance except the inlet portion of Laguna El Carmen. Sediment deposition will be estimated to occur around the most downstream reach of the Rio Blanco and Laguna El Carmen. Hence, periodical maintenance of the river bed will be necessary for the downstream reach.

Furthermore, as the degradation of the river bed of the mid-stream reach is caused by the excessive sand taking in the present, restriction of the excessive sand taking will be necessary to maintain the river bed.

Detailed informations of the flood mitigation facilities are described below.

1) Design Discharge

The design discharges at major stations are as follows;

- Canal San Roque (Sta. 0.00 km, Jct. Rio Choloma) : 1,110 m^3/s
- Canal San Roque (Sta. 6.40 km, Jct. Qda. San Agustin) : 890 m^3/s
- Rio Blanco (Sta. 20.50 km, Inlet Laguna El Carmen) : 660 m^3/s
- Rio Blanco (diversion of Alternative 2, Sta. 21.90 km) : 420 m^3/s
- Rio Blanco (Sta. 23.90 km, national road bridge) : 420 m^3/s

2) Design Longitudinal Section

The design longitudinal section is determined to be I = 1/4210 for the Canal San Roque, and I = 1/350 to 1/250 for the Rio Blanco considering the existing river bed slope. This design longitudinal section of the Rio Blanco will be stable as described in the Supporting Report E "Sedimentorology". The design longitudinal section is shown in *Fig*.F.2.14.

3) Design Cross Section

A compound cross section is planned by considering easy operation and maintenance. The design cross section is determined as follows;

Rio Blanco (Sta. 20.50 km - Sta. 23.90 km)

Use the existing channel in principle

Canal San Roque (Sta. 0.0 km - Sta. 6.40 km)

-	Width of low water channel (B1)	:	60 m
-	Height of low water channel (h1)	:	3.0 m
-	River width(B)	:	146 m

Qda. San Agustin (Sta. 6.40 km - Sta. 9.80 km)

-	Width of low water channel (B1)	:	60 m
-	Height of low water channel (h1)	:	2.0 m
-	River width (B)	:	134 m

The typical cross section is shown in *Fig*.F.2.15.

4) Design High Water Level

The design high water level at major points are as follows;

-	Canal San Roque (Sta. 0.0 km)	:	El. 12.00 m
-	Canal San Roque (Sta. 6.4 km)	:	El. 15.70 m
-	Rio Blanco (Sta. 20.50 km)	:	El. 56.10 m
-	Rio Blanco (Sta. 21.90 km)	:	El. 62.00 m
-	Rio Blanco (Sta. 23.90 km, national road bridge)	:	El. 69.50 m

Detailed information is presented in *Fig*.F.2.14.

5) Flood Mitigation Facilities and Their Work Quantities

Flood mitigation facilities of the Alternative 1 of the Rio Blanco and their work quantities are as follows;

Rio Blanco (Sta. 20.50 km - Sta. 23.90 km)

-	Embankment	1.50 km	85,500 m^3
-	Sodding	1.50 km	28,500 m^2

-	Land acquisition		4.2 ha

<u>Canal San Roque (Sta. 0.0 km - Sta. 6.40 km)</u>

-	Embankment	12.80 km	1,488,300 m^3
-	Channel improvement (excavation)	6.40 km	998,400 m^3
-	Sodding	12.8 km	429,100 m^2
-	Rehabilitation of bridges	2 places	146 m x 5 m x 2 no.
-	Land acquisition		149.8 ha

<u>Oda. San Agustin (Sta. 6.40 km - Sta. 14.07 km)</u>

-	Embankment	2.20 km	147,400 m^3
-	Channel improvement (excavation)	4.40 km	533,400 m^3
-	Sodding	2.20 km	55,700 m^2
-	Bridge rehabilitation	1 place	150 m x 5 m x 1 no.
-	Ground sill	3 places.	70m(L)x4m(H)x3no.
-	Revetment(gabion)	3 places	3,600 m^2
-	Land acquisition		53.7 ha

<u>Laguna El Carmen (Sta. 14.07 km - Sta. 20.50 km)</u>

-	Embankment	1.85 km	536,000 m^3
-	Revetment (gabion)	1.85 km	78,800 m^2
-	Sodding	1.85 km	69,600 m^2
-	Culvert	4 places	2mx2mx15mx2x4no.
-	Outlet	1 place	10mx8mx36mx1no.
-	Land acquisition		5.2 ha

2.4.5 Flood Mitigation Measures of the Rio El Sauce (Alternative 1)

In this sub-section, the river improvement of the Alternative 1 of the Rio El Sauce is described.

River Improvement of Alternative 1 of the Rio El Sauce

As the existing channel of the Rio El Sauce has enough capacity for flowing 50 year floods except in the downstream reach (0.0 km - 9.75 km), river improvement with embankment or heightening of the existing embankment as well as enlargement of the channel will be necessary for preventing the inundation in the downstream reach. The proposed flood mitigation facilities are shown in *Fig*.F.2.13.

As the left bank area of the downstream reach is being developed very much as housing area etc., more intensified land use will be possible by this river improvement.

As for the sediment balance of the Rio El Sauce, some unbalance of the sediment will be remained in the river reaches. Hence, periodical maintenance of the river bed will be necessary.

Detailed informations of the flood mitigation facilities are described below.

1) Design Discharge

The design discharge at major stations are as follows;

- Junction of the Rio Chamelecon (Sta. 0.00km) : 1,310 m^3/s
- Junction of the Rio Chotepe(Sta.1.60 km) : 790 m^3/s
- Junction of the diversion of Alternative 2 (Sta. 12.60 km) : 610 m^3/s
- Junction of the Rio Bermejo (Sta. 14.60 km) : 610 m^3/s

2) Design Longitudinal Section

The design longitudinal section is determined to be I = 1/1000 to 1/350 as shown in Fig.F.2.16.

3) Design Cross Section

A compound cross section is planned. The design cross section is determined as follows;

Rio El Sauce (Sta. 0.00 km - Sta. 9.75 km)

- Width of low water channel (B1) : 40 m

-	Height of low water channel (h1)	:	2.0 m
-	River width (B)	:	144 m

<u>Rio El Sauce (Sta. 9.75 km - Sta. 14.60 km)</u>

Existing section

The typical cross section is shown in *Fig*.F.2.15.

4) Design High Water Level

The design high water level at major points are as follows;

-	Junction of the Rio Chamelecon (Sta. 0.00 km)	:	El. 25.00 m
-	Junction of the Rio Chotepe (Sta. 1.60 km)	:	El. 25.53 m
-	Junction of the diversion of Alternative 2 (Sta. 12.60 km)	:	El. 53.97 m
-	Junction of the Rio Bermejo/Santa Ana (Sta. 14.60 km)	:	El. 58.93m

Detailed information is presented in *Fig*.F.2.16.

5) Flood Mitigation Facilities and Their Work Quantities

Flood mitigation facilities of the Alternative 1 of the Rio El Sauce and their work quantities are as follows;

<u>Rio El Sauce (Sta. 0.00 km - Sta. 14.60 km)</u>

-	Embankment (left bank)	5.50 km	296,300 m^3
-	Heightening of existing embankment	7.50 km	300,000 m^3
-	Channel improvement (excavation)	7.50 km	510,000 m^3
-	Sodding	11.00 km	563,500 m^2
-	Revetment (wet masonry)	2.00 km	41,100 m^2
-	Bridge (Sta. 12.60 km)	1 place	10 m x 150 m x 1 no.
-	Land acquisition		95.3 ha

2.4.6 Flood Mitigation Measures of the Rio Blanco and the Rio El Sauce (Alternative 2)

In this sub-section, the river improvement of the Alternative 2 which includes the diversion channel of the Rio Blanco to the Rio El Sauce is described.

River Improvement of Alternative 2

In the Alternative 2, the Rio Blanco and the Rio El Sauce will be combined by the diversion channel of the Rio Blanco. The river course of the Rio Blanco will be shifted to the present river course of the Rio El Sauce. The Canal San Roque and the Qda. San Agustin will drain the water of their own catchments.

The river improvements of the Alternative 2 are almost same as those of the Rio Blanco and the Rio El Sauce of the Alternative 1 except the diversion channel of the Rio Blanco (from the Sta. 21.90 km of the Rio Blanco to the Sta. 12.60 km of the Rio El Sauce). The proposed flood mitigation facilities are shown in *Fig*.F.2.17.

As for the sediment balance, as the sediment of the Rio Blanco will be flowed down to the Rio Chamelecon, the sediment deposition into Laguna El Carmen by the Rio Blanco will be stopped. But, there will be some deposition of sediment around the junction of the diversion channel with the Rio El Sauce and some unbalance of sediment in the river reaches of the Rio El Sauce. Hence, periodical maintenance of the river bed will be necessary.

Detailed informations of the flood mitigation facilities are described below.

1) Design Discharge

The design discharge at major stations are as follows;

Rio Blanco and the Diversion Channel

- Proposed diversion point (Sta. 21.90 km) : 420 m^3/s
- National road bridge (Sta. 23.90 km) : 420 m^3/s
- Proposed diversion channel : 600 m^3/s

Rio El Sauce

- Junction of the Rio Chamelecon (Sta. 0.00km) : 1,660 m^3/s
- Junction of the Rio Chotepe(Sta.1.60 km) : 1,170 m^3/s
- Junction of the diversion (Sta. 12.60 km) : 1.050 m^3/s
- Junction of the Rio Bermejo/Santa Ana (Sta. 14.60 km) : 610 m^3/s

2) Design Longitudinal Section

The design longitudinal section of the Rio Blanco and the diversion channel is shown in *Fig*.F.2.18. The design bed slope of the diversion channel is I = 1/300. The design longitudinal section of the Rio El Sauce is same as the Alternative 1 as shown in *Fig*.F.2.16.

3) Design Cross Section

A compound cross section is planned. The design cross section is determined as follows;

Rio Blanco (Sta. 21.90 km - Sta. 23.90 km)

Existing section

Proposed Diversion Channel

- Width of low water channel (B1) : 40 m
- Height of low water channel (h1) : 1.5 m
- River width (B) : 126 m

Rio El Sauce (Sta. 0.00 km - Sta. 9.75 km)

- Width of low water channel (B1) : 60 m
- Height of low water channel (h1) : 2.0 m
- River width (B) : 184 m

Rio El Sauce (Sta. 9.75 km - Sta. 14.60 km)

Existing section

The typical cross section is shown in *Fig*.F.2.15.

4) Design High Water Level

The design high water level at major points are as follows;

Rio Blanco

-	Proposed diversion point (Sta. 21.90 km)	: El. 61.20 m
-	National road bridge (Sta. 23.90 km)	: El. 65.66 m

Rio El Sauce

-	Junction of the Rio Chamelecon (Sta. 0.00 km)	: El. 25.00 m
-	Junction of the Rio Chotepe (Sta. 1.60 km)	: El. 25.53 m
-	Junction of the diversion (Sta. 12.60 km)	: El. 53.97 m
-	Junction of the Rio Bermejo/Santa Ana (Sta. 14.60 km)	: El. 58.93m

Detailed information is presented in *Fig*.F.2.16 and *Fig*.F.2.18.

5) Flood Mitigation Facilities and Their Work Quantities

Flood mitigation facilities of the Alternative 2 of the Rio Blanco, the proposed diversion channel and the Rio El Sauce and their work quantities are as follows;

Rio Blanco (Sta. 21.40 km - Sta. 23.90 km)

-	Embankment	1.50 km	85,500 m^3
-	Sodding	1.50 km	28,500 m^2
-	Land acquisition		4.2 ha

Diversion Channel (Length 2.60 km)

-	Embankment	5.20 km	296,400 m^3
-	Excavation	2.60 km	431,600 m^3
-	Sodding	5.20 km	98,700 m^2
-	Bed protection (gabion)	70 m x 50 m	3,500 m^3
-	Diversion weir and bridge(B 10 m)	1 place	70 m(L) x 3 m(H)

- Land acquisition 56.7 ha

Rio El Sauce (Sta. 0.00 km - Sta. 14.60 km)

-	Embankment (left bank)	5.50 km	296,300 m^3
-	Heightening of existing embankment	7.50 km	300,000 m^3
-	Channel improvement (excavation)	7.50 km	810,000 m^3
-	Sodding	11.00 km	563,500 m^2
-	Revetment (wet masonry)	2.00 km	41,100 m^2
-	Bridge (Sta. 12.60 km)	1 place	10 m x 150 m x 1 no.

- Land acquisition 117.8 ha

2.5 Conclusion

The conclusion of the flood mitigation study in the master plan stage are described below.

(1) Among the flood mitigation plans of the Rio Choloma, the Rio Blanco and the Rio El Sauce described in sub-section 2.4, the river improvements of the Rio Choloma and the Alternative 2 of the Rio Blanco and the Rio El Sauce were selected as the optimum plans.

This is because these plans have well flood mitigation effects to the study area as well as sufficient economic efficiency as described in the Supporting Report J "Economic Evaluation".

(2) As for the sediment balance of these plans, the Rio Choloma and the Rio Blanco will have good sediment balance from the upstream to the downstream of the river improvement reaches. But, some unbalance of sediment will be remained in the Rio El Sauce.

3. THE FEASIBILITY STUDY STAGE

3.1 General

As a result of the master plan study, the Rio Choloma basin (upstream from the junction of the Canal San Roque) was selected as the feasibility study area for the flood mitigation as well as the erosion and sediment control.

In this chapter, the study for the flood mitigation measures of the Rio Choloma in the feasibility study stage is described.

3.2 Basic Concepts of Formulating the Flood Mitigation Plans

The basic concepts of formulating the flood mitigation plan of the Rio Choloma are as follows;

(1) The flood mitigation plan of the Rio Choloma is composed of that of the long term plan and the urgent plan.

(2) The long term plan aims to mitigate the inundation for the whole reaches of the Rio Choloma between the junction of the Canal San Roque and the design control point of the erosion and sediment control (proposed No.1 consolidation dam of the Rio Choloma). The long term plan coincides with that of the flood mitigation plan of the master plan stage.

(3) The urgent flood mitigation plan aims to mitigate the inundation for the areas with higher damage potential of floods than the other areas. This area includes the town of Choloma City and its suburbs of future urbanization area identified by the municipality of Choloma City. The facility of the urgent flood mitigation plan is one part of the long term plan.

(4) The design scale of the long term flood mitigation plan is the floods with 50-year flood frequency.

Therefore, the main contents of the study are as follows;

a) Supplemental study of the inundation conditions
b) Formulating the long term flood mitigation plan
c) Formulating the urgent flood mitigation plan

3.3 Supplemental Study of the Inundation Conditions

Supplemental study of the inundation conditions was conducted by using the surveyed cross sections with 200 m interval by this study and the revised discharge distribution (refer to the Supporting Report A "Hydrology"). The results of this were used for revising the estimation of flood damage as well as formulation of the flood mitigation plan.

The simulation was done by using non-uniform flow calculation. The conditions of the non-uniform calculation such as the roughness coefficients and the downstream water level were same as the simulation of the master plan stage. The simulated area and depth of the inundations of the 2-year floods, the 50-year floods and the 100-year floods are shown in *Fig*.F.3.1.

The simulated flood water level of the 50-year floods in the present conditions is shown in *Fig*.F.3.2. As shown in this figure, in the almost all river reaches, inundation will occur by the 50-year floods. Furthermore, the existing national railway bridge is one of the big bottleneck for the flow.

3.4 Formulation of the Flood Mitigation Plan

3.4.1 Design Criteria

The design criteria of formulating the flood mitigation plan of the Rio Choloma is almost same as that of the master plan stage.

a) Design flood

Design flood is 50-year floods (refer to *Fig*.F.3.3).

b) Design high water level

Design high water level is determined by conducing non-uniform calculation.

c) Design longitudinal section

Design longitudinal section is determined so that the bed slope is almost same as the existing river bed slope. Furthermore, excessive excavation of the river bed is avoided.

d) Design cross section

Compound cross section is applied. The cross section of the low water channel is determined so that it has the discharge capacity of 3 to 5 year floods. The cross section of the high water channel is determined so that the water depth above the high water channel of the design flood will be less than the inundation water depth of the existing river conditions.

The design freeboard of the embankment is 1.0 m. The slope of the banks of the low water channel is 1 : 2. The embankment has the slope of 1 : 3 and the top width of 4.00 m.

3.4.2 Long Term Flood Mitigation Plan

The long term flood mitigation plan of the Rio Choloma was formulated for the river reach between the junction of the Canal San Roque and the proposed No.1 consolidation dam of the Rio Choloma which locates about 700 m upstream from the national road bridge. The proposed flood mitigation facilities are shown in *Fig*.F.3.4.

By this river improvement, the area around the above reach will be protected from the floods of the Rio Choloma. However, the backwater effect of the flood water level of the Rio Chamelecon is estimated to reach up to about 1.5 km upstream from the junction of the Canal San Roque (refer to *Fig*.F.3.2 (1)). Hence, river improvement of the Canal San Roque-Cuabanos as well as the Canal Copen-Higuero-Cuabanos will be necessary to mitigate the inundation of the downstream reach of the Rio Choloma.

As for the sediment balance of the Rio Choloma, the unbalance of the sediment in the present conditions will be much improved by the long term flood mitigation plan. But, the tendency of the local scouring around the national road bridge will be remained.

Furthermore, as the existing railway bridge is assessed to be a bottleneck for flowing the floods, rehabilitation of the bridge including heightening will be necessary if the social requirement of the national railway is big.

Although the existing national road bridge has enough clearance for the flood water level in the present (refer to *Fig*.F.3.2 (2)), the present width of the bridge (100 m) is narrower than the proposed river width of 190 m. Hence, extension of 80 m will be necessary. Furthermore, river bed protection around the bridge will be necessary to prevent the local scouring.

Detailed informations of the flood mitigation facilities are described below.

1) Design Discharge

The design discharges at major stations are as follows;

- Junction of the Canal San Roque(Sta. CH-001,11.250 km) : 790 m^3/s
- Sta. CH-012 (13.440 km) : 720 m^3/s
- Sta. CH-031 (16.960 km) : 680 m^3/s
- National railway bridge (Sta. CH-036, 17.815 km) : 680 m^3/s
- National road bridge (Sta. CH-040, 18.185 km) : 680 m^3/s
- Sta. CH-043 (18.815 km) : 680 m^3/s

2) Design Longitudinal Section

The design longitudinal section is shown in *Fig*.F.3.5. The design river bed slopes are as follows;

Sta. CH-001 to Sta. CH-012 (11.250 km to 13.440 km) : 1/378
Sta. CH-012 to Sta. CH-031 (13.440 km to 16.960 km) : 1/289
Sta. CH-031 to No.1 consolidation dam(16.960 km to 18.815 km) : 1/247

3) Design Cross Section

The standard design cross sections is determined as follows;

Sta. CH-001 to Sta. CH-012 (11.250 km to 13.440km)

- Width of low water channel (B1) : 50 m
- Height of low water channel (h1) : 2.0 m
- River width (B) : 158 m

Sta. CH-012 to Sta. CH-019 (13.440 km to 14.670 km)

- Width of low water channel (B1) : 40 m
- Height of low water channel (h1) : 2.0 m
- River width (B) : 138 m

Sta. CH-019 to Sta. CH-040 (14.670 km to 18.185 km)

- Width of low water channel (B1) : 40 m
- Height of low water channel (h1) : 2.5 m
- River width (B) : 130 m to 180 m

Sta. CH-040 to No.1 Consolidation Dam (18.185 km to 18.815 km)

- Width of low water channel (B1) : 180 m
- Height of low water channel (h1) : 2.5 m
- River width (B) : 180 m to 360 m

The design cross sections for the major stations are shown in *Fig*.F.3.6.

4) Design High Water Level

The design high water level at major points are as follows;

- Junction of the Canal San Roque(Sta. CH-001,11.250 km) : El. 11.00 m
- Sta. CH-012 (13.440 km) : El. 16.50 m
- Sta. CH-031 (16.960 km) : El. 28.80 m
- National railway bridge (Sta. CH-036, 17.815 km) : El. 32.22 m
- National road bridge (Sta. CH-040, 18.185 km) : El. 33.70 m
- Sta. CH-043 (18.815 km) : El. 36.22 m

Detailed information is presented in *Fig*.F.3.5.

5) Flood Mitigation Facilities and Their Work Quantities

Flood mitigation facilities and their work quantities are as follows;

- Embankment	15.13 km	476,800 m^3
- Channel improvement (excavation)	7.57 km	988,400 m^3
- Filling (common) of high water channel	-	130,300 m^3
- Spoiling (common)	-	381,300 m^3
- Revetment (wet masonry)	4.80 km	44,130 m^2

- Sodding		15.13 km	139,000 m^2
- Rehabilitation of bridges		2 places	
a) National road bridge	:	·extension 90 m x 26.5 m x 1 no. ·foot protection by gabion mat 16,800 m^2 (3,900 m^3)	
b) National railway bridge	:	reconstruction 160m x 5.0 m	
- Land acquisition			91.1 ha

The typical design of the revetment is shown in *Fig*.F.3.7. The proposed river bed protection of the national road bridge is shown in *Fig*.F.3.8. An example of the rehabilitation of the railway bridge is shown in *Fig*.F.3.9.

3.4.3 Urgent Flood Mitigation Plan

The urgent flood mitigation plan of the Rio Choloma was formulated for the river reach between the Sta. CH-023 to the proposed consolidation dam No.1 of the Rio Choloma (15.390 km to 18.815 km). This reason of this selection was that this reach covers the town of Choloma City as well as the future urbanization area identified by the municipality of Choloma City. Hence, the flood damage potential of the area around this reach is higher than the other reaches. The proposed flood mitigation facilities are shown in *Fig*.F.3.4.

For the urgent flood mitigation plan, the river improvement of this reach is same as that of the long term plan except the reach between the national road bridge and the proposed No.1 consolidation dam. This is because that the extension of the national road bridge will not be done in the urgent flood mitigation plan. The river bed protection around the bridge is also necessary to prevent the local scouring.

Detailed informations of the flood mitigation facilities are described below.

1) Design Longitudinal Section

The design longitudinal section of the urgent flood mitigation plan is same as the long term plan for the river reach between CH-023 and the proposed No.1 consolidation dam (refer to *Fig*.F.3.5(2)).

2) Design Cross Section

The design cross sections between the national road bridge and the proposed No.1 consolidation dam are shown in *Fig*.F.3.6 (4).

3) Design High Water Level

The design high water level is same as that of the long term plan as shown in *Fig*.F.3.5(2).

4) Flood Mitigation Facilities and Their Work Quantities

Flood mitigation facilities and their work quantities are as follows;

-	Embankment	6.86 km	134,400 m^3
-	Channel improvement (excavation)	3.43 km	536,500 m^3
-	Filling (common) of high water channel	-	96,900 m^3
-	Spoiling (common)	-	305,200 m^3
-	Revetment (wet masonry)	3.43 km	30,420 m^2
-	Sodding	6.86 km	49,000 m^2
-	Rehabilitation of bridges	2 places	

a) National road bridge : foot protection by gabion mat 11,400 m^2 (2,620 m^3)

b) National railway bridge : reconstruction 160m x 5.0 m

- Land acquisition 42.1 ha

4. RECOMMENDATION

Considering the existing conditions of the pilot rivers and other small rivers and canals in the study area and the proposed flood mitigation plans of the master plan study stage and the feasibility study stage, followings are the major recommendations by this study.

1) Establishment of Hydrological Observation Network in the Sula Valley

As the floods of the Sula Valley including the study area is mainly affected by the flood run-off of the Rio Ulua basin and the Rio Chamelecon basin, it is very important to observe the precipitation of the basins. This observation will be necessary to be conducted not only for the pilot rivers of the study area but also for the Ulua River and the Chamelecon River. But there are only few hydrological gauging stations including rainfall gauging stations and water level gauging stations in the Sula Valley.

Therefore, the hydrological gauging stations in the Rio Ulua basin and the Rio Chamelecon basin are necessary to be increased and their operation and maintenance are necessary to be continued for ever.

The observed data of these hydrological gauging stations will be very useful for flood mitigation study and works in the Sula Valley.

2) River Improvement of the Downstream Canals of the Rio Choloma

The existing downstream canals of the Rio Choloma of the Canal San Roque-Cuabanos and the Canal Copen-Higuero-Cuabanos have rather smaller discharge capacity than the flood discharge such as the floods of Fifi. Hence, in order to mitigate the inundation around these canals, improvement of these canals including embankment and enlargement will be necessary.

3) Drainage Improvement of the Rio Chotepe- Rio El Sauce (viejo) and Canal San Roque

The Rio Chotepe-Rio El Sauce (viejo) are one of the major drainage channels of San Pedro Sula City. These channels flow down not only the rainfall run-off but also the waste water of San Pedro Sula City. But, as the discharge capacity of the Rio Chotepe-Rio El Sauce (viejo) is small, inundation occurs annually in some areas of these drainage channels. Therefore, drainage improvement of these channels will be necessary.

As the discharge capacity of the Canal San Roque is small, it will cause inundation even by the flood with 2 - 5 year flood frequency even under the condition of the flood mitigation plan of the Alternative 2. In order to utilize or develop the land around the Canal San Roque in the future, drainage improvement will be indispensable.

TABLES

TABLE F.2.1 RECOMMENDED PROJECT WORKS BY SIR WILLIAM HALCROW & PARTNERS (1975)

River/Canal (RV)	Work Items (WK)	Location (LO)	Embankment(EM) B(m)	Embankment(EM) S	Revetment(RV)	Construction (CO) Agency(A)/Date(D)	Remarks(RM)
Rio Chiquito	Diversion Work	Ch1				MUNICIP./1978	
Rio Blanco	Flood Dike	Bc1	10,00	1:2/1:3	To be provided	MUNICIP./1978	
	Bridge Protection	Bc2				No construction	
Rio Sauce	Flood Dike	Sa1	10,00	1:2/1:3	No	MUNICIP./1977	
	Bridge removal	Sa2				No construction	
	Bridge Protection	Sa3				No construction	
Rio Bermejo	Flood Dike	Br1	10,00	1:2/1:3	No	MUNICIP./1977	
	Pass Removal	Br2				MUNICIP.	
	Bridge Protection	Br3				No construction	
Rio Santa Ana	Flood Dike	Sa1	10,00	1:2/1:3	To be provided	MUNICIP./1977	
Rio Piedras	Flood Dike	Pd1	10,00	1:2/1:3	To be provided(portion	MUNICIP./1977	
	Gate Removal	Pd2				MUNICIP./1977	
	Bridge Protection	Pd3				No construction	
Rio Primavera	Diversion Work	Pr1				No construction	
	Flood Dike	Pr2	10,00	1:2/1:3	To be provided	No construction	
	Bridge construction	Pr3				No construction	

Note/Nota:

1.(RV):River/Canal /
2.(WK):Work Items/
Diversion Work/
Flood Dike/
Bridge Protection/
Bridge removal/
Bridge construction/
Pass Removal/
Gate Removal/

3.(LO):Location/
4.(EM)Embankment
5.(RV):Revetment/
6.(CO):Construction/
(A):Agency/
(D):Date/
7.(RM):Remarks/
8.MUNICIP.:Municipality of San Pedro Sula