4) Rio Piedras

Seven(7) check dams and channel works are planned to cope with the design sediment amount. The location of facilities is shown in *Figs* 7.4 (4) and 7.5 (3) and their details are shown in *Table* 7.7 (4). They are explained as follows:

a) Plain area

- Channel improvement works are planned at the reach (1/30~1/100) between the design control point and the sub-control point in order to stabilize the river course

b) Mountainous area

- Five(5) check dams are planned at the reach (1/19~1/15) upstream of the sub-control point. Also two check dams each of the two tributaries are planned in order to control debris flows.

7.5 Potential Debris Flow Hazard Area

The land forms such as talus cones, alluvial cones and alluvial fans explain a history of the regional sediment yield and discharge. Alluvial cones and alluvial fans might have been developed by sediment flows and debris flows in the past. Since the occurrence of debris flows, etc., is repeated over a certain period of time, the areas around these landforms will most probably continue to experience the same occurrences.

For a part of the proposed non-structural measures, the debris flow hazard areas are tentatively identified for the study area. These debris flow hazard areas are decided by referring both to the information obtained from landforms, identified based on the aerial photographs taken 1992, and to the designation method of debris flow hazard areas developed in Japan.

Hazardous debris flows and areas are identified from factors most related to occurrence of debris flows, such as riverbed slope, scale of drainage basin and past records of debris flows. The result is shown in *Figs*. 7.6 (1)~(4).

TABLES

TABLE 7.1 SEDIMENT YIELD OF NEWLY AND EXPANDING COLLAPSED AREA

C.P Drainage Basin Cuenca de Drenaje	D.A km²	A km²	rl %	dl m	L0 m	W0 m	d0 m	V1 $\times 10^3$ m³
Rio Choloma Basin								
① Rio Majaine	34.63	33.49	9.68	1.0				3241.7
② Rio La Jutosa	20.39	18.29	9.68	1.0				1770.5
Remains	16.62	10.04	9.68	1.0				972.0
△ Rio Choloma (Total)	71.64							5984.2
Rio Blanco Basin								
① Rio del Zapotal	17.92	17.92	9.68	1.0				1734.5
② Rio de Armenta	9.02	9.02	9.68	1.0				873.1
③ Rio Chiquito	7.47	6.98	9.68	1.0				675.7
Remains	9.49	5.29	9.68	1.0				512.2
△ Rio Blanco (Total)	43.90	39.21						3795.5
Rio Santa Ana Basin								
① Rio Santa Ana	22.39	22.39			33760	2	1	67.4
Remains	15.24	6.02			13500	2	1	27.0
△ Rio Santa Ana (Total)	37.63	28.59			47260	2	1	94.4
Rio Piedras								
① Rio Piedras	20.09	20.09			25470	2	1	51.0
Remains	10.78	6.68			10680	2	1	21.4
△ Rio Piedras (Total)	30.87	26.77			36150	2	1	72.4

Note/Nota :

C.P, △ : Design control point / Punto de control de diseño
① : Sub-control point and number / Punto de sub-control y numero
Remains : Remains of drainage area / Restos en area de cuenca
D.A : Drainage area / Area de cuenca
A : Mountain slope area / Area montañosa
rl : Ratio of collapsed area occured in 1974
/ Porcentaje de area de derrumbamiento ocurrio en 1974
dl : Average collapsed depth
/ Profundidad promedio de pendiente derrumbadas
L0 : Zero order valley length / Longitud del valle de orden cero
W0 : Zero order valley width / Ancho del valle de orden cero
d0 : Thickness of zero order valley deposits
/ Espesor de depositos en el valle de orden cero
V1 : Sediment yield of newly and expanding collapsed area
/ Produccion de sedimentos en areas nuevas y areas derrumbados en expansion

Value of L0, W0, and d0 have been estimated based on aerial photo-interpretation and field investigations

[Rio Choloma and Rio Blanco]

$V1 = A \times rl \times dl$

[Rio Santa Ana and Rio Piedras]

$V1 = L0 \times W0 \times d0$

TABLE 7.2 CALCULATION OF FLOOD DISCHARGE

River Basin / River	Stream Order & Name	A	Main Stream H₁	H₂	H	L	L/H	W	T₀	T₁	T	R₂₄	r	f	Q
Rio Choloma Basin															
Rio Majaine	4-1	12.91	317	103	214	5560	26	3.5	26	30	56	340	68	0.73	178
Rio del Ocotillo	4-2	13.51	377	103	274	3200	12	3.5	15	30	45	340	71	0.70	187
Rio Chiolma	4-1,4-2	26.42													365
			103	75	28	1530	55	3.5	7						
Rio Chiolma	5-1-1	34.63	75	68	7	2020	289	2.1	16		79	340	63	0.67	406
Rio La Jutosa	4-3	20.39	549	68	481	8650	18	3.5	41	30	71	340	65	0.67	247
Rio Choloma	4-3,5-1-1	55.02													653
			68	65	3	600	200	2.1	5						
Rio Choloma		71.64	65	31	34	4050	119	3.0	23		107	340	58	0.64	739
Rio Blanco															
Rio Armenta	3-3-1	9.02	500	120	380	2000	5	3.5	10	30	40	340	72	0.80	144
Rio Armenta	3-3	9.31	120	76	44	1980	45	3.5	9		49	340	70	0.80	145
Rio del Zapotal	4-1-1	17.92	940	160	780	4500	6	3.5	21	30	51	340	69	0.80	275
Rio del Zapotal	4-1	19.93	160	76	84	3600	43	3.5	17		68	340	66	0.80	292
Rio Chiquito	3-5,3-6	7.47	240	160	80	2000	25	3.5	10	30	40	340	72	0.80	120
Rio Chiquito	4-3	9.97	160	60	100	4000	40	3.5	19		59	340	68	0.80	151
Rio Santa Ana															
Rio Santa Ana	4-1-1	22.39	1200	150	1050	8200	8	3.5	39	30	69	340	65	0.80	323
Rio Santa Ana	4-1	37.63	150	64	86	4200	49	3.5	20		89	340	61	0.80	510
Rio Piedras															
Rio Piedras	3-1-1,3-1-2	20.09	1000	69	931	7500	8	3.5	36	30	66	340	66	0.80	295
Rio Piedras	4-1	30.87	69	66	3	4600	1533	2.1	37		103	340	58	0.80	398

Note:
A (km²) = Catchment area / Area de cuenca
H_1 (m) = Highest elevation(segment) / Elevacion mas alta
H_2 (m) = Lowest elevation(Segment) / Elevacion mas bajo
$H = H_1 - H_2$
L (m) = Length of watercourese(Segment) / Longitud del canal
W = Average flood velocity / Velocidad media del flujo (3.5=(L/H≦100), 3.0=(200≧L/H>100), 2.1=(L/H>200))
T_0 (min) = Arrival time from a upatream point to the calculation point along the river (L/W)
/ Tiempo de llegada desde un punto aguas arriva a lo largo del rio
T_1 (min) = Arrival time of surfacewater or groundwater from at a rainfall point on mountaonous slope to the river course
/ Tiempo de concentracion desde un punt de lluvia en vertiente montaña hasta curso del rio
T (min) = Arrival time of flood concentration to the calculation point
/ Tiempo de llegada del concentracion del flojo a un punto de calculo
R_{24} (mm/24 hour) = Maximum recorded 24-hour rainfall / Lluvia maxima recuerda de diaria
r (mm/hr) = Average rainfall intensity within the time of flood concentration / Intensidad media de lluvia
$r = R_{24} \times Ct/100$, Ct=34710/(t^1.35+1502)(Ii z uka formula)
f = Run-off coefficient / Coeficiente de escorrentia
Q (qu.m/sec) = Peak discharge / Descarge pico, $Q = 0.2778 \cdot f \cdot r \cdot A$ (Rational formula)

TABLE 7.3 SEDIMENT YIELD DUE TO RIVER BANK EROSION

River Basin Name, Stream Order and Number C.P Nombre del Rio, Orden de La Corriente y Numero de Cuenca	D.A km²	Lz m	Wo m	Wf m	Hb m	V4 m³
① Rio Majaine 5-1-1	34.63	-	-	-	-	246360
② Rio La Jutosa 4-3	20.39	-	-	-	-	212480
Remains	16.62	-	-	-	-	598570
△ Rio Choloma Basin	71.64	-	-	-	-	1057410
① Rio del Zapotal 4-1-1	17.92	-	-	-	-	67872
② Rio de Armenta 3-3-1	9.02	-	-	-	-	6200
③ Rio Chiquito 3-5,3-6	7.47	-	-	-	-	39300
Remains	9.49	-	-	-	-	325760
△ Rio Blanco Baisin	43.90	-	-	-	-	439132
① Rio Santa Ana 4-1-1	22.39	-	-	-	-	5000
Remains	15.24	-	-	-	-	181350
△ Rio Santa Ana Basin	37.63	-	-	-	-	186350
① Rio Piedras 3-1-2	20.09	-	-	-	-	84624
Remains	10.78	-	-	-	-	91600
△ Rio Piedras Basin	30.87	-	-	-	-	176224

Note/Nota :

C.P, △ : Design control point / Punto de control de diseño
① : Sub-control point & number / Punto de sub-cotrol y numero
Remains : Remains of drainage area / Restos en area de cuenca
D.A : Drainage area / Area de cuenca
Lz : Length of unstable deposits area along the river
/ Longitud de area de depositos inestables a lo largo del rio
Wo : River width of ordinary water level / Ancho normal del nivel de agua del rio
Wf : River width of high water level / Ancho del nivel de agua alta en el rio
Hb : Eroded depth of river bank / Profundidad de las riberas
V4 : Sediment yield due to river bank erosion
/ Produccion de sedimentos debido a la erosion de la ribera del rio

TABLE 7.4 DESIGN SEDIMENT YIELD

C.P Drainage Basin Cuenca de Drenaje	D.A km²	V1 x10³ m³	V2 x10³ m³	V3 x10³ m³	V4 x10³ m³	V10 x10³ m³
Rio Choloma Basin						
① Rio Majaine	34.63	3241.7	16.8	483.6	246.4	3988.5
② Rio La Jutosa	20.39	1770.5	6.8	352.2	212.5	2342.0
Remains	16.62	972.0	2.5	149.3	598.8	1722.6
△ Rio Choloma (Total)	71.64	5984.2	26.1	985.1	1057.7	8053.1
Rio Blanco Basin						
① Rio del Zapotal	17.92	1734.5	16.5	212.2	67.9	2031.1
② Rio de Armenta	9.02	873.1	4.8	88.5	6.2	972.6
③ Rio Chiquito	7.47	675.7	0.3	105.1	39.3	820.4
Remains	9.49	512.2	0.4	32.7	287.8	833.1
△ Rio Blanco (Total)	43.90	3795.5	22.0	438.5	401.2	4657.2
Rio Santa Ana Basin						
① Rio Santa Ana	22.39	67.4	12.5	325.7	5.0	410.8
Remains	15.24	27.0	0.5	92.8	181.4	301.8
△ Rio Santa Ana (Total)	37.63	94.4	13.0	418.5	186.4	712.6
Rio Piedras						
① Rio Piedras	20.09	51.0	1.6	266.8	84.6	404.0
Remains	10.78	21.4	0.2	60.6	91.6	173.8
△ Rio Piedras (Total)	30.87	72.4	1.8	327.4	176.2	577.8

Note/Nota :

C.P, △ : Design control point / Punto de control de diseño

① : Sub-control point and number / Punto de sub-control y numero

Remains : Remains of drainage area / Restos en area de cuenca

D.A : Drainage area / Area de cuenca

V1 : Sediment yield of newly and expanding collapsed area
Produccion de sedimentos en areas nuevas y areas derrumbados en expansion

V2 : Residual collapsed sediment yield of existing past collapsed area
Produccion de sedimentos residuales existentes debido a areas derrubadas anterirmente

V3 : Sediment yield of surrounding riverbed area
Produccion de sedimentos alrededor en el area de lecho del rio

V4 : Sediment yield due to river bank erosion
Produccion de sedimentos debido a la erosion de la ribera del rio

V10 : Design sediment yield (V10=V1+V2+V3+V4)
Produccion de sedimentos de diseño

TABLE 7.5 DESIGN BASIC SEDIMENT

C.P Drainage Basin Cuenca de Drenaje	D.A km²	V10 X10³ m³	V20 X10³ m³	V30 X10³ m³	V40 X10³ m³	V50 X10³ m³
Rio Choloma Basin						
① Rio Majaine	34.63	3988.5	2696.0	1292.5	0.0	1292.5
② Rio La Jutosa	20.39	2342.0	1379.9	962.1	0.0	962.1
Remains	16.62	1722.6	2548.9			
△ Rio Choloma (Total)	71.64	8053.1	6624.8	1428.3	142.8	1285.5
Rio Blanco Basin						
① Rio del Zapotal	17.92	2031.1	357.7	1673.4	0.0	1673.4
② Rio de Armenta	9.02	972.6	197.0	775.6	0.0	775.6
③ Rio Chiquito	7.47	820.4	586.1	234.3	0.0	234.3
Remains	9.49	833.1	2715.8			
△ Rio Blanco (Total)	43.90	4657.2	3856.6	800.6	80.1	720.5
Rio Santa Ana Basin						
① Rio Santa Ana	22.39	410.8	20.0	390.8	0.0	390.8
Remains	15.24	301.8	286.6			
△ Rio Santa Ana (Total)	37.63	712.6	306.6	406.0	40.6	365.4
Rio Piedras						
① Rio Piedras	20.09	404.0	40.0	364.0	0.0	364.0
Remains	10.78	173.8	207.2			
△ Rio Piedras (Total)	30.87	577.8	247.2	330.6	33.1	297.5

Noto/Nota :

△ : Design control point / Punto de control de diseño
① : Sub-control point and number / Punto de sub-control y numero
Remains : Remains of drainage area / Restos en area de cuenca
D.A : Drainage area / Area de cuenca
V10 : Design sediment yield / Produccion de sedimentos de diseño
V20 : Naturally controlled sediment discharge along the river course / Descarga de sedimento controlada naturalmente a lo largo de los cursos del rio
V30 : Design sediment discharge / Descarga de sedimentos de diseño
V40 : Design allowable sediment discharge / Descarga de sedimentos permisible de diseño
V50 : Design excess sediment discharge / Descarga de sedimentos exceso de diseño

TABLE 7.6 PROPOSED SEDIMENT BALANCE

C.P D.N	D.A	V10 X$10^3 m^3$	V20 X$10^3 m^3$	V30 X$10^3 m^3$	V40 X$10^3 m^3$	V50 X$10^3 m^3$	E1 X$10^3 m^3$	E2 X$10^3 m^3$	E1+E2 X$10^3 m^3$	P1 %	P2 %
Rio Choloma Basin											
① Rio Majaine	34.63	3988.5	2696.0	1292.5	-	1292.5	0.0	348.6	348.6	0	27
② Rio La Jutosa	20.39	2342.0	1379.9	962.1	-	962.1	20.9	260.8	281.7	2	29
Remains	16.62	1722.6	2548.9				0.0	655.2	655.2		
△ Rio Choloma (Total)	71.64	8053.1	6624.8	1428.3	142.8	1285.5	20.9	1264.6	1285.5	2	100
Rio Blanco Basin											
① Rio del Zapotal	17.92	2031.1	357.7	1673.4	-	1673.4	0.0	604.0	604.0	0	36
② Rio de Armenta	9.02	972.6	197.0	775.6	-	775.6	0.0	116.7	116.7	0	15
③ Rio Chiquito	7.47	820.4	586.1	234.3	-	234.3	0.0	0.0	0.0	0	0
Remains	9.49	833.1	2715.8				0.0	0.0	0.0		
△ Rio Blanco (Total)	43.90	4657.2	3856.6	800.6	80.1	720.5	0.0	720.7	720.7	0	100
Rio Santa Ana Basin											
① Rio Santa Ana	22.39	410.8	20.0	390.8	-	390.8	2.3	202.0	204.3	1	2
Remains	15.24	301.8	286.6				0.0	160.9	160.9		
△ Rio Santa Ana (Total)	37.63	712.6	306.6	406.0	40.6	365.4	2.3	362.9	365.2	1	100
Rio Piedras											
① Rio Piedras	20.09	404.0	40.0	364.0	-	364.0	1.1	202.6	203.7	0	56
Remains	10.78	173.8	207.2				0.0	95.2	95.2		
△ Rio Piedras (Total)	30.87	577.8	247.2	330.6	33.1	297.5	1.1	297.8	298.9	0	100

Note/Nota :

△ : Design control point / Punto de control de diseño
① : Sub-control point and number / Punto de sub-control y numero
Remains : Remains of drainage area / Restos en area de cuenca
D.N : Drainage name / Nombre de cuanca
D.A : Drainage area / Area de cuenca
V10 : Design sediment yield / Produccion de sedimentos de diseño
V20 : Naturally controlled sediment discharge along the river courses / Descarga de sedimento controlada naturalmente a lo largo de los cursos del rio
V30 : Design sediment discharge / Descarga de sedimentos de diseño
V40 : Design allowable sediment discharge / Descarga de sedimentos permisible de diseño
V50 : Design excess sediment discharge / Descarga de sedimentos exceso de diseño
E1 : Facilities effect(Existing) / Instalaciones efectivas(Existentes)
E2 : Facilities effect(Plan) / Instalaciones efectivas(Propuesta)
P1 : Sediment control ratio(Existing)(=100XE1/V50) / Porcentaje de control de sedimentos(Existentes)
P2 : Sediment control ratio(Plan)(=100X(E1+E2)/V50) / Porcentaje de control de sedimentos(Propuesta)

TABLE 7.7 (1) PROPOSED FACILITIES (RIO CHOLOMA)

Rio Choloma

D.N	T.F	H m	h m	L m	B1 m	B2 m	d1 m	d2 m	1/N	ALF	lc m	Vc1 m³	Vc2 m³	Vr m³	Vd m³	Ve m³
R4-1	D-1	14.0	11.5	197	50	55	2.0	2.0	28.6	0.37	658	208030	20800	80930		71790
R4-1	D-2	14.0	11.5	78	30	40	2.0	2.0	31.7	0.37	729	167690	16770	60510		54890
R4-1	D-3	14.0	11.5	76	27	35	2.0	2.0	24.0	0.37	552	111090	11110	42500		37890
R4-1	D-4	10.0	8.0	71	25	35	2.0	2.0	16.0	0.37	256	35840	3580	16900		14230
R4-1	(Sub-total)											522650	52260	200840		178800
R4-2	D-5	12.0	10.0	190	20	70	2.0	2.0	26.5	0.14	530	185500	18550	31800		45900
R4-2	D-6	14.0	11.0	84	20	50	2.0	2.0	15.0	0.14	330	90750	9080	20460		26680
R4-2	(Sub-total)											276250	27630	52260		72580
R3-5	D-7	14.0	11.0	97	10	40	2.0	2.0	15.0	0.05	330	72600	7260	13860		20430
R3-5	(Sub-total)											72600	7260	13860		20430
R5-1-1	CO.W1		2.5		150		2.0			0.52	200	0	0	60000		28800
R5-1-1	CO.W2		3.0		100		2.0			0.52	500	0	0	100000		48000
R5-1-1	(Sub-total)											0	0	160000		76800
Total	(Rio Majaine)															348610
2-30	D-8	10.0	8.0	121	20	55	2.0	2.0	14.5	0.17	232	51040	5100	12990		15880
2-30	(Sub-total)											51040	5100	12990		15880
R4-3	D-9	14.0	11.2	209	50	55	2.0	2.0	23.0	0.49	515	158680	15870	63040		48020
R4-3	D-10	14.0	11.0	123	30	40	2.0	2.0	20.0	0.49	440	96800	9680	36080		28080
R4-3	CO.W		1.5~3.0		150~250		2.0			0.49	870			331000		168810
R4-3	(Sub-total)											255480	25550	430120		244910
Total	(Rio La Jutosa)											306520	30650	443110		260790
R5-1-2	CO.W		1.0~2.0		200~300		2.0			0.58	2950			1560000		655200
R5-1-2	TL			1325												0
R5-1-2	(Sub-total)													1560000		655200
Total	(Rio Choloma)													1560000		655200

Note / Nota : Refer to the note of table for the Rio Santa Ana
Referirse a la nota de la tabla para el Rio Santa Ana

TABLE 7.7 (2) PROPOSED FACILITIES (RIO BLANCO)

Rio Blanco

D.N	T.F	H m	h m	L m	B1 m	B2 m	d1 m	d2 m	1/N	ALF	lc m	Vc1 m³	Vc2 m³	Vr m³	Vd m³	Ve m³
R3-1-2	D-5	14.0	11.0	68	20	35	2.0	2.0	9.0	0.08	198	38120	3810	12280		15110
R3-1-2	(TOTAL)											38120	3810	12280		15110
R4-1-1	D-1	14.0	12.0	122	35	60	2.0	2.0	25.6	0.16	614	221180	22120	57720		70600
R4-1-1	OD-2	11.0	9.0	193	30	90	2.0	2.0	28.7	0.16	517	209220	20920	40330	167380	222180
R4-1-1	OD-3	14.0	12.0	117	25	55	2.0	2.0	17.6	0.16	422	139390	13940	31230	111510	151680
R4-1-1	D-4	14.0	11.0	82	22	50	2.0	2.0	10.1	0.16	222	61110	6110	14650		18420
R4-1-1	CO.W				150		2.0			0.16	500			150000		126000
R4-1-1	(Sub-total)											630900	63090	143930	278890	588880
Total	(Rio del Zapotal)															603990
R3-3-1	D-6	11.0	9.0	55	20	40	2.0	2.0	20.0	0.20	360	64800	6480	20880		23180
R3-3-1	D-7	14.0	12.0	95	30	60	2.0	2.0	15.0	0.20	360	129600	12960	30240		37150
R3-3-1	D-8	14.0	12.0	83	25	55	2.0	2.0	14.0	0.20	336	110880	11090	24860		30980
R3-3-1	D-9	14.0	11.0	61	25	45	2.0	2.0	14.0	0.20	308	76230	7620	22180		25360
R3-3-1	DC			500												0
R3-3-1	(Sub-total)											381510	38150	98160		116670
Total	(Rio de Armenta)															116670
R4-1-2	DC			430												0
R4-1-2	DC			420												0
R4-1-2	DC			650												0
R4-1-2	DC			1050												0
R4-1-2	DC			500												0
R4-1-2	DC			400												0
R4-1-2	(Sub-total)															0
2-14	DC			110												0
2-14	(Sub-total)															0
R4-3	G	3.0		120												0
Total	(Rio Chiquito)															0
R5-1	G	3.0		150												0
R5-1	CH.W										1650					0
R5-1	(Sub-total)															0
Total	(Rio Blanco)															0

Note / Nota : Refer to the note of table for the Rio Santa Ana
Referirse a la nota de la tabla para el Rio Santa Ana

TABLA 7.7 (3) PROPOSED FACILITIES (RIO SANTA ANA)

Rio Santa Ana

D.N	T.F	H m	h m	L m	B1 m	B2 m	d1 m	d2 m	1/N	ALF	Lc m	Vc1 m³	Vc2 m³	Vr m³	Vd m³	Ve m³
R4-1-1	D-1	14.0	11.0	103	20	50	2.0	2.0	21.0	0.05	462	127050	12710	28640		39920
R4-1-1	D-2	14.0	11.0	78	20	40	2.0	2.0	18.0	0.05	396	87120	8710	24550		32030
R4-1-1	D-3	14.0	12.0	98	25	45	2.0	2.0	14.0	0.05	336	90720	9070	24860		32690
R4-1-1	D-4	14.0	11.5	51	15	25	2.0	2.0	12.0	0.05	276	39680	3970	14630		17870
R4-1-1	D-5	14.0	11.0	66	20	40	2.0	2.0	11.0	0.05	242	53240	5320	15000		19570
R4-1-1	D-6	14.0	12.0	57	25	35	2.0	2.0	15.0	0.05	360	75600	7560	26640		32870
R4-1-1	D-7	14.0	11.0	51	22	35	2.0	2.0	15.0	0.05	330	63530	6350	21780		27040
R4-1-1	(Sub-total)											536940	53690	156100		201990
TOTAL	(Rio Santa Ana)															201990
R4-1-2	CH.W				65		1.5			0.34	2500			243750		160880
R4-1-2	(Sub-total)													243750		160880
TOTAL	(Rio Santa Ana)															160880

Note / Nota :

D.N : Stream order and drainage number / Orden de la corriente y número de cuenca   R : Remains of drainage area / Restos en area de cuenca

T.F : Facility type / Tipo de estructuras

D : Check dam(Sabo dam) / Presa de retención   OD : Open type dam / Tipo de presa de retención abierta

CH.W : Channel warks / Trabajos en los cauces   G : Consolidation dam / Presa consolidación

CO.W : Consolidation works / Trabajos de consolidación   TL : Trainning levee / Dique de guía

H : Dam height / Altura de presa   h : Effective dam height / Altura efectiva de presa

L : Dam length / Longitud de presa   B1 : Riverbed width / Ancho del lecho del río

B2 : Average width of sedimentation area / Anchura promedio del área de sedimentación

d1 : Thickness of riverbed deposits / Espesor de sedimentos en del cauce del rio

d2 : Thickness of sediments at river bank slope / Espesor de sedimentos en la ribera del Rio

1/N : Riverbed gradient / Inclinación del cauce del río

ALF : Portion of V20 at calculation point to total volume of V10 at calculation point and V30 at the upper reaches of calculation point
Porcion en los V20 en punto de calculacion por totalidad volumen de V10 en punto de calculacion y V30 en area de parte mas alta del rio

Lc : Length of sedimentation area / Longitud de area de sedimentacion(=2XNXh)

Vc1 : Sediment trap capacity / Capacidad de la trampa de sedimentos(=NXB2XH²)

Vc2 : Contorolled sediment discharge capability / Capacidad de descarga de sedimentos controlados(0.1xVc1)

Vr : Sediment discharge suppression capability / Capacidad de descarga de sedimentos represiro(=LcX(hXd2+B1Xd1))

Vd : Deposit volume / Volumen de depósitos(=0.8XVc1)

Ve : Effective sedimentation capacity / Capacidad de sedimentacion efectiva(=Vr(1-ALF)+Vd)

TABLE 7.7 (4) PROPOSED FACILITIES (RIO PIEDRAS)

Rio Piedras

D.N	T.F	H m	h m	L m	B1 m	B2 m	d1 m	d2 m	I/N	ALF	Lc m	Vc1 m^3	Vc2 m^3	Vr m^3	Vd m^3	Ve m^3
R3-1-2	D-1	14.0	11.5	71	25	50	2.0	2.0	19.0	0.10	437	125640	12560	31900		41270
R3-1-2	D-2	14.0	11.0	93	30	55	2.0	2.0	16.0	0.10	352	106480	10650	28860		36620
R3-1-2	D-3	14.0	11.0	107	45	60	2.0	2.0	16.0	0.10	352	116160	11620	39420		47100
R3-1-2	D-4	14.0	11.0	99	40	60	2.0	2.0	15.0	0.10	330	108900	10890	33660		41180
R3-1-2	D-5	14.0	11.0	69	35	50	2.0	2.0	15.0	0.10	330	90750	9080	30360		36400
R3-1-2	(Sub-total)											547930	54800	164200		202570
Total	(Rio Piedras)															202570
R3-2	D-6	14.0	11.5	86	20	35	2.0	2.0	8.0	0.06	184	37030	3700	11590		14590
R3-2	(Sub-total)											37030	3700	11590		14590
2-9	D-7	10.0	8.0	57	15	25	2.0	2.0	7.0	0.00	112	11200	1120	5150		6270
2-9	(Sub-total)											11200	1120	5150		6270
R3-1-3	CH.W				35		1.0			0.20	1500			52500		42000
R3-1-3	(TOTAL)													52500		42000
R4-1	CH.W				35		1.5			0.23	800			42000		32340
R4-1	(Sub-total)													42000		32340
TOTAL	(Rio Piedras)														-	95200

Note / Nota : Refer to the note of table for the Rio Santa Ana
Referirse a la nota de la tabla para el Rio Santa Ana

FIGURES

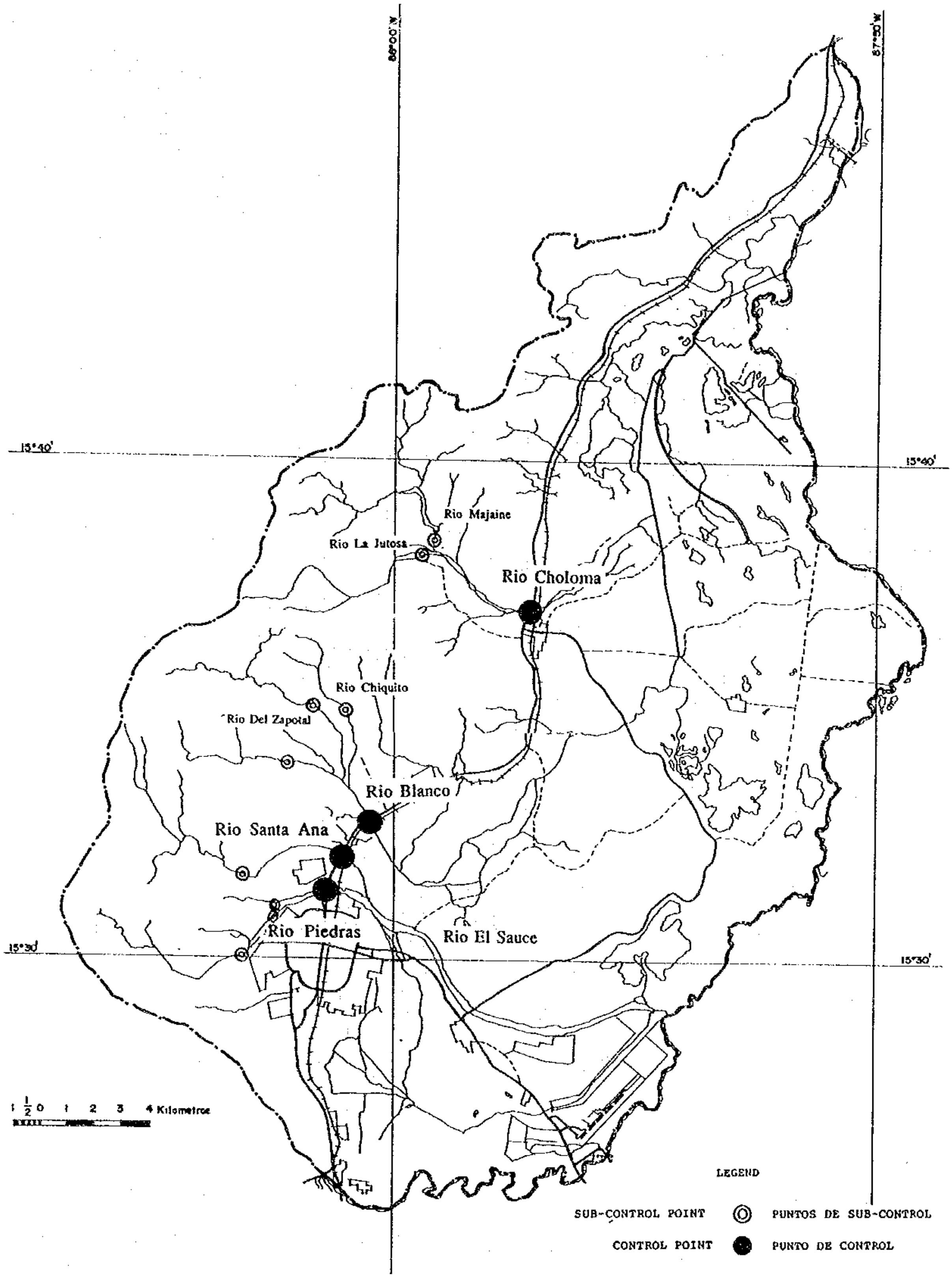
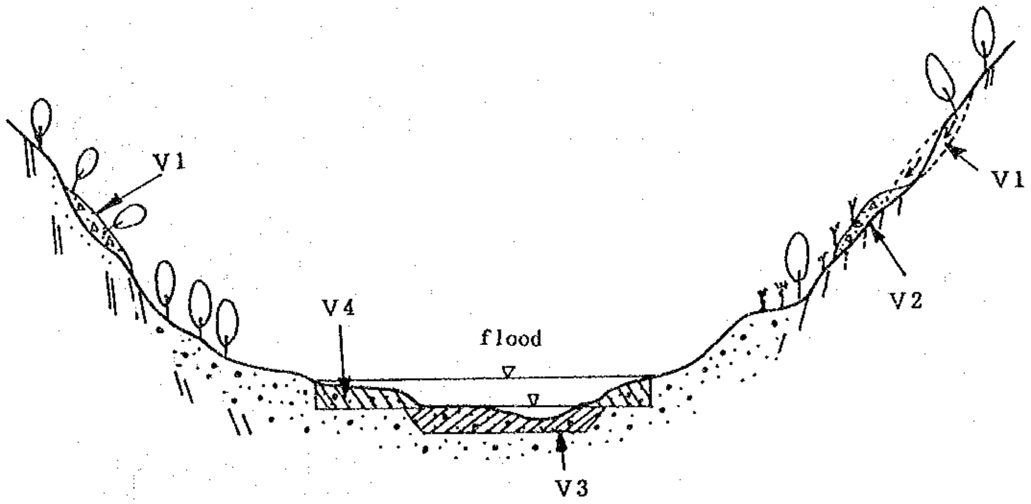
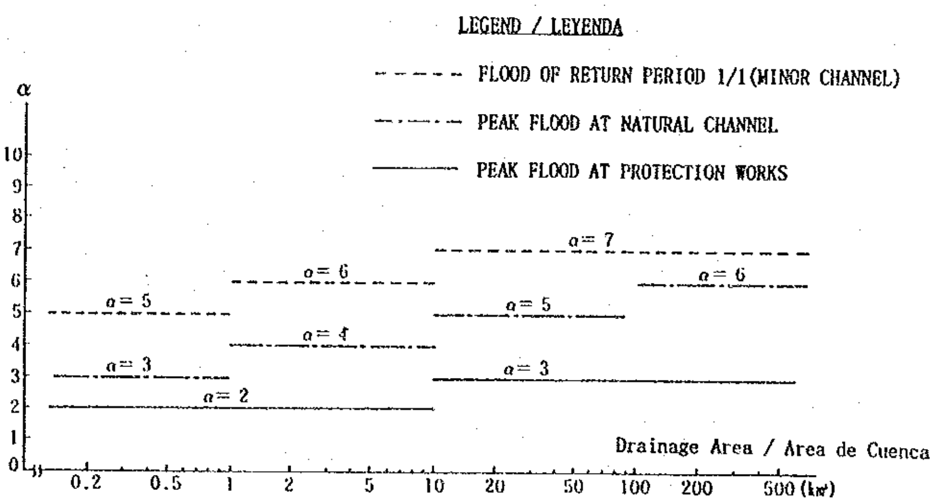


FIG. 7.1 CONTROL POINT



V1=Sediment yield of expanding collapsed area
Produccion de sedimontos de areas derrumbadas en expansion
V1=Sediment yield of newly collapsed area
Produccion de sedimento de nueva area derrumbada
V2=Residual collapsed sediment yield of existing past collapsed area
Produccion de sedimentos residuales existentes debido a areas derrumbadas anteriormente
V3=Sediment yield of surrounding riverbed area
Produccion de sedimentos alrededor en el area de lecho del rio
V4=Sediment yield due to river bank erosion
Produccion de sedimentos debido a la erosion de la ribera del rio
V10=design sediment yield / Produccion de sedimentos de diseño(=V1+V2+V3+V4)

FIG. 7.2 CONCEPT OF DESIGN SEDIMENT YIELD



FLOOD OF RETURN PERIOD 1/1(MINOR CHANNEL) / PERIODO DE RETORNO DEL FLUJO 1/1(CANAL MENOR)
PEAK FLOOD AT NATURAL CHANNEL / FLUJO MAXIMO EN CANAL NATURAL
PEAK FLOOD AT PROTECTION WORKS / FLUJO MAXIMO EN TRABAJOS DE PROTECCION

FIG. 7.3 COEFFICIENT OF REGIME THEORY

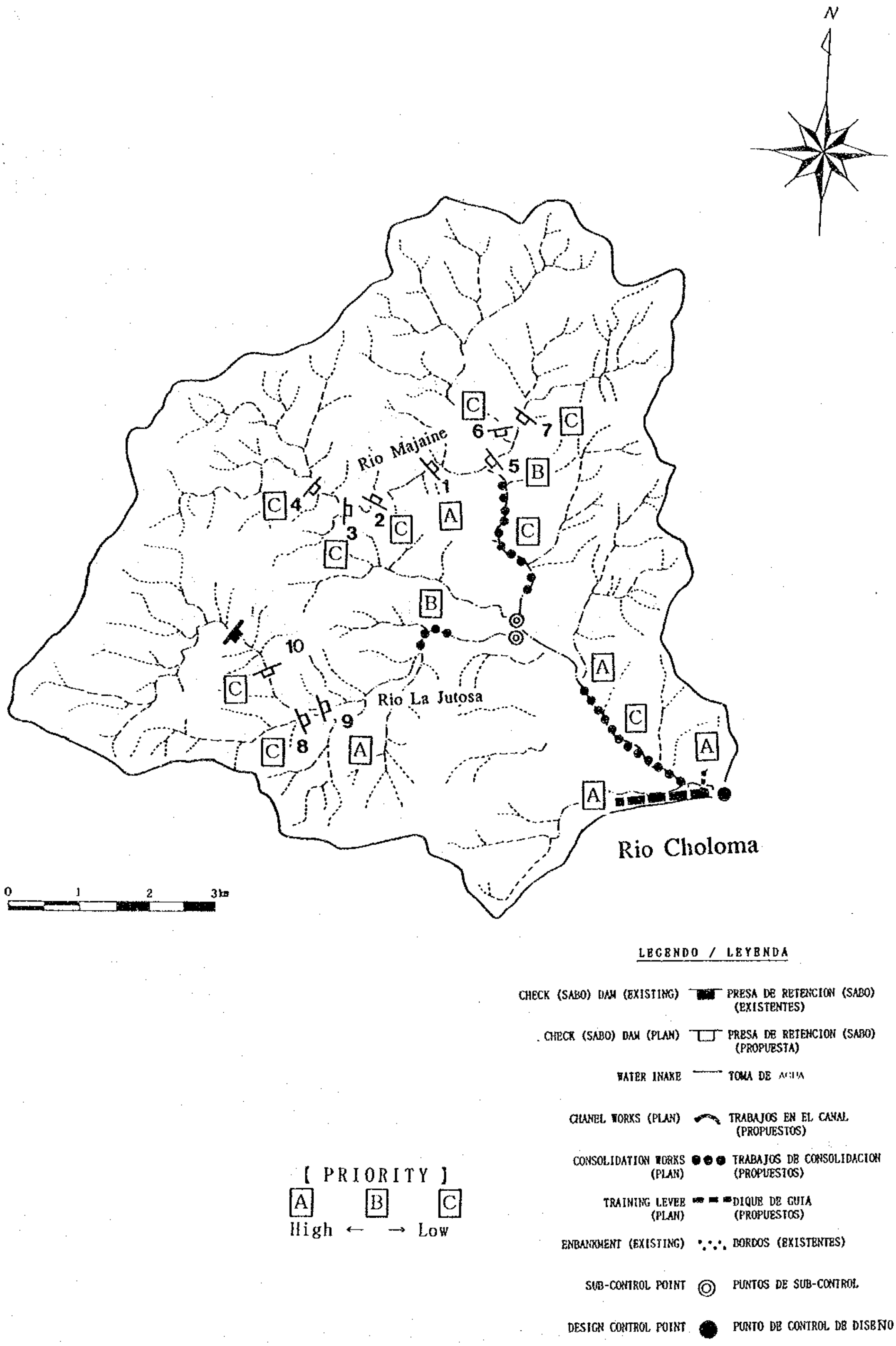


FIG. 7.4 (1) LOCATION OF EROSION CONTROL FACILITY AND PRIORITY SEQUENCE (RIO CHOLOMA)

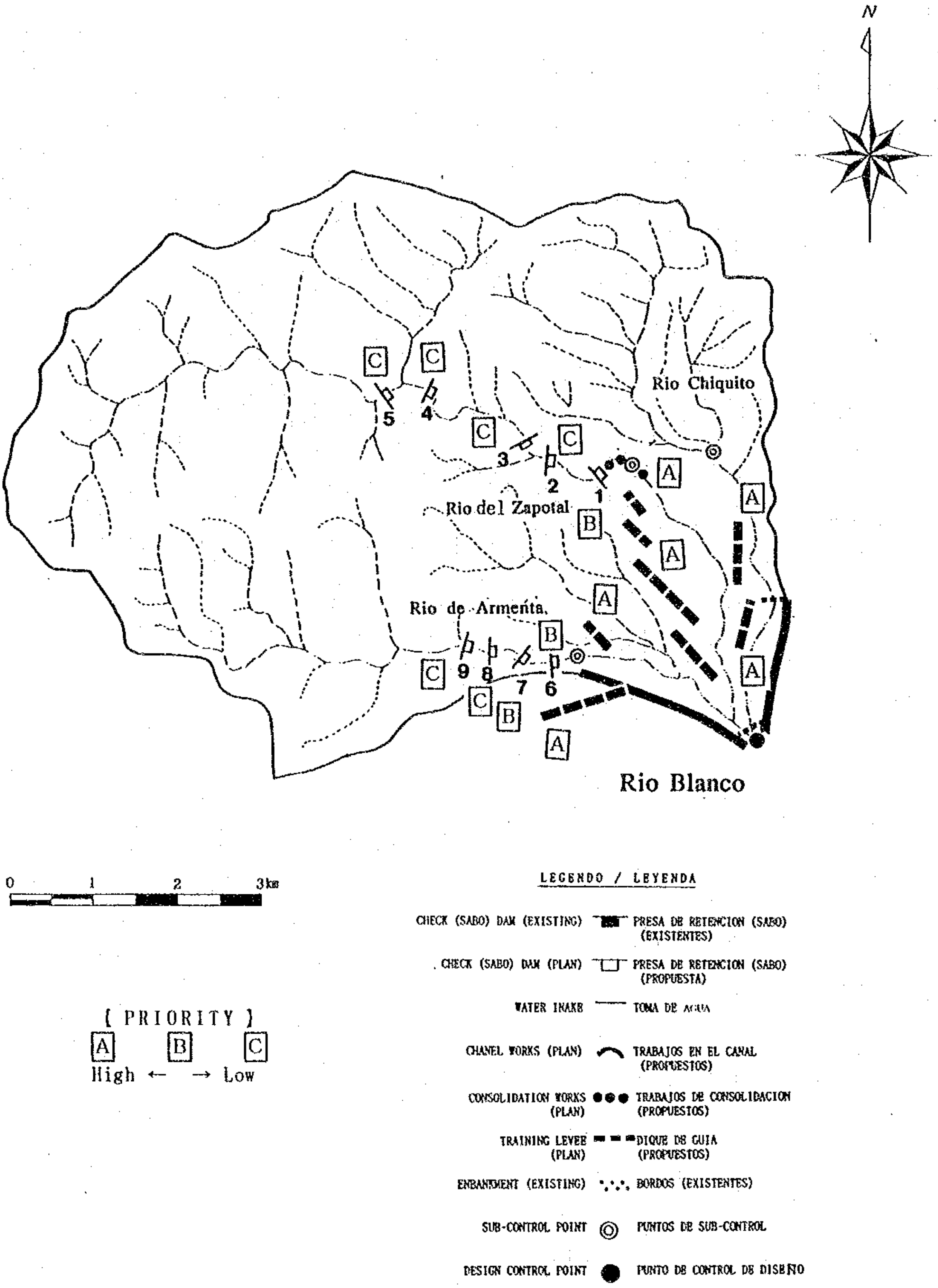


FIG. 7.4 (2) LOCATION OF EROSION CONTROL FACILITY AND PRIORITY SEQUENCE (RIO BLANCO)

JICA

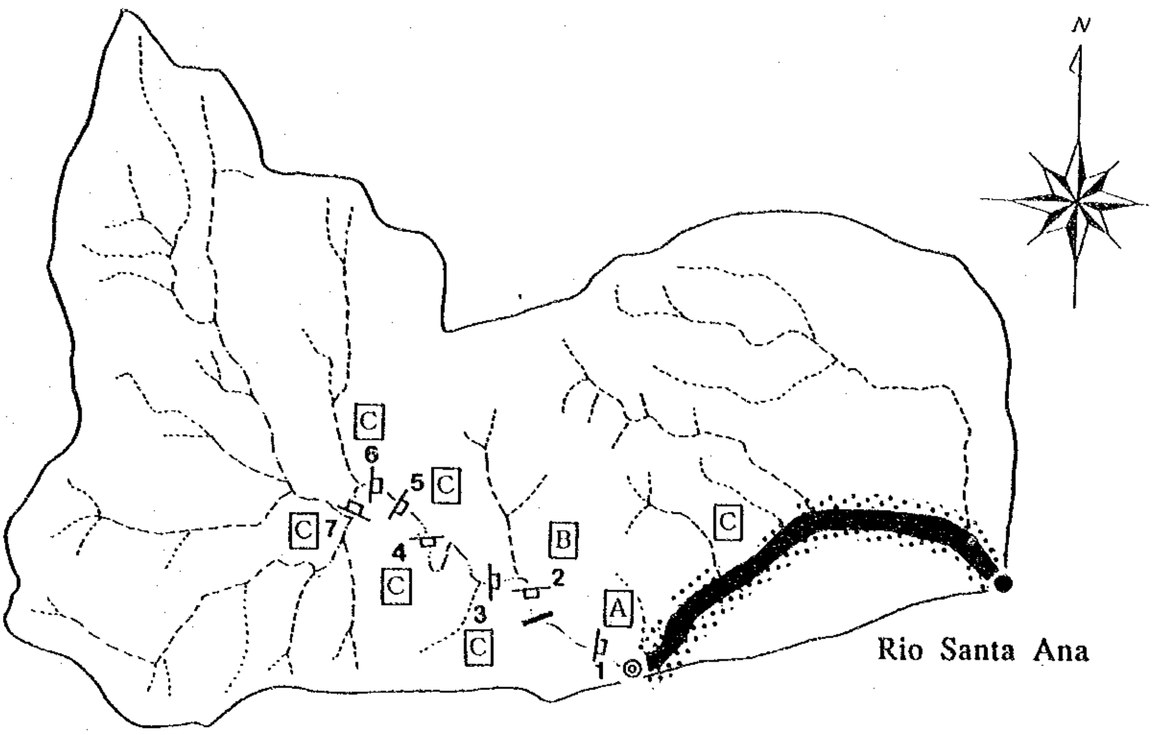


FIG. 7.4 (3) LOCATION OF EROSION CONTROL FACILITY AND PRIORITY SEQUENCE (RIO SANTA ANA)

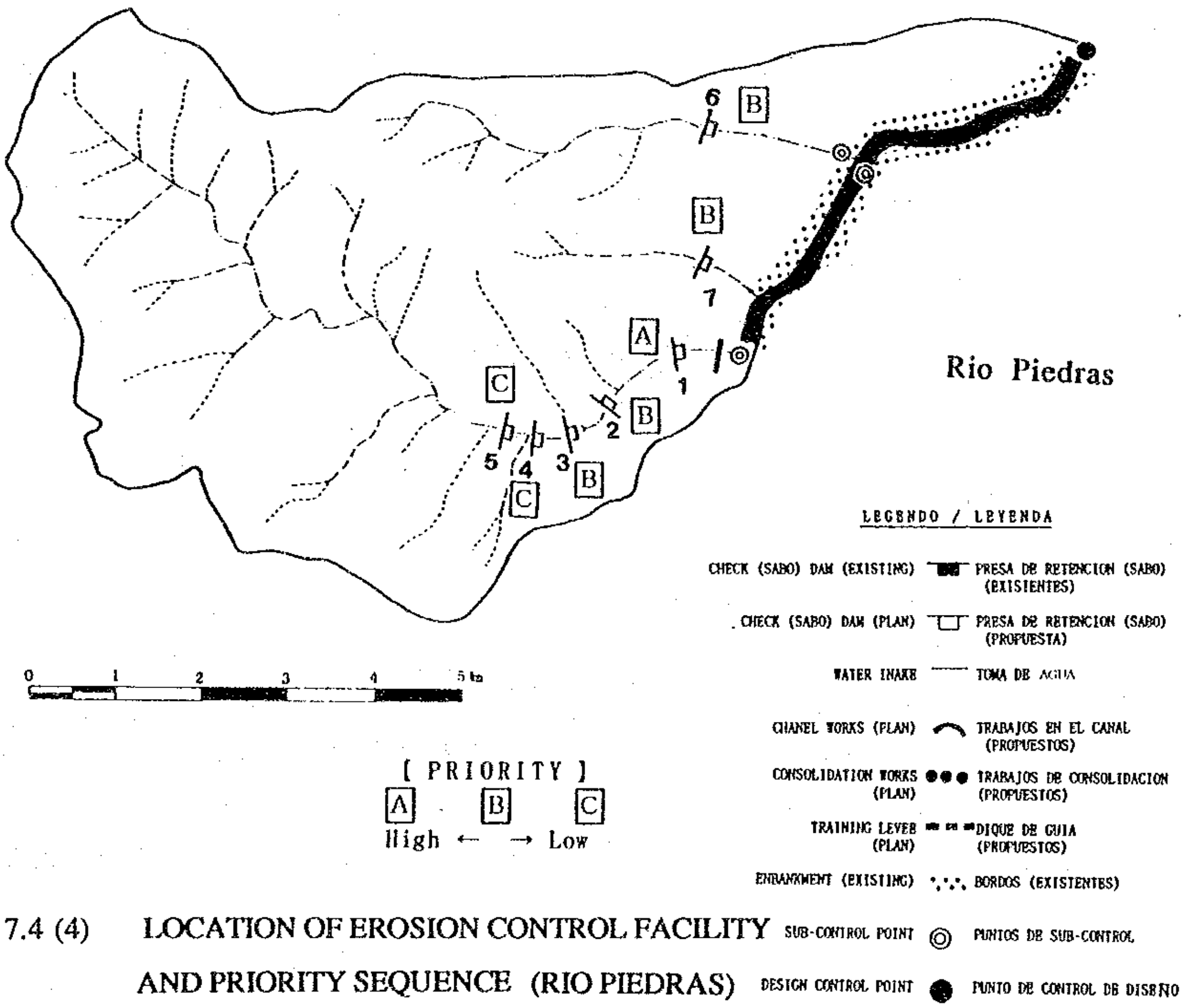


FIG. 7.4 (4) LOCATION OF EROSION CONTROL FACILITY AND PRIORITY SEQUENCE (RIO PIEDRAS)

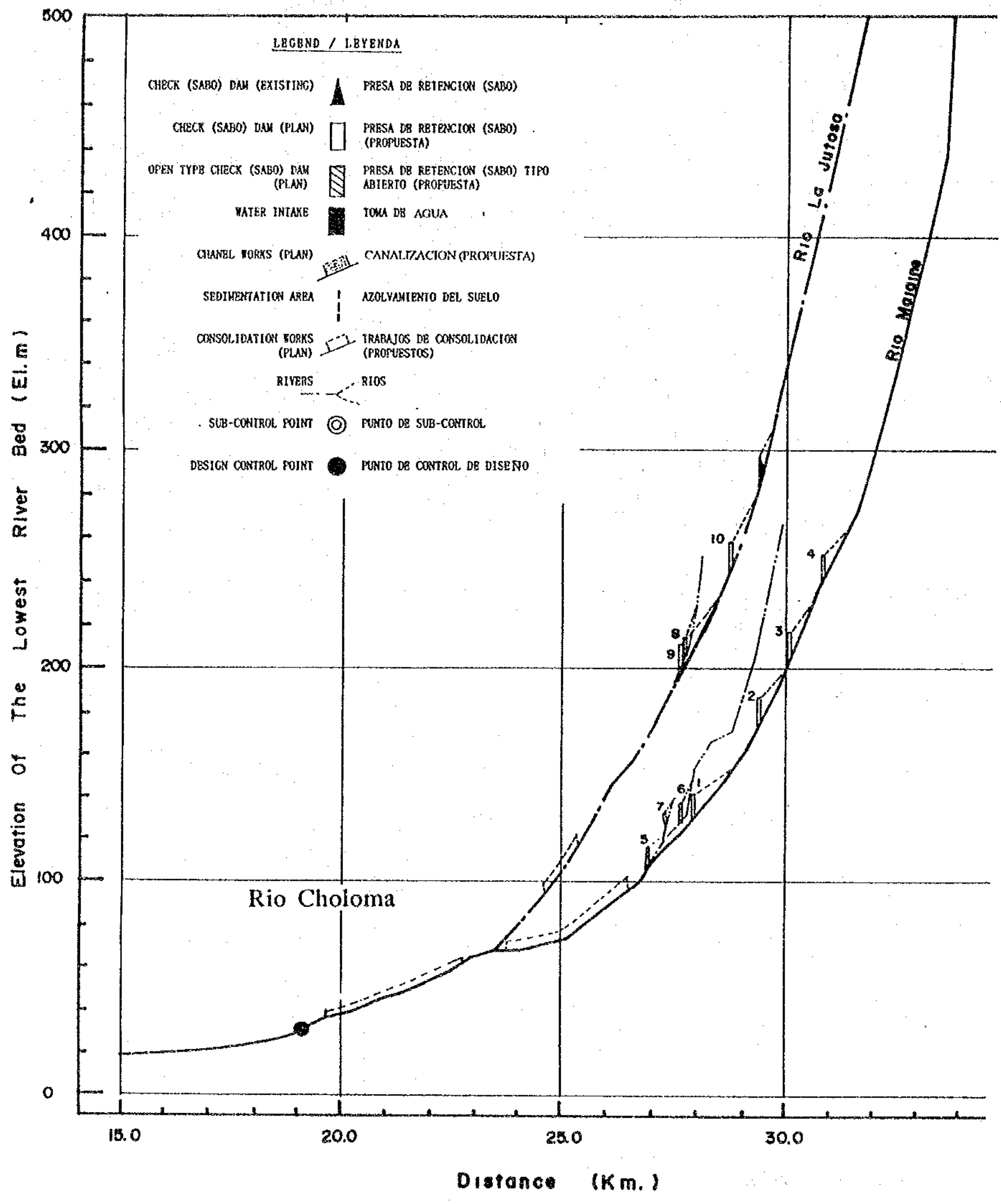


FIG. 7.5 (1) LONGITUDINAL PROFILE OF EROSION CONTROL FACILITY ARRANGEMENT (RIO CHOLOMA)

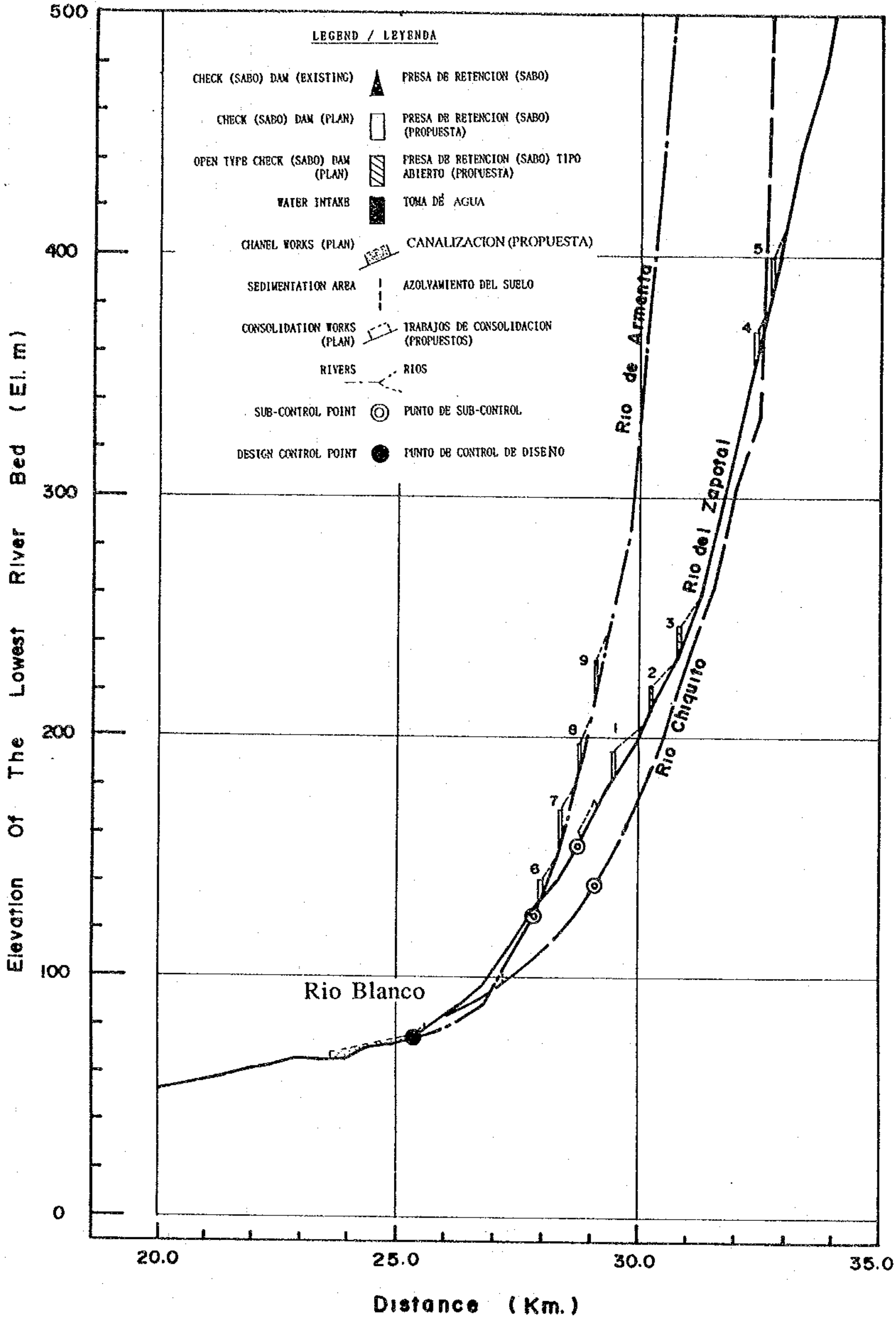


FIG. 7.5 (2) LONGITUDINAL PROFILE OF EROSION CONTROL FACILITY ARRANGEMENT (RIO BLANCO)

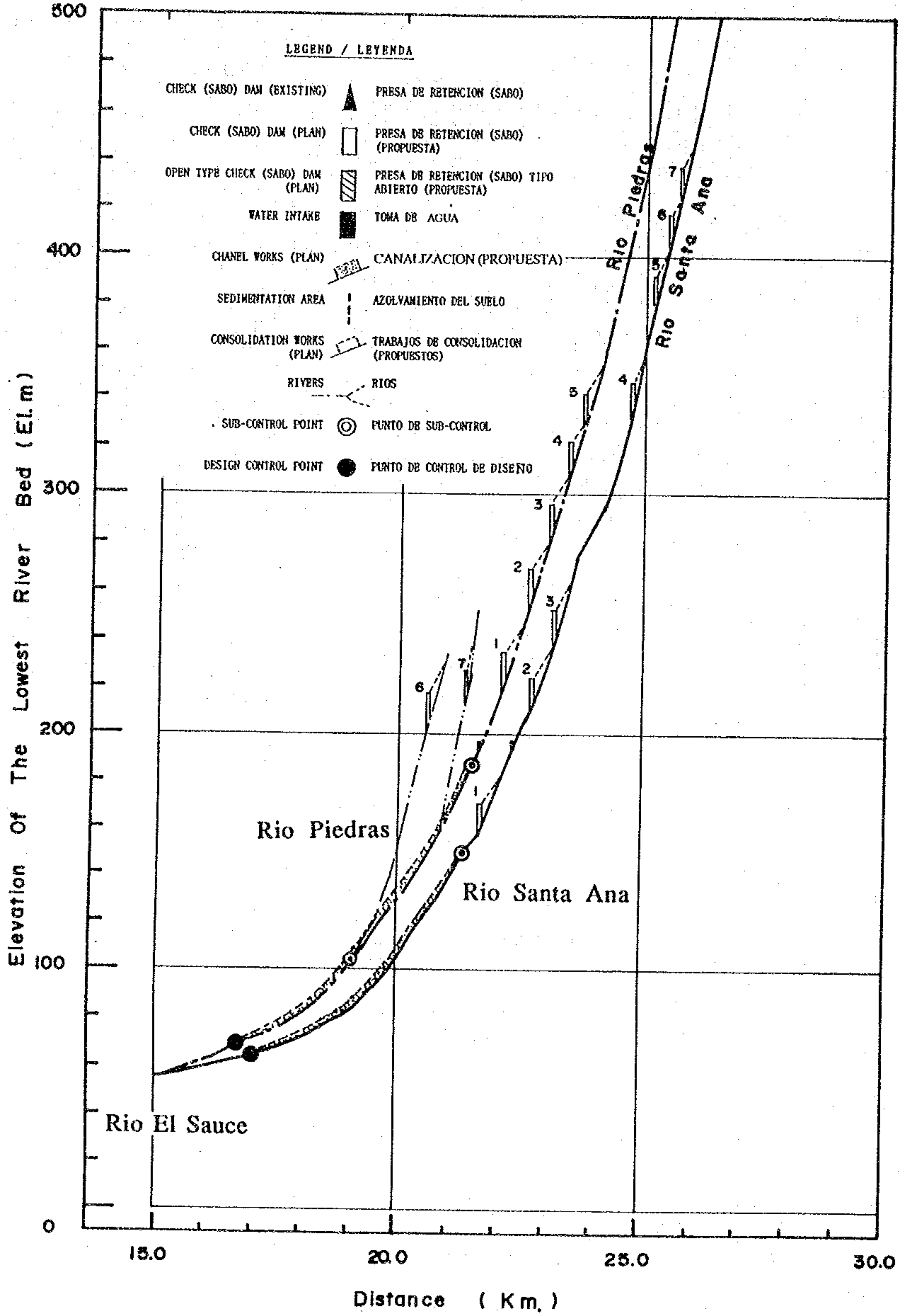


FIG. 7.5 (3) LONGITUDINAL PROFILE OF EROSION CONTROL FACILITY ARRANGEMENT (RIO EL SAUCE)

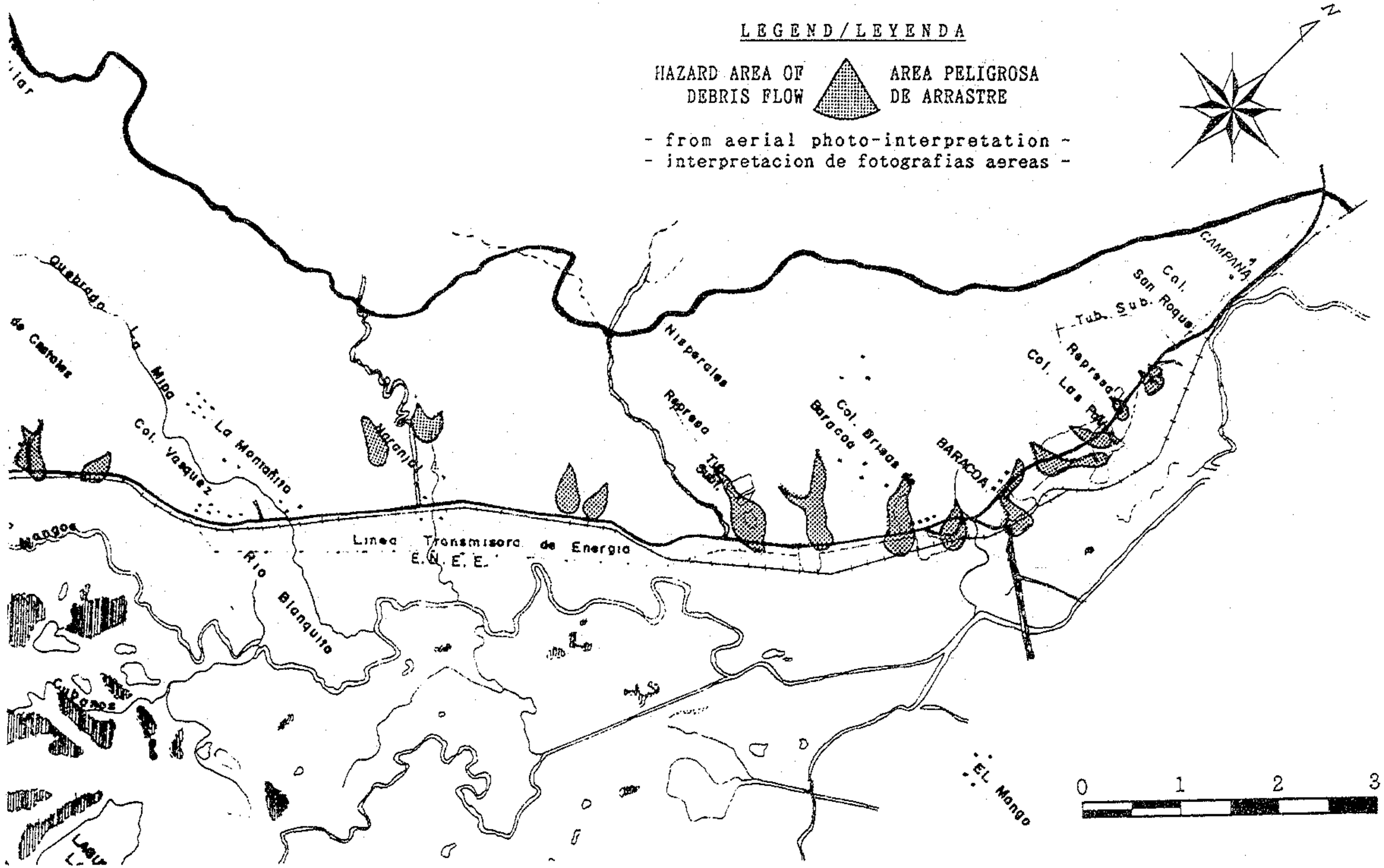


FIG. 7.6 (1) POTENTIAL DEBRIS FLOW HAZARD AREA

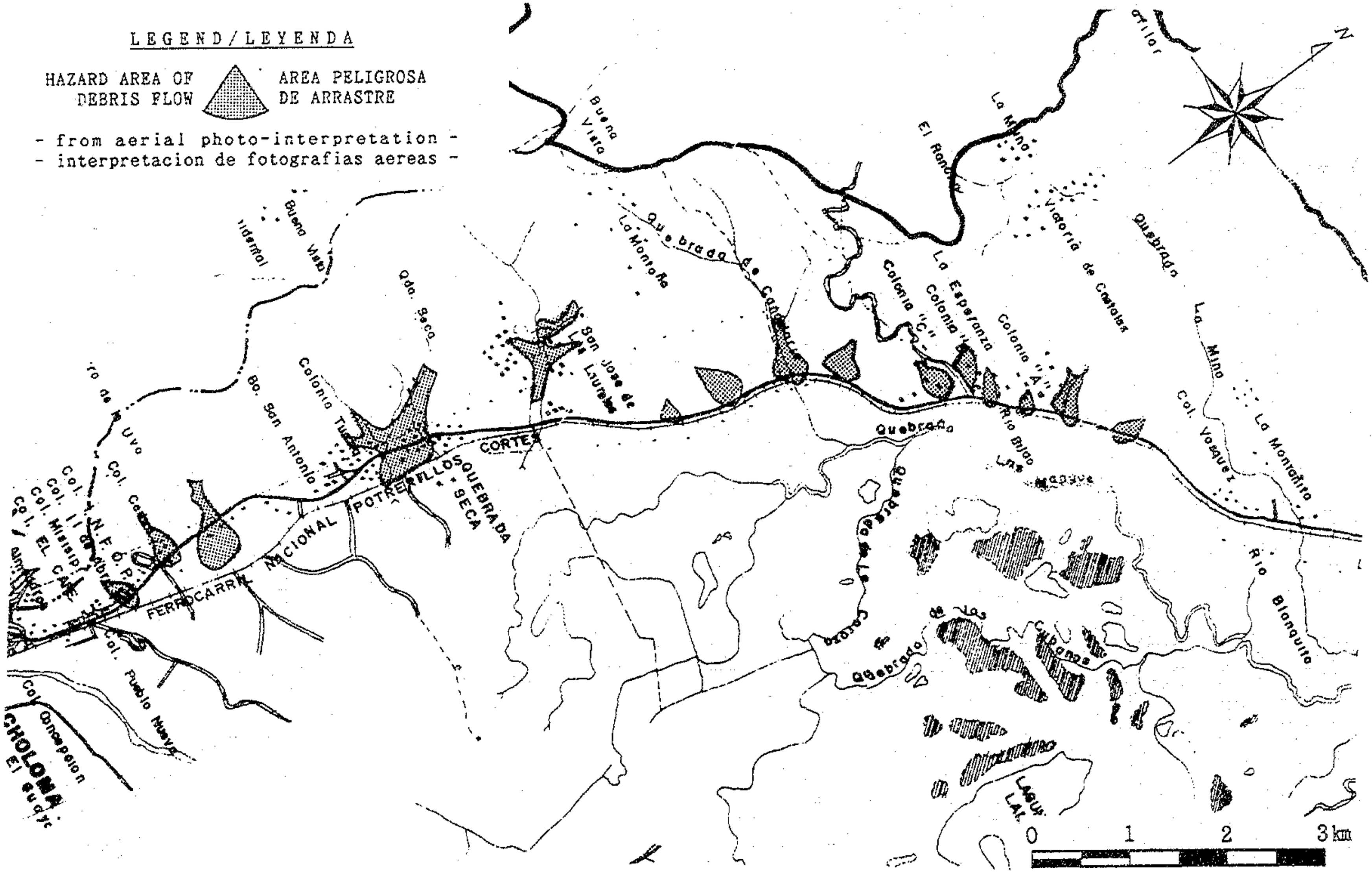


FIG. 7.6 (2) POTENTIAL DEBRIS FLOW HAZARD AREA

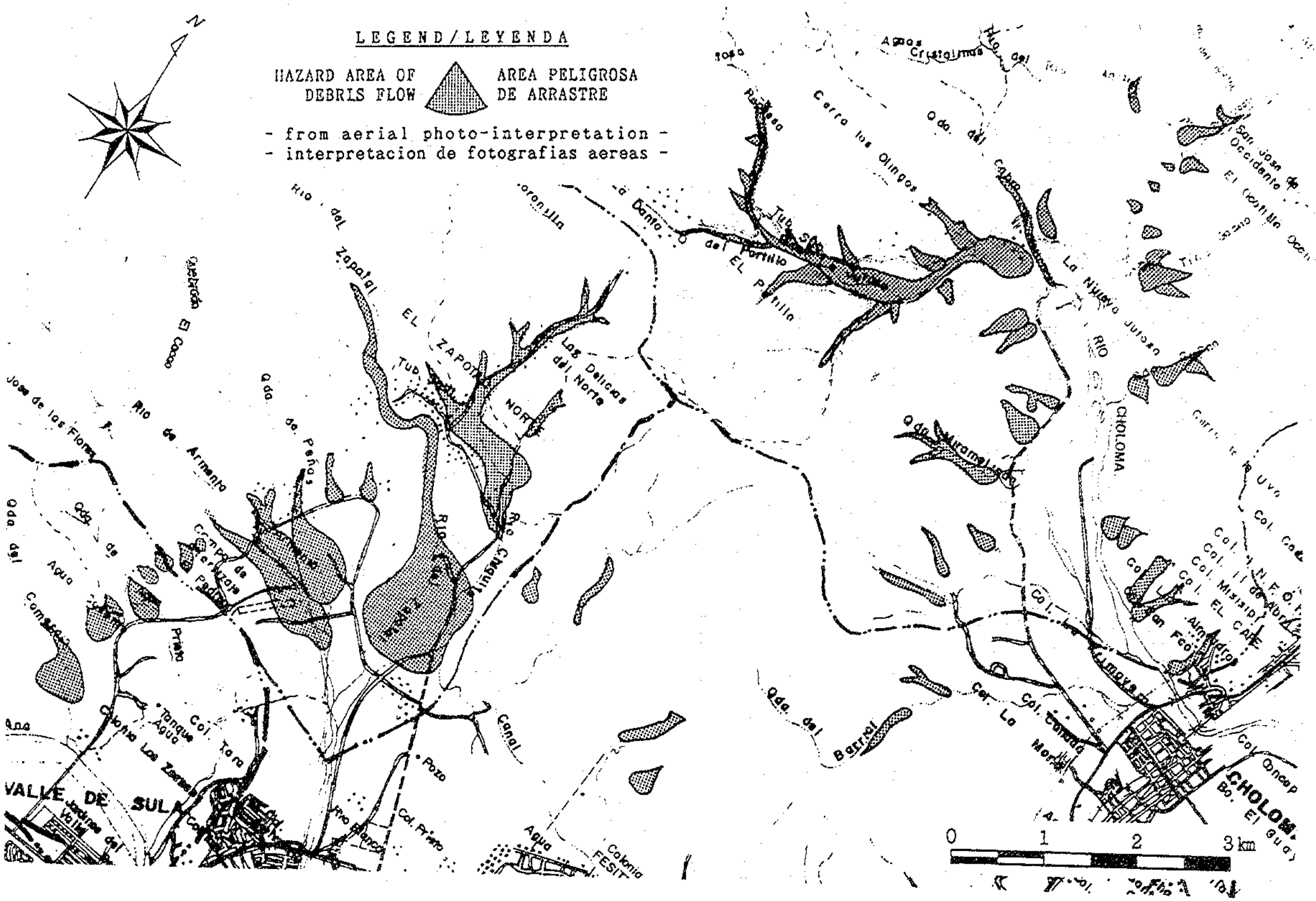


FIG. 7.6 (3) POTENTIAL DEBRIS FLOW HAZARD AREA

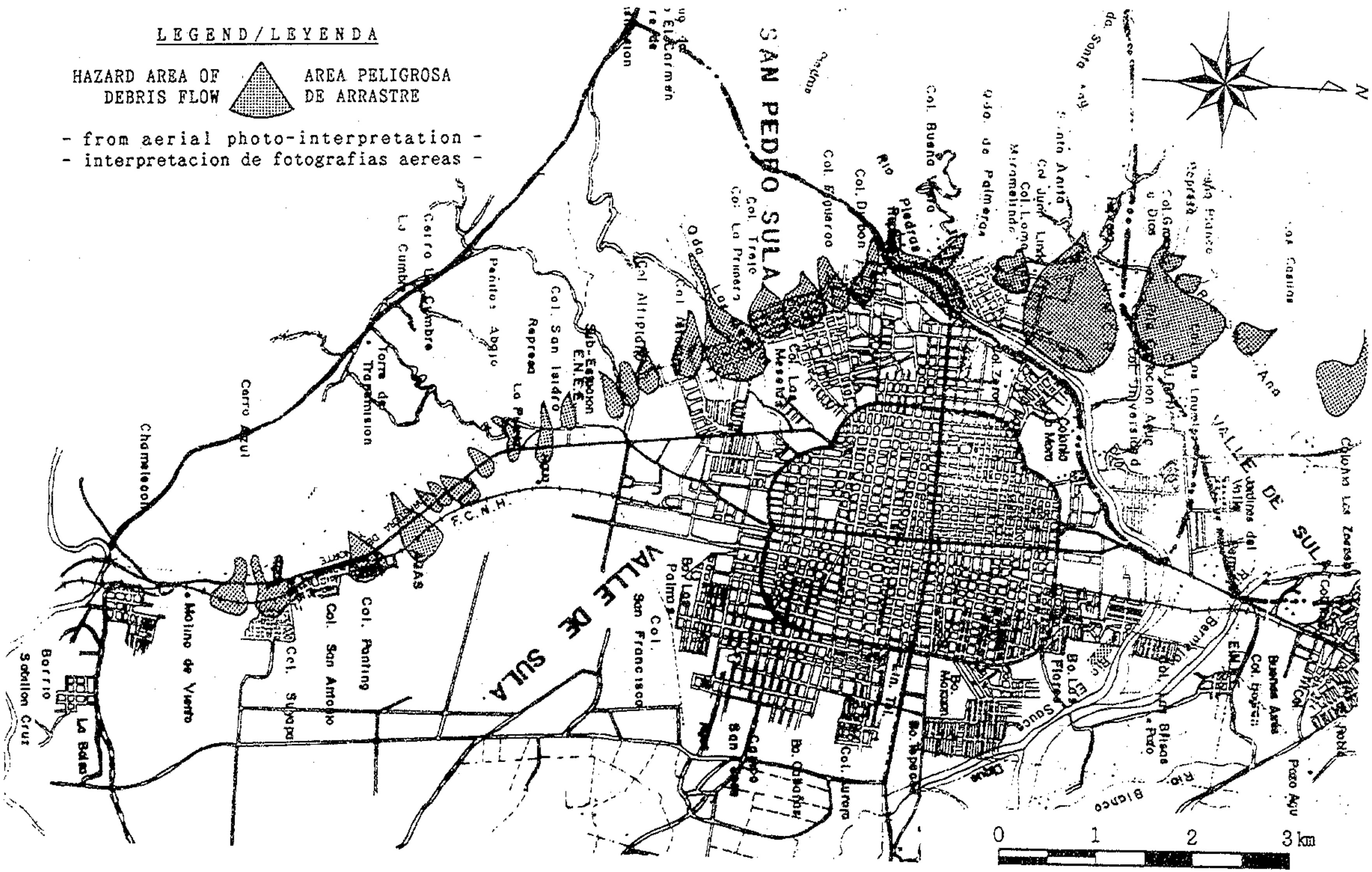


FIG. 7.6 (4) POTENTIAL DEBRIS FLOW HAZARD AREA

AGGRADATION OF THE RIVER BED IN THE DOWNSTREAM REACH OF THE RIO CHOLOMA (1993)

CHAPTER 8
SEDIMENTOLOGY

CHAPTER 8 SEDIMENTOLOGY

8.1 General

In the Study area, there are three major tributaries and several other small tributaries of the Rio Chamelecon. The major tributaries are the Rio Choloma (catchment area 106.89 km^2, the Rio Blanco (catchment area 190.24 km^2) and the Rio El Sauce (catchment area 118.33 km^2). As the quantities of sediment discharge of these rivers are very large, sediment deposition can be observed especially in the midstream and downstream reaches of these rivers. This causes the sediment problems including aggradation of river bed and reducing the flood discharge capacity.

On the contrary, by the excessive sand taking from the river bed, erosion and degradation can be observed in the midstream of the Rio Blanco. By this degradation of the river bed, the footing and wooden piles of the foundation of the existing National Railway Bridge have been exposed above the river bed and the National Railway Bridge is about to be in a dangerous condition.

Hence, for the stabilization of river channel, it is necessary to keep the dynamic equilibrium condition of sediment discharge of the channel which means the balance of sediment inflow into the upstream channel and sediment outflow from the downstream sections of the channel.

In this chapter, sediment flow conditions and the balance of sediment discharge of the Rio Choloma, Rio Blanco and the Rio El Sauce are described.

8.2 Sediment Flow Conditions of the Rivers

By the hurricane "Fifi" in September 1974, the largest debris flows occurred in the rivers of the study area, and huge quantities of sediment was deposited in the rivers or overflowed from the rivers.

In the Rio Choloma, the depth of the sediment deposition by the above debris flow is estimated to be 0.5 m to 3.0 m in the reach between the National Road Bridge and the junction with the Rio La Jutosa and 0.5 m to 1.0 m in the downstream reach from the National Road Bridge.

As for the Rio Blanco, the depth of the sediment deposition by the above debris flow is estimated to be 1.0 m to 3.0 m in the alluvial fans of the Rio del Zapotal and Rio de Armenta including the upstream reach of the Rio Blanco from the National Road Bridge and 1.0 m to 0.2 m in the downstream reach from the National Road Bridge.

In the Rio El Sauce, Rio Santa Ana and the Rio Piedras, large debris flows like those of the Rio Choloma and the Rio Blanco did not occur even by "Fifi". But the sediment deposition in the downstream reach of the Rio Santa Ana/Bermejo by "Fifi" is estimated to be about 2.0 m.

Considering the above sediment flow and deposition by the "Fifi" and site investigations, sediment flow conditions of the existing rivers are studied in this sub-section.

8.2.1 Pattern of Sediment Flow of the Rivers

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

a) Debris flow

Debris flow is the very condensed flow of mud, sand, cobbles, stones and water. The velocity of debris flow is very high. It generally occurs in a place with slope of more than 15 degree (1/3.7) and stops flowing in a place with slope of 3 to 4 degree (1/14.3 to 1/19.1).

b) Transition flow between debris flow and bed load

Transition flow is the sediment flow between the debris flow and the bed material load in which some thickness of sand and cobbles of the river bed move with water. Transition flow generally occurs in the river with bed slope of 4 degree to 10 degree (1/14.3 to 1/5.7).

c) Bed load

Bed load is one of the bed material load which is the sediment flow composed of the sand and cobbles existing in the river bed. Bed load can be observed in the downstream reach of a transition flow.

d) Suspended load

Suspended load is also one of the bed material load. The suspended load can be observed generally in a river reach with bed material including high percentage of fine sand. In the downstream reach, suspended load and bed load can be observed generally in same place.

e) Wash load

Wash load is the sediment flow composed of very fine materials. The floating materials of the wash load are not deposited in the river course while they are transported.

The sediment flow patterns which are important for the quantity of sediment discharge of the rivers in the Study Area are debris flow, transition flow, bed load and suspended load. By the site investigation and analysis of aerophotographs, the river reaches of the debris flow, transition flow and bed load of the Rio Choloma, Rio Blanco and Rio El Sauce are approximately identified as shown in *Fig*. 8.1.

Although the suspended flow occurs in the midstream and downstream reaches of these rivers, the reaches of the suspended load can not be identified cleary.

8.2.2 River Bed Materials of the Rivers

In order to study the sediment balance and utilize these results for planning the river channel with dynamic stability, river bed investigation including sampling and laboratory testing for the Rio Choloma, Rio Blanco and the Rio El Sauce were conducted by this Study.

The total sampling sites are 9, composed of 3 sites each for the Rio Choloma, Rio Blanco and Rio El Sauce. In the each river samples were taken in the downstream reach, midstream reach and upstream reach with 3 samples each from the right side, center and left side of the river. The locations of the sampling sites are shown in *Fig*. 8.2.

Fig. 8.3 shows the longitudinal variation of diameter and longitudinal average of the specific gravity of the river bed materials of those three rivers. There is a common characteristics of abrupt change of the diameter in the midstream reach from cobbles in the upstream reach to sand in downstream reach. The reason of this abrupt change is the abrupt reduction of tractive force of the river due to the abrupt reduction of the slope of the river bed in the midstream reach.

8.3 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. In this Study, simulations of sediment discharges of the rivers were conducted to check the sediment balance and tendency of aggradation or degradation of the river bed.

8.3.1 Sediment Simulation of the Master Plan Study Stage

The procedure of sediment simulation for the Rio Choloma, Rio Blanco and the Rio El Sauce of the Master Plan study stage is as follows;

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

(2) Hydraulic parameters for the simulation are obtained by conducting non-uniform calculation for the design hydrograph of 50 year floods.

(3) River cross sections data at 1.0 km interval including the surveyed data of this Study are used for the simulation.

(4) Sediment discharge are calculated as bed load discharge of Ashida-Michiue's method.

(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 between the upstream reaches of debris flow and transition flow and the bed load reaches is checked at the control points for erosion and sediment control planning.

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.* 8.4)

(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.* 8.5)

(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.* 8.6)

(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 along with river improvement of the Rio El Sauce and erosion and sediment control of the Rio Blanco basin and Rio El Sauce basin (ref. to *Fig.* 8.7)

Results of the simulations are described below.

1) The Rio Choloma

Fig. 8.8 and *Fig.* 8.9 show the results of Case 1-1 and Case 1-2 respectively.

(1) For the without project condition (Case 1-1), there is an unbalance of sediment discharge in the river channel. Especially, notable tendency of deposition and aggradation of river bed is estimated to occur in the most downstream reach. But, these tendencies will be much improved and the river channel will be almost in the dynamic stability condition for the with project condition (Case 1-2).

(2) Design sediment discharge or design allowable sediment discharge from the upstream reaches, the control point (at the National Road Bridge) of erosion and sediment control planning (debris flow, transition flow etc.), are larger than the sediment discharge volume of the downstream reaches (bed load). In the Case 1-1, the difference is 1,421,600 m^3 and the sediment deposition with about 75 cm will occur in the downstream reaches (distance 7.8 km). But, for the Case 1-2, the difference will be 137,900 m^3 and the deposition depth will be about 30 cm only. Hence, the influence of this deposition of Case 1-2 will be small.

2) The Rio Blanco

Fig. 8.10 shows the results of Case 2-1. As the river improvement is considered for the San Roque Canal and the downstream reach around the inlet of Laguna El Carmen, the upstream reach from Laguna El Carmen will remain without any river improvement. Hence, the sediment balance and tendency of aggradation and degradation of Case 2-2 are same as Case 2-1.

(1) Altough there are some unbalance of sediment discharge volume in the river channel for the conditions of without projects (Case 2-1) and with projects (Case 2-2), the river channel is almost in the dynamic stability condition. But, due to the excessive sand taking from the river bed, artificial degradation of the

river bed is occurred and the pier of the National Railway Bridge is in a dangerous condition. This excessive sand taking should be restricted.

(2) Annual inflow volume of sediment into Laguna El Carmen is estimated to be about 21,700 m^3. By this sediment inflow, deposition of sediment around the inlet portion of the Laguna Carmen will occur and the most downstream reach of the Rio Blanco will become gentle. Before 1974, as the Rio Blanco had flowed into the present river course of the Rio El Sauce and partly flowed into Laguna El Carmen, this kind of sediment unbalance around the inlet portion of Laguna El Carmen had not occurred.

(3) Design sediment discharge or design allowable sediment discharge from the upstream reaches of the control point (at the National Road Bridge) for erosion and sediment control planning (debris flow, transition flow etc.) are larger than the sediment discharge volume of the downstream reaches (bed load). In the Case 2-1, the difference is 787,600 m^3 and the sediment deposition of about 165 cm depth will occur in the downstream reaches (distance 3.4 km). But, for the Case 2-2, the difference will be 66,700 m^3 and the deposition depth will be about 15 cm only. Hence, the influence of this deposition of Case 2-2 will be small.

3) The Rio El Sauce (including the Rio Santa Ana/Bermejo and the Rio Piedras)

Fig. 8.11 to 8.13 and *Fig.* 8.14 to 8.16 show the results of Case 3-1 and Case 3-2 respectively.

(1) The unbalance of sediment discharge volume in the river channels under without project condition (Case 3-1) will not be improved much even under the with project condition (Case 3-2). Hence, periodical maintenance of the channel will be necessary.

(2) Design sediment discharge or design allowable sediment discharge from the upstream reaches of the control points (at the both National Road Bridges of the Rio Santa Ana/Bermejo and the Rio Piedras) of erosion and sediment control planning (debris flow, transition flow etc.) are larger than the sediment discharge volume of the downstream reaches (bed load). In the Case 3-1, the difference is 736,000 m^3 and the sediment deposition of about 20 cm depth will occur in the downstream reaches (total distance 18.3 km). But, for the Case 3-2, the difference will be 72,300 m^3 and the deposition depth will be about 6 cm only. Hence, the influence of this deposition of Case 3-2 will be small.

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

Fig. 8.17 to 8.20 show the results of Case 4-1.

(1) As for the diversion channel of the Rio Blanco, sediment deposition will occur around the junction with the Rio El Sauce with the deposition depth of about 25 cm. As for the Rio El Sauce including the Rio Santa Ana/Bermejo and the Rio Piedras, longitudinal unbalance in sediment discharge will occur. Hence, periodical maintenance of these channels including dredging will be necessary.

(2) Design allowable sediment discharge from the upstream reaches of the control points (at the National Road Bridges of the Rio Blanco, Rio Santa Ana/Bermejo and Rio Piedras) of erosion and sediment control planning (debris flow, transition flow etc.) are larger than the sediment discharge volume of the downstream reaches (bed load). The differences and the sediment deposition depths for the Rio Blanco and the Rio El Sauce are almost same as the Case 2-2 and the Case 3-2 respectively. Hence, the influence of the sediment deposition will be small.

8.3.2 Sediment Simulation of the Feasibility Study Stage

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, Rio La Jutosa and the Rio Majaine were selected as the river reaches of the feasibility study (ref. to Chapter 11).

In the feasibility study stage, 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 including the Rio Majaine and the Rio La Jutosa was upgraded (ref. to Chapter 7 and 9). Also the long term flood control and erosion and sediment control project and urgent project of those were formulated.

The sediment discharge and tendency of aggradation or degradation of the river bed of the Rio Choloma are simulated and evaluated by using the above upgraded data. The following conditions are different from the conditions of the simulations of the Master Plan study.

(1) The river reaches of the Rio Choloma for the sediment simulations are between the junction with the Canal San Roque and the proposed consolidation dam at about 700 m upstream from the National Road Bridge (existing accumulative distance is 11.250 km to 19.780 km).

(2) The river cross sections for the sediment simulations are the surveyed data of the JICA study in 1993, at about 200 m distance interval.

The Simulation cases are as follows;

Case 1 : without flood control and erosion and sediment control project

Case 2 : with long term flood control and erosion and sediment control project

- river improvement between the junction with the Canal San Roque and the proposed consolidation dam located at about 700 m upstream from the National Road Bridge (future accumulative distance is 11.250 km to 18.885 km)
- erosion and sediment control by 10 check dams (the Rio Majaine 7 nos., the Rio La Jutosa 3 nos.), 17 consolidation dams (the Rio Choloma 7 nos., the Rio Majaine 2 nos., Rio La Jutosa 8 nos.) and 1 training levee in the Rio Choloma

Case 3 : with urgent flood control and erosion and sediment control project

- river improvement between the middle reach and the proposed consolidation dam (provisional accumulative distance is 15.610 km to 19.105 km)
- erosion and sediment control by 2 check dams (the Rio Majaine 1 no., the Rio La Jutosa 1 nos.), 2 consolidation dams (the Rio Choloma 2 nos.) and 1 training levee in the Rio Choloma

Fig. 8.21, *Fig.* 8.22 and *Fig.* 8.23 show the results of Case 1, Case 2 and Case 3 respectively.

(1) As for the sediment discharge balance of the river channel, there is an unbalance of sediment discharge volume in the without project condition (Case 1). By this unbalance, notable tendency of deposition of sediment and aggradation of the river bed (maximum about 100 cm) will occur in the most downstream reach near the junction of the Canal San Roque. Furthermore notable tendency of erosion will occur around the National Road Bridge (20 to 60 cm).

The above unbalance of the sediment discharge volume will be much improved in the river improvement reaches of the long term projet (Case 2) as well as the urgent project (Case 3) and these river reaches will have good sediment balances.

But the local tendency of the sediment deposition in the most downstream reaches of the river improvement of the Case 2 and Case 3 will remain. These depositions can not be improved without the river improvements for the Canal San Roque-Cuabanos and the Canal Copen-Higuero-Cuabanos as well as the Rio Chamelecon. Although the estimated deposition depths are less than 30 cm, periodical maintenance by dredging will be necessary.

Furthermore, the local tendency of erosion around the National Road Bridge will improve to some extent in the Case 2 and Case 3, and degradation depths of about 20 to 50 cm will remain. Hence, river bed protection around the National Road Bridge is necessary in the Case 2 and Case 3.

(2) Design sediment discharge of Case 1 or design allowable sediment discharges of Case 2 and Case 3 from the upstream reaches of the control point (at the proposed consolidation dam) of erosion and sediment control planning (debris flow, transition flow etc.) are larger than the sediment discharge volume of the downstream reaches (bed load). In Case 1, the difference is 1,426,700 m^3 and the sediment deposition with average depth of about 70 cm will occur in the downstream reaches (distance 8.5 km).

As for Case 2, the difference will be 137,900 m^3. Supposing that the sediment deposition will occur within the low water channel, the average deposition depth will be about 40 cm which is less than the design allowable height for the embankment of 1.0 m. Hence, the influence of this deposition will be small.

As for Case 3, the difference will be 979,900 m^3 and the average deposition depth of about 80 cm will occur within the low water channel of the river improvement reach and the natural flood plain of the existing river reach. Considering that the deposition depth of the upstream reach will be higher than that of the downstream reach, 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 upstream reach. Hence, it will be necessary to continue with the step by step construction of the entire erosion and sediment control facilities of the long term plan.

FIGURES

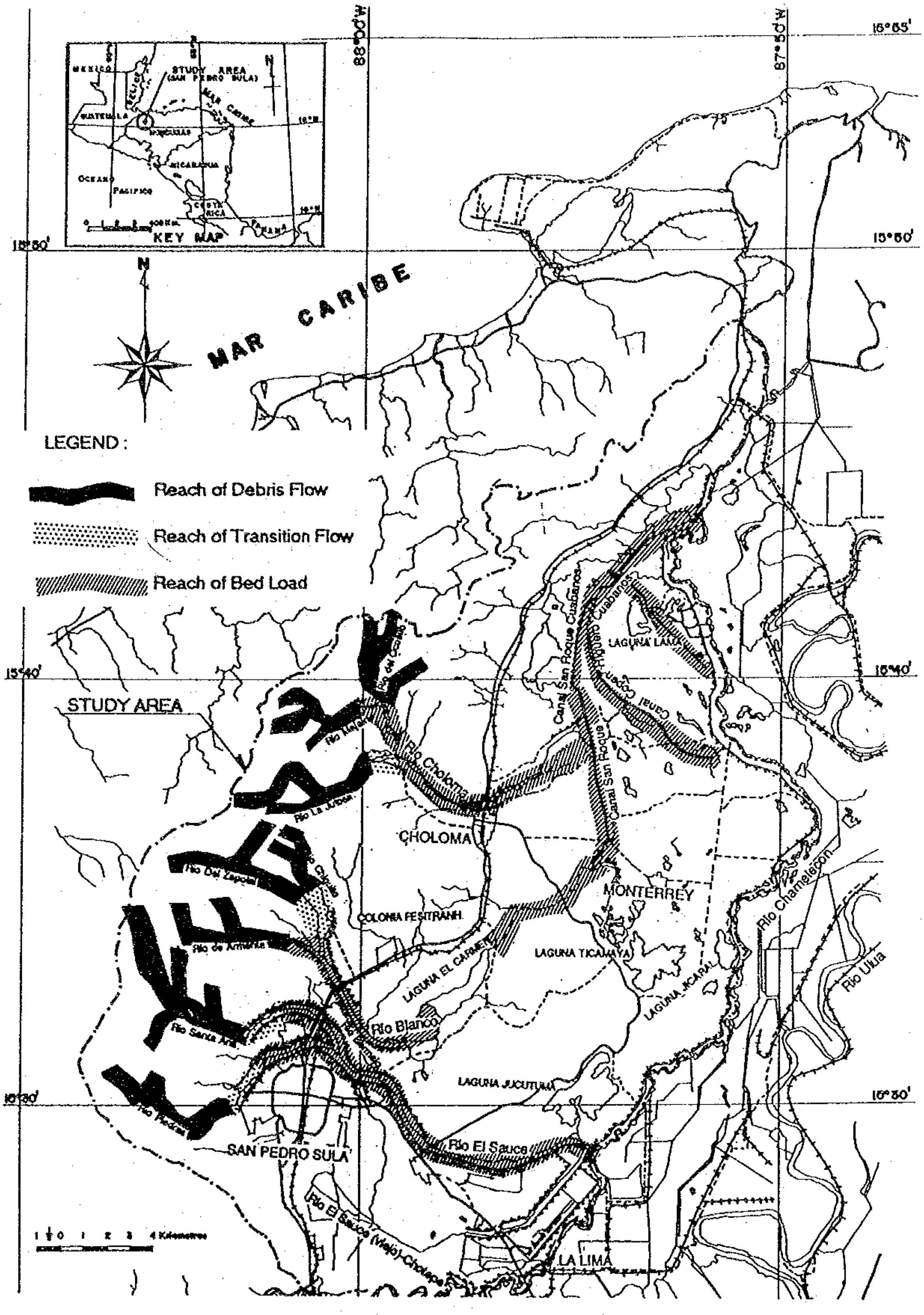


FIG. 8.1 **PATTERNS OF THE SEDIMENT FLOW OF THE RIO CHOLOMA, THE RIO BLANCO AND THE RIO EL SAUCE**

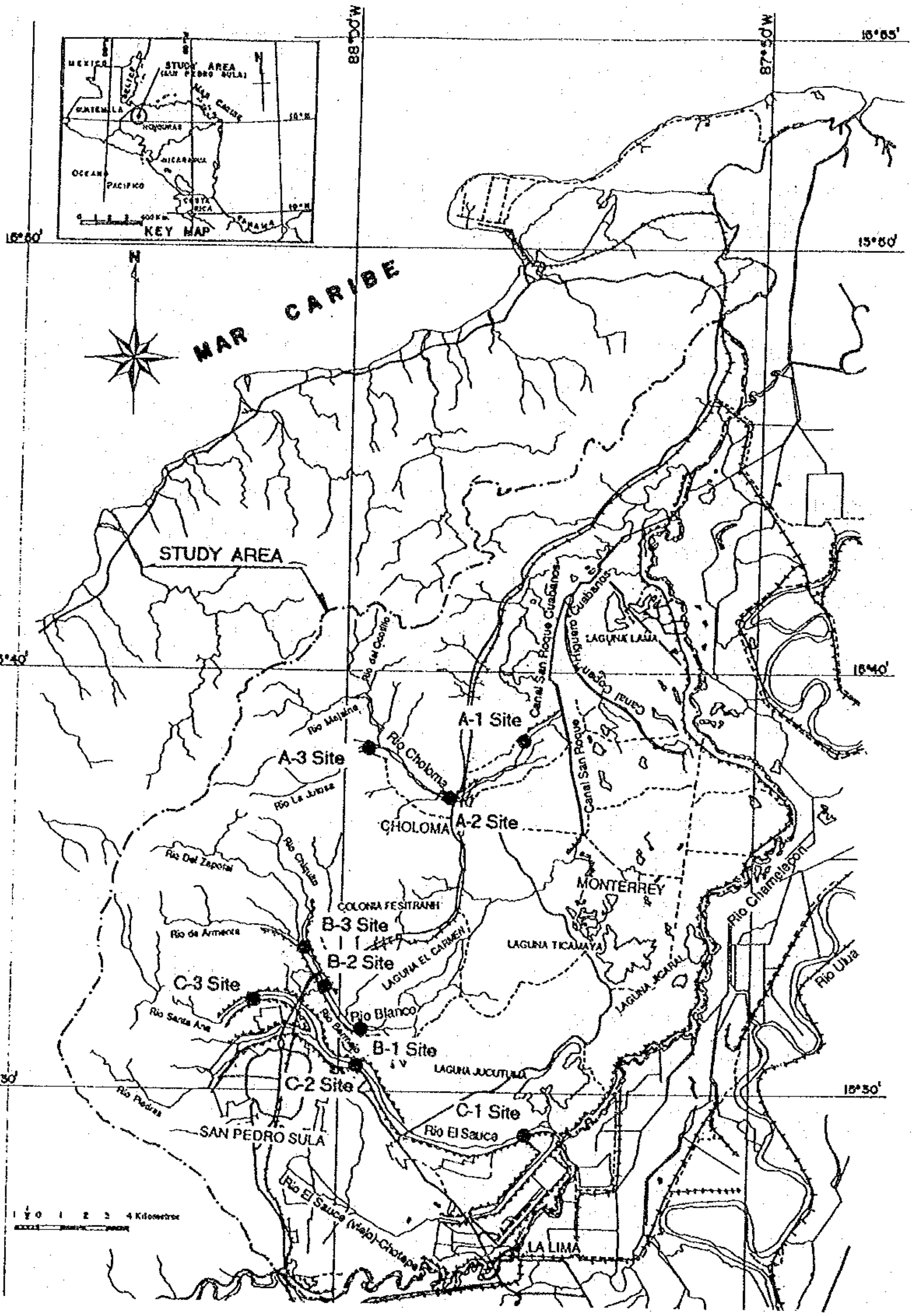


FIG. 8.2 **SAMPLING SITES OF THE RIVER BED MATERIALS INVESTIGATIONS FOR THE RIO CHOLOMA, RIO BLANCO AND RIO EL SAUCE**

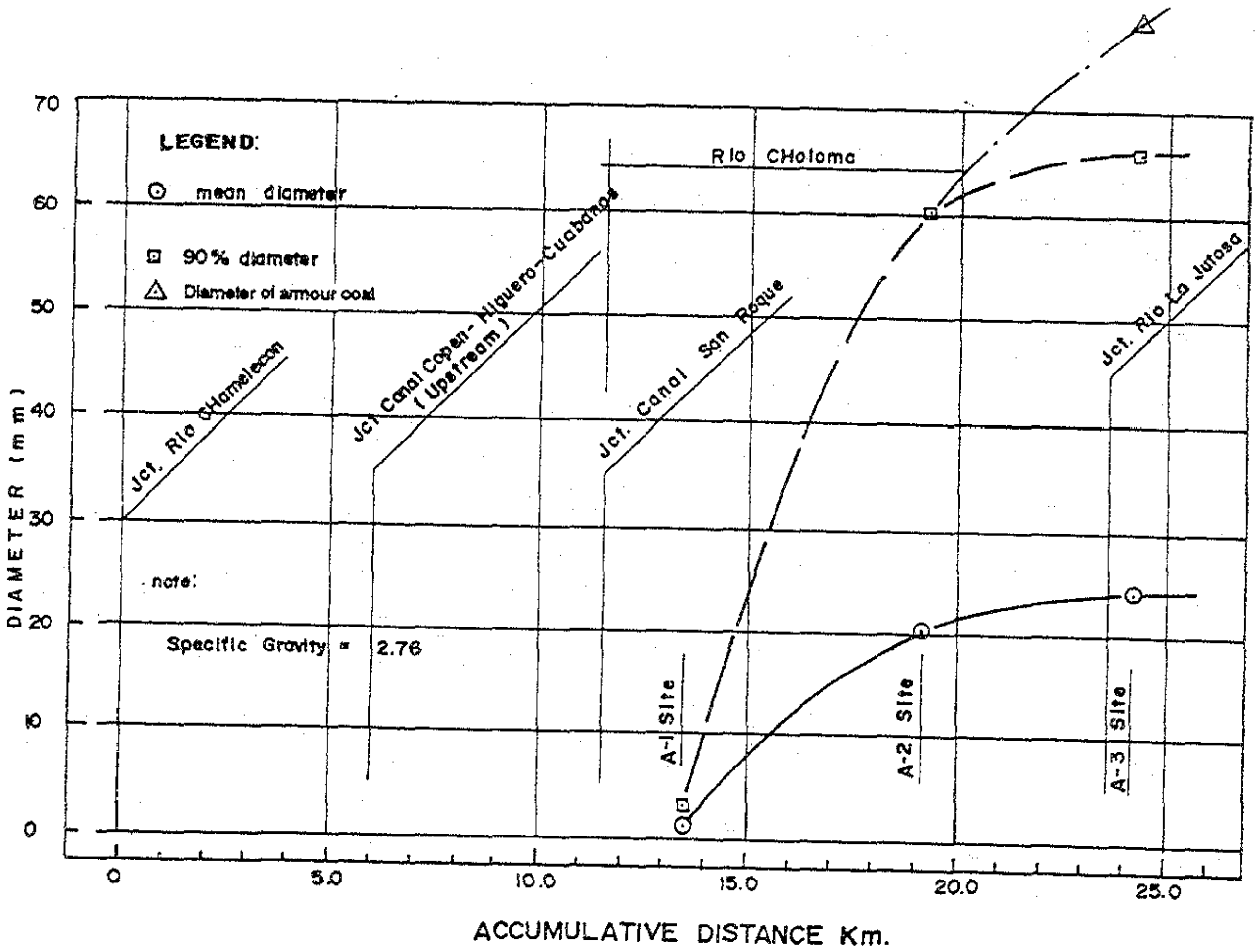


FIG. 8.3 LONGITUDINAL VARIATION OF THE DIAMETER OF RIVER BED MATERIALS (1/3)
THE RIO CHOLOMA

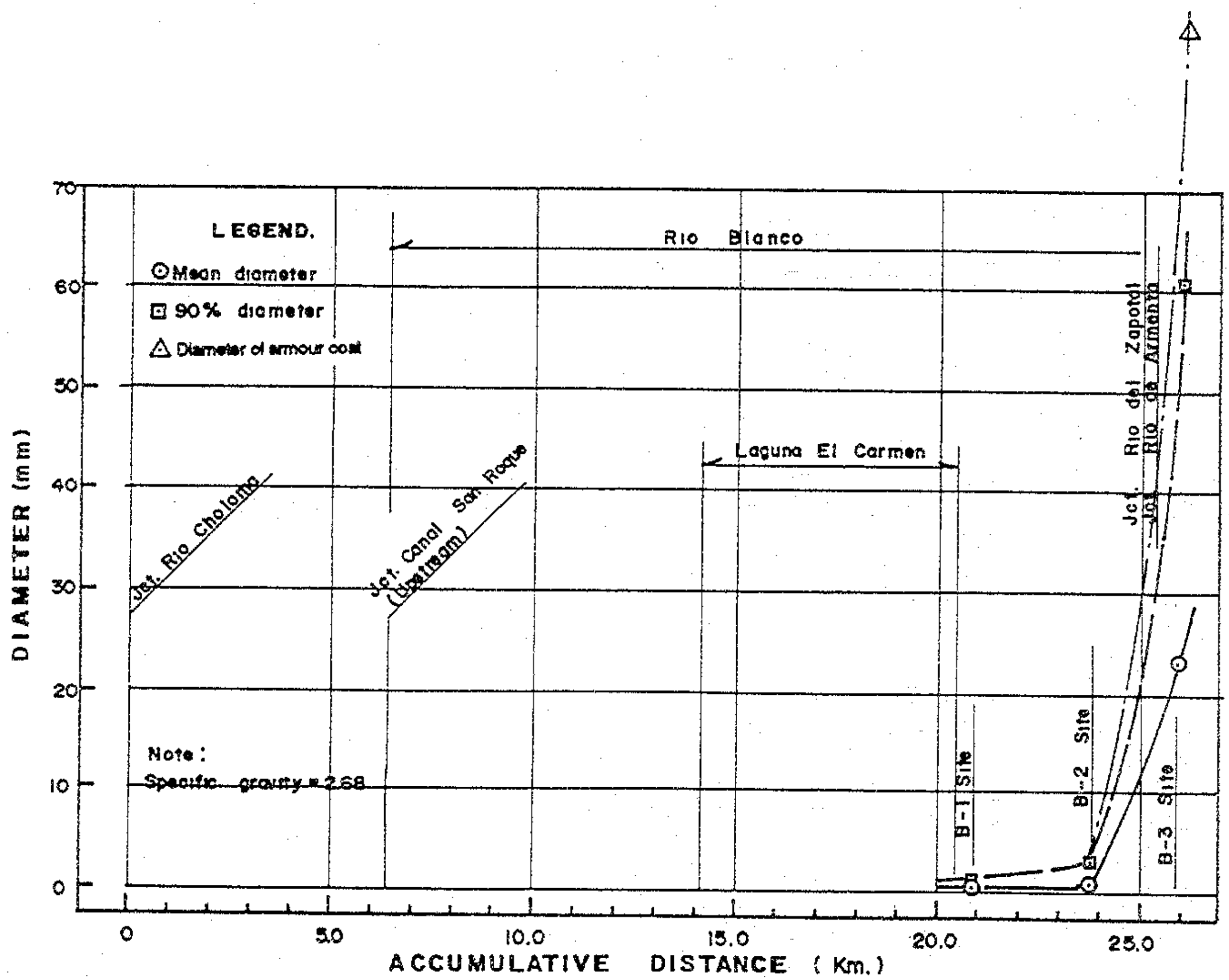


FIG. 8.3 LONGITUDINAL VARIATION OF THE DIAMETER OF RIVER BED MATERIALS (2/3)
- THE RIO BLANCO

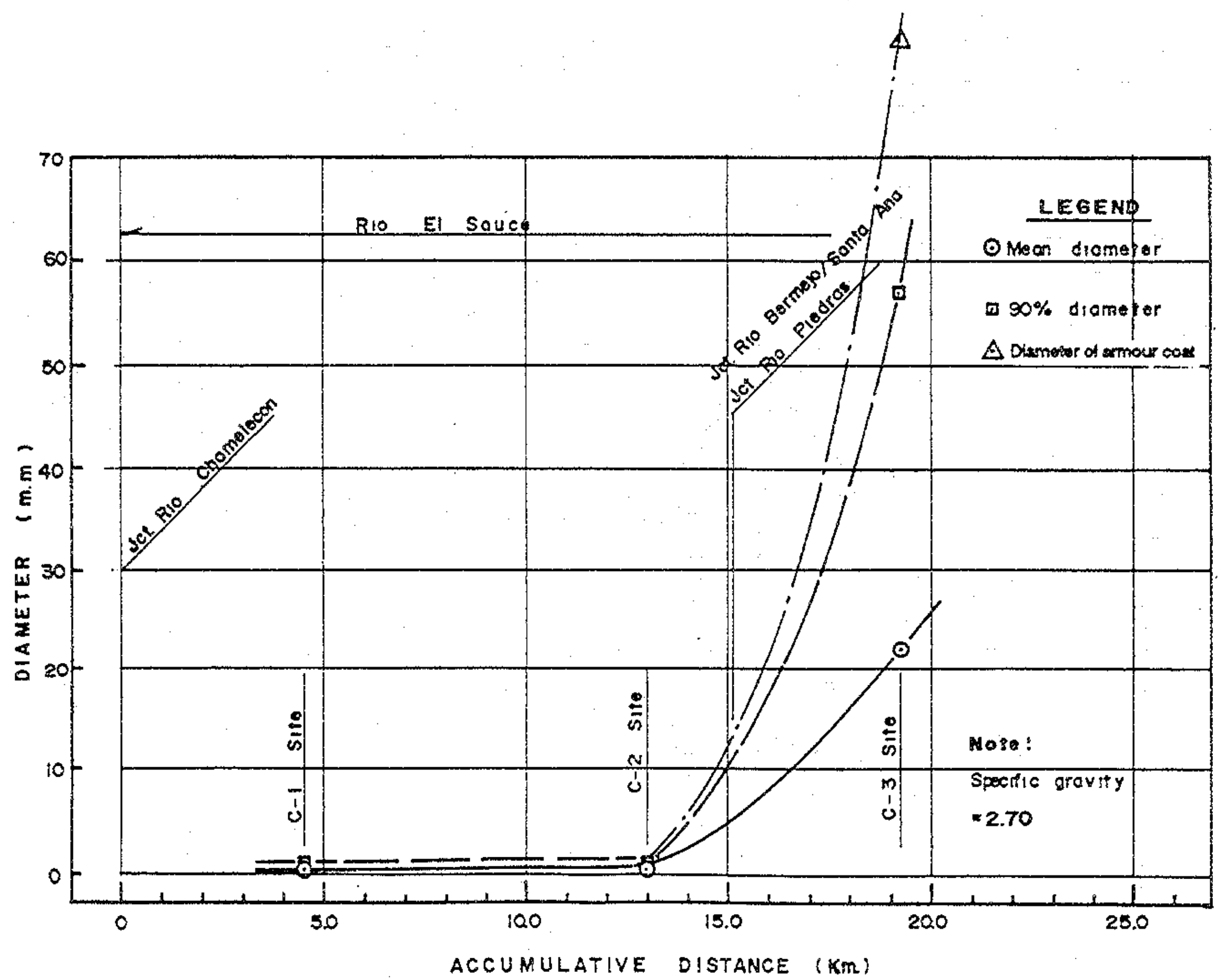


FIG. 8.3 LONGITUDINAL VARIATION OF THE DIAMETER OF RIVER BED MATERIALS (3/3)
- THE RIO EL SAUCE

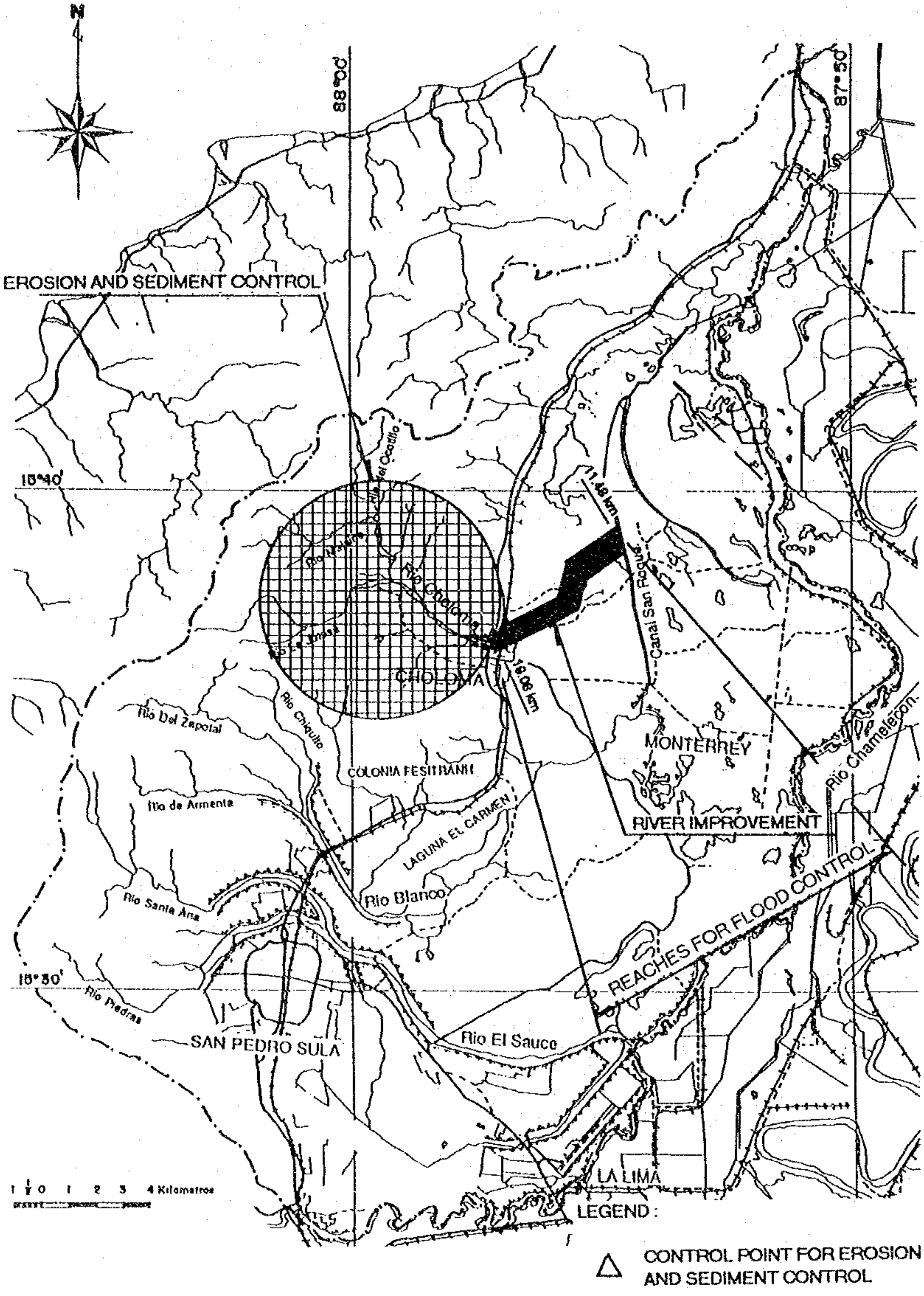


FIG. 8.4 **COMBINATION OF RIVER IMPROVEMENT AND EROSION AND SEDIMENT CONTROL FOR CASE 1-2 - RIO CHOLOMA (WITH PROJECT)**

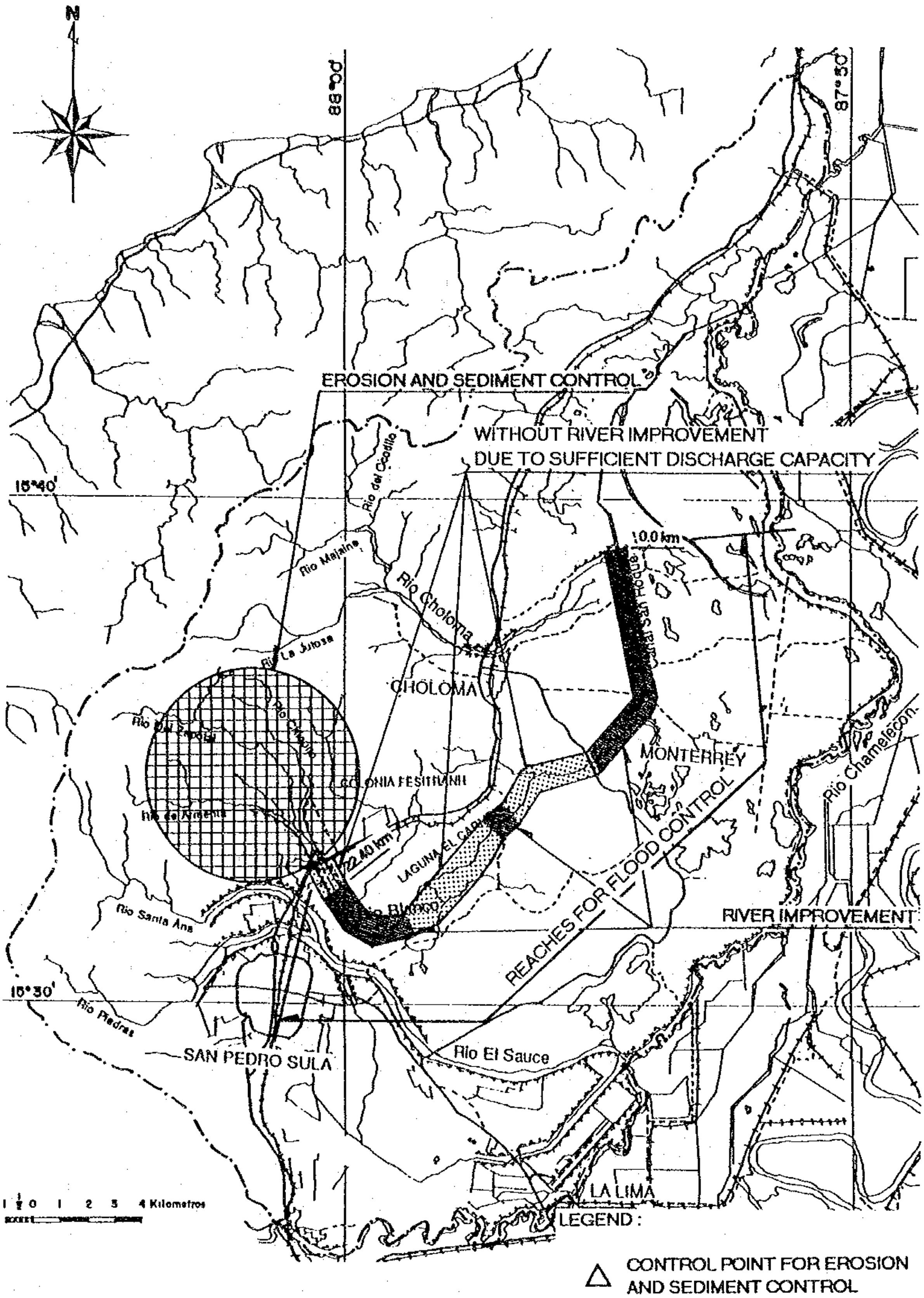


FIG. 8.5 **COMBINATION OF RIVER IMPROVEMENT AND EROSION AND SEDIMENT CONTROL FOR CASE 2-2 - RIO BLANCO (WITH PROJECT)**

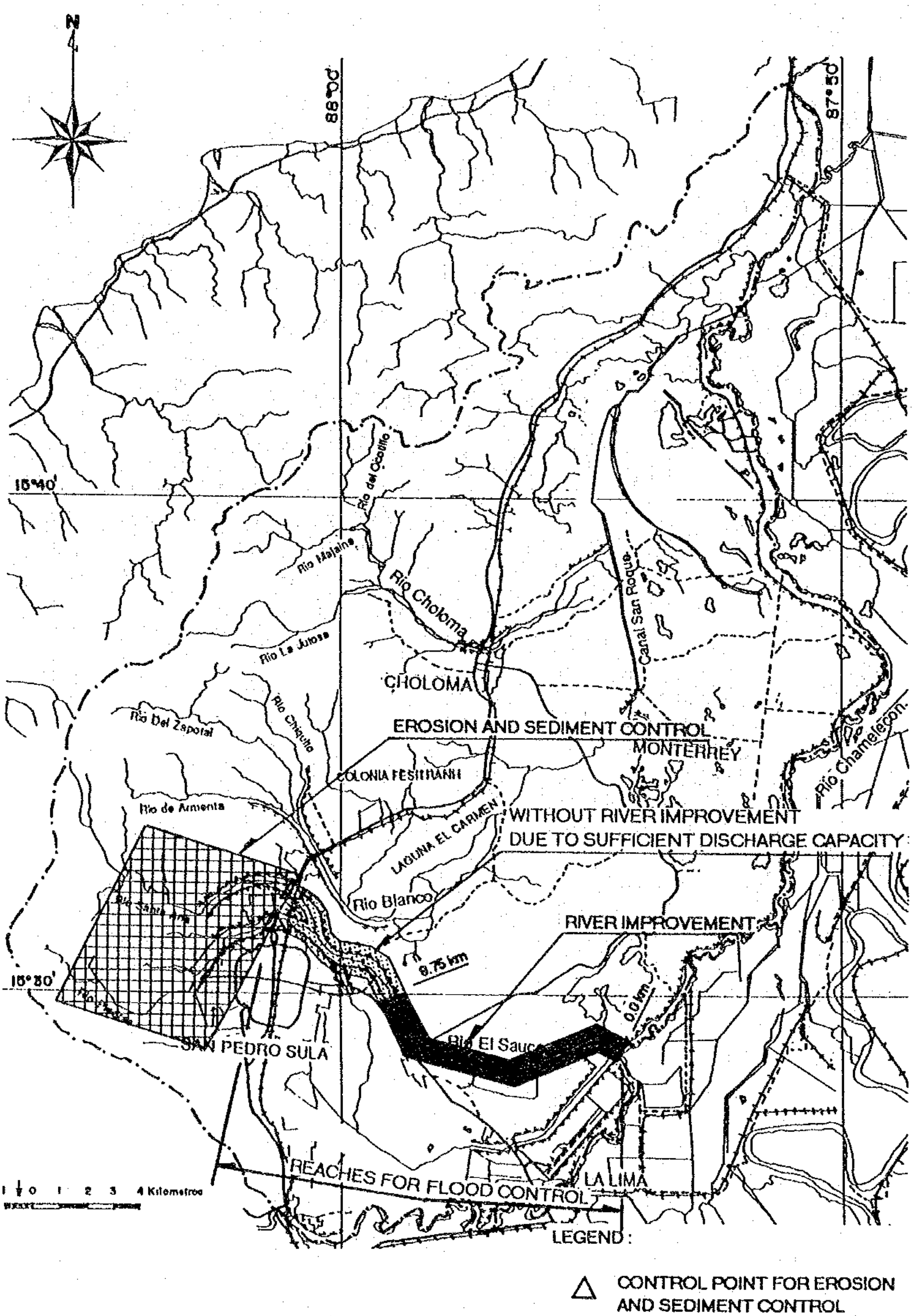


FIG. 8.6 **COMBINATION OF RIVER IMPROVEMENT AND EROSION AND SEDIMENT CONTROL FOR CASE 3-2 - RIO EL SAUCE (WITH PROJECT)**

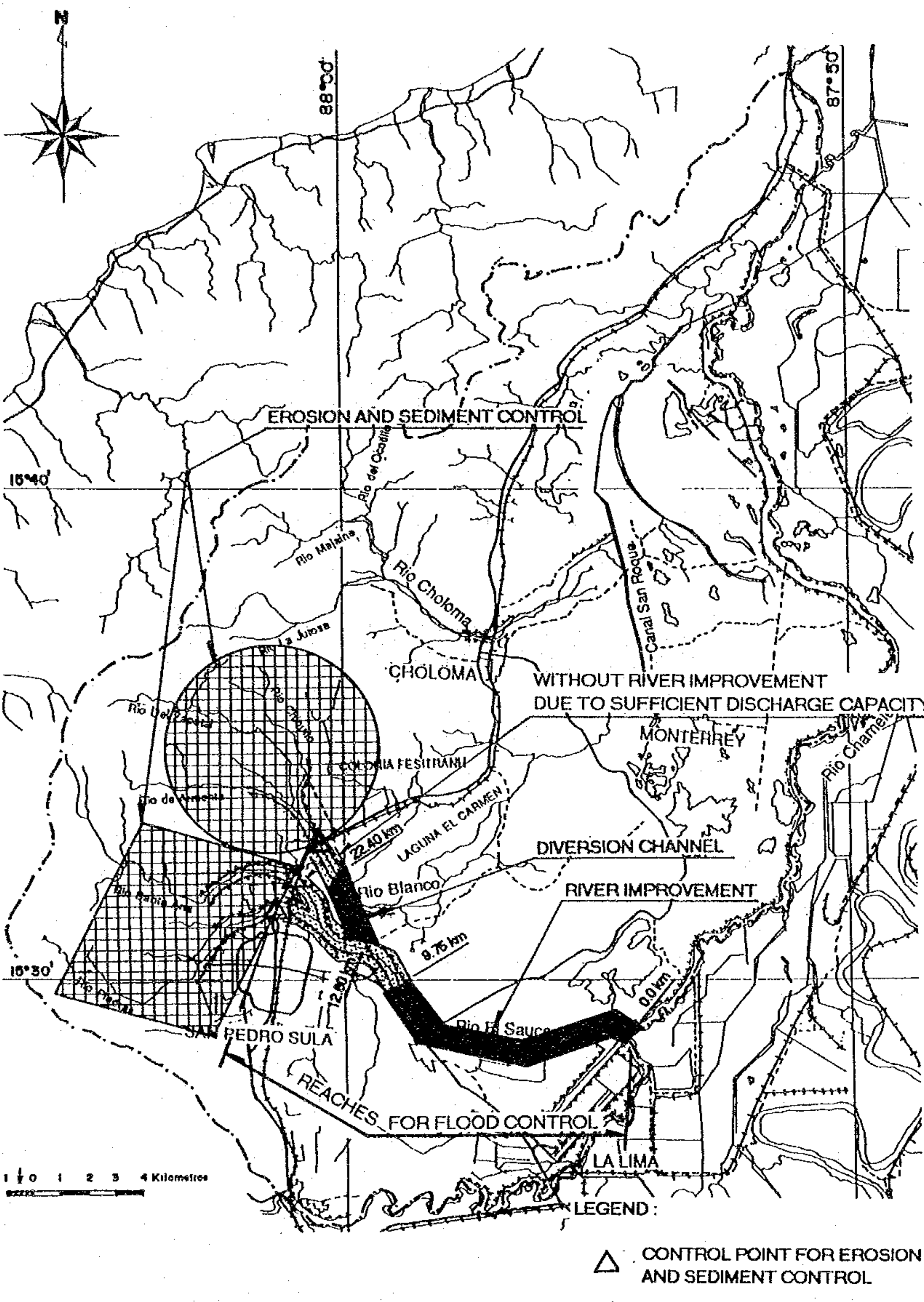


FIG. 8.7 **COMBINATION OF RIVER IMPROVEMENT AND EROSION AND SEDIMENT CONTROL FOR CASE 4-1 - DIVERSION PLAN OF THE RIO BLANCO**

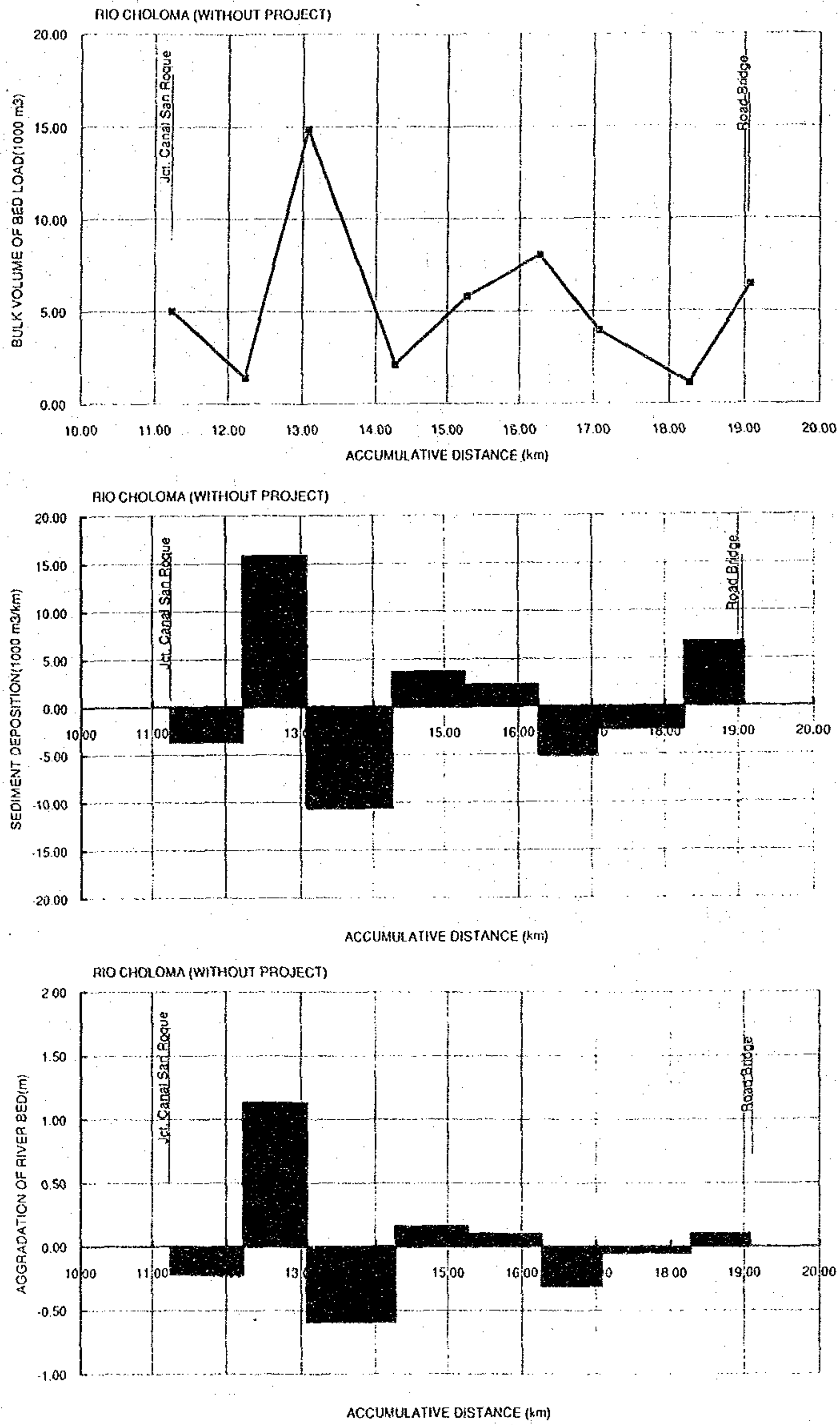


FIG. 8.8 RESULTS OF SEDIMENT SIMULATION OF THE RIO CHOLOMA (CASE 1-1 WITHOUT PROJECT)

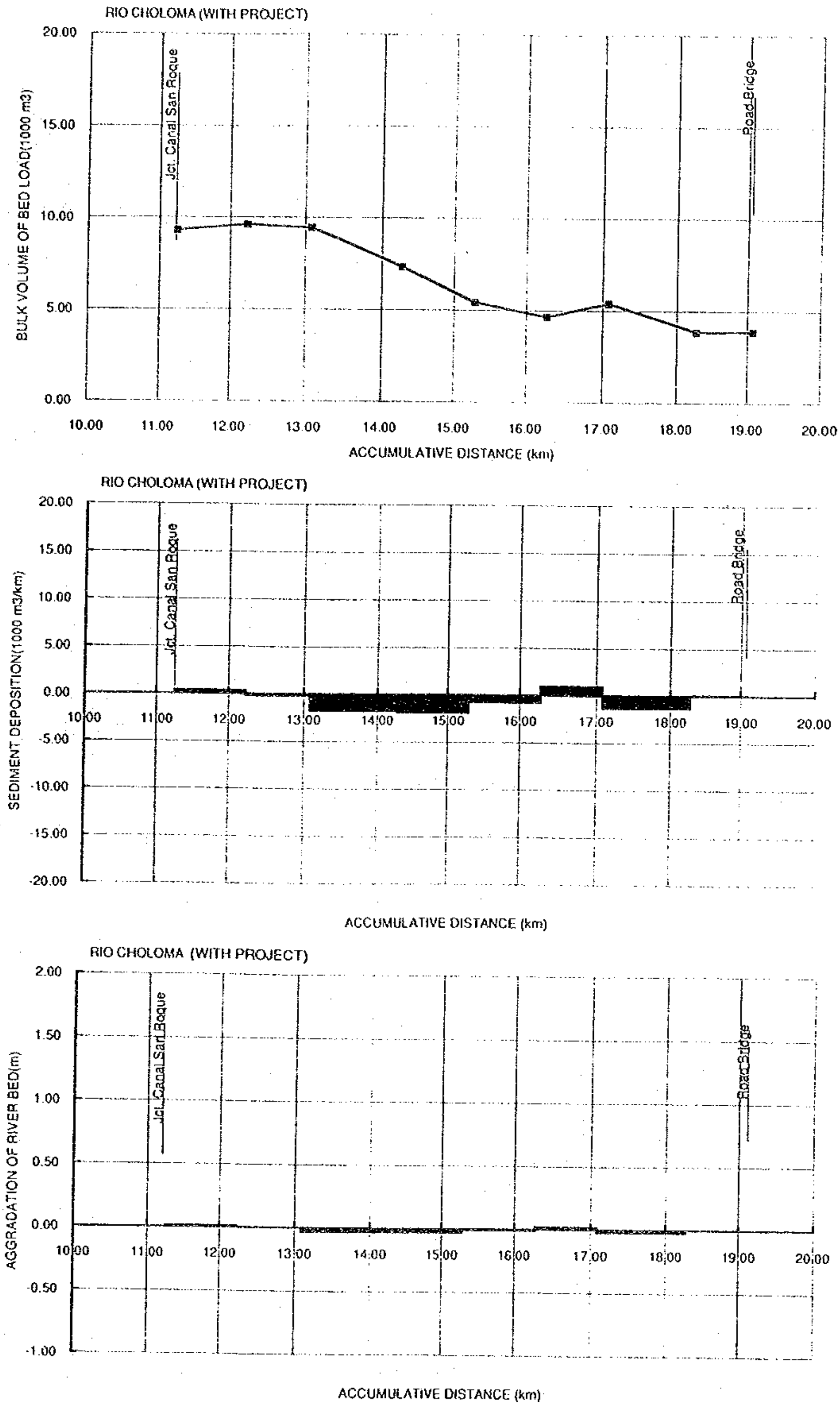


FIG. 8.9 RESULTS OF SEDIMENT SIMULATION OF THE RIO CHOLOMA (CASE 1-2 WITH PROJECT)

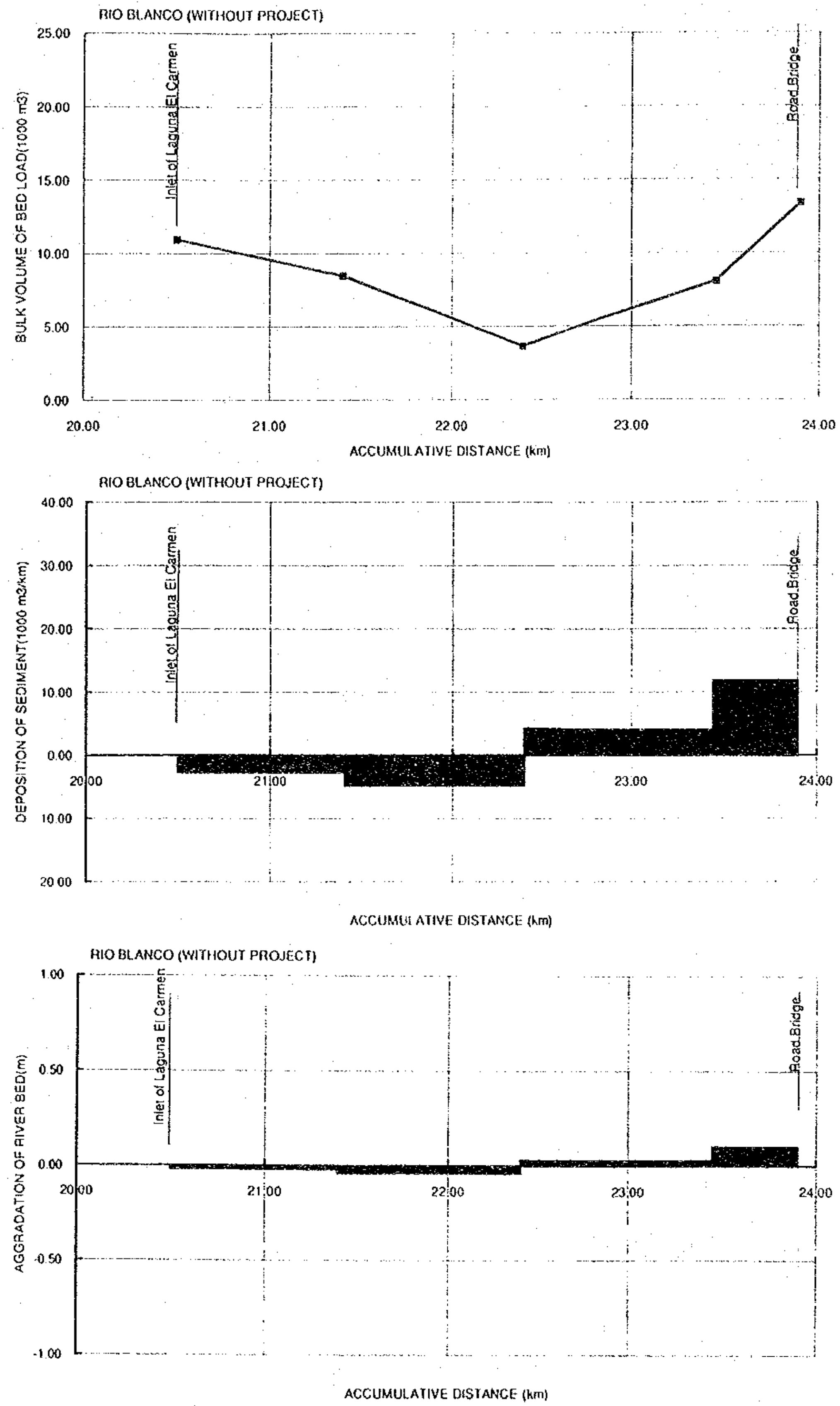


FIG. 8.10 RESULTS OF SEDIMENT SIMULATION OF THE RIO BLANCO (CASE 2-1 WITHOUT PROJECT)

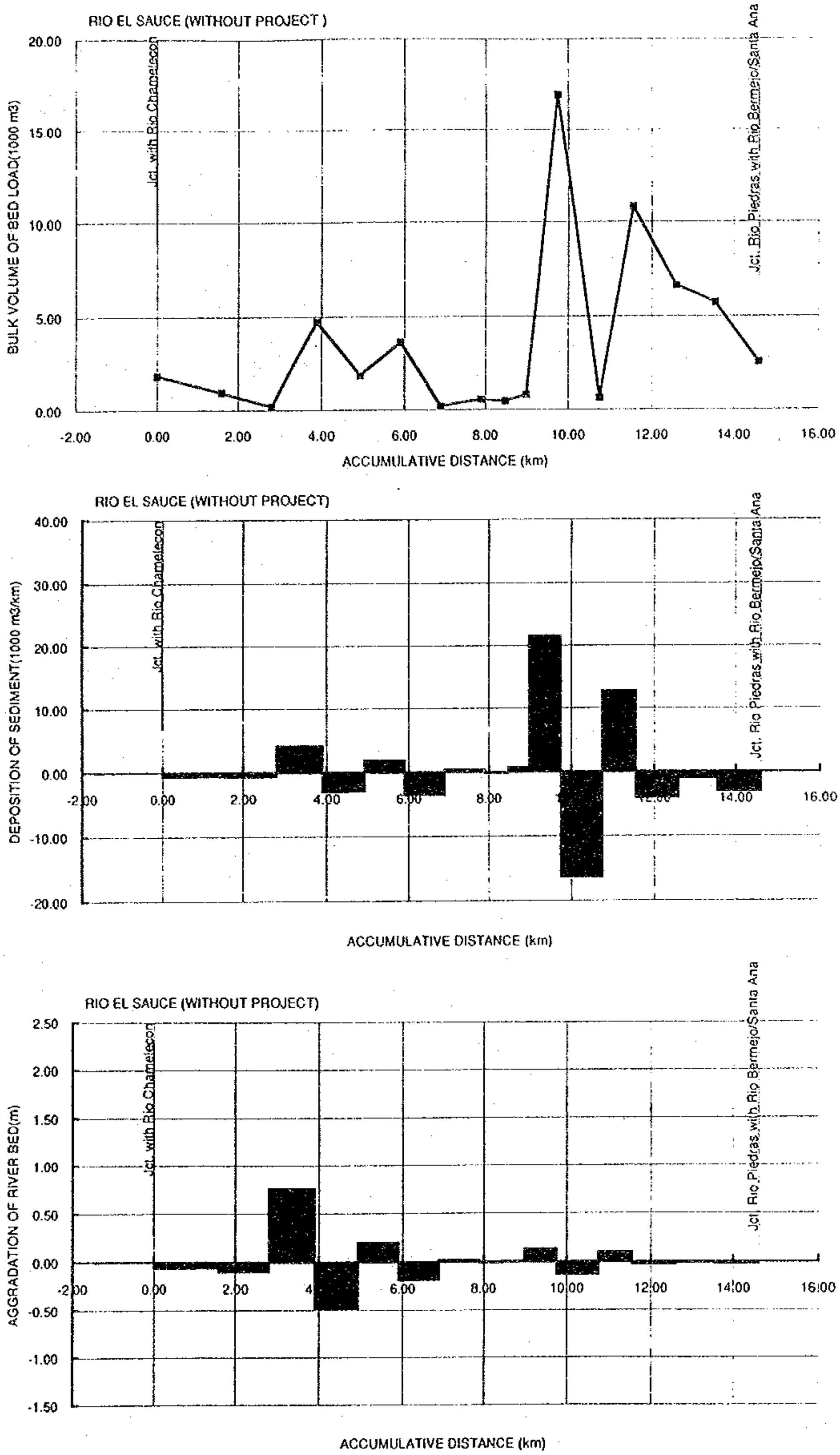


FIG. 8.11 RESULTS OF SEDIMENT SIMULATION OF THE RIO EL SAUCE (CASE 3-1 WITHOUT PROJECT)

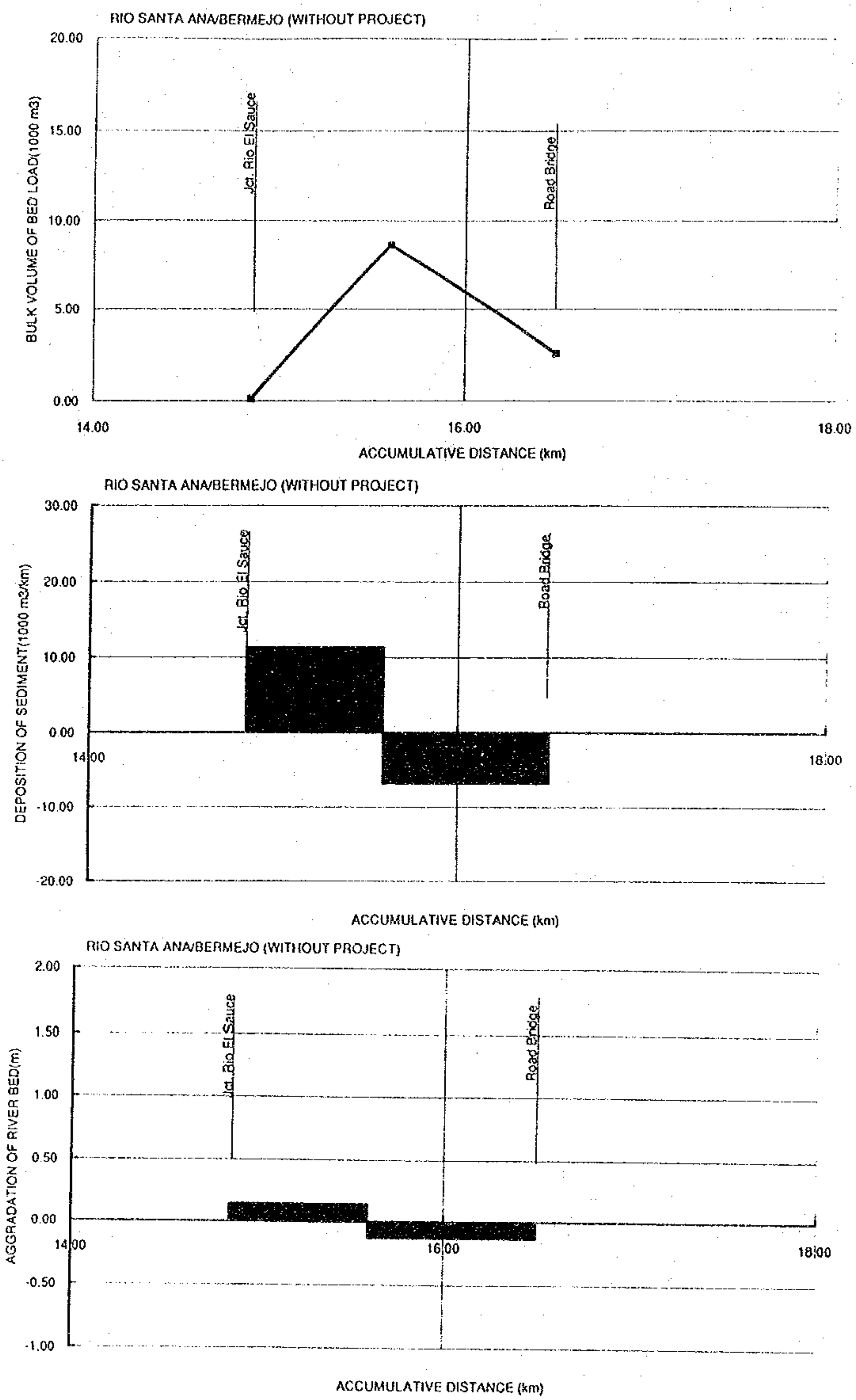


FIG. 8.12 RESULTS OF SEDIMENT SIMULATION OF THE RIO SANTA ANA/BERMEJO (CASE 3-1 WITHOUT PROJECT)

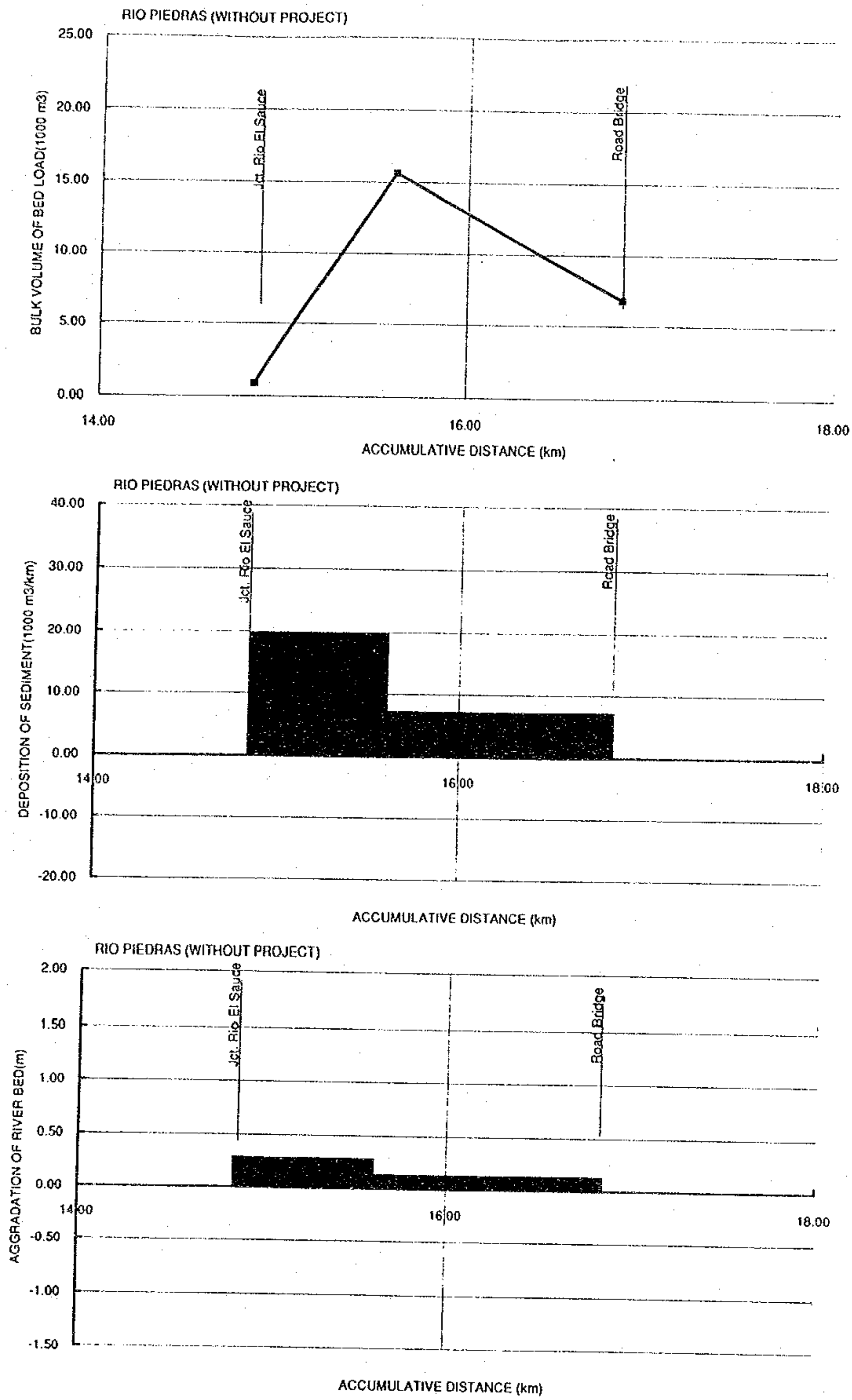


FIG. 8.13 RESULTS OF SEDIMENT SIMULATION OF THE RIO PIEDRAS (CASE 3-1 WITHOUT PROJECT)

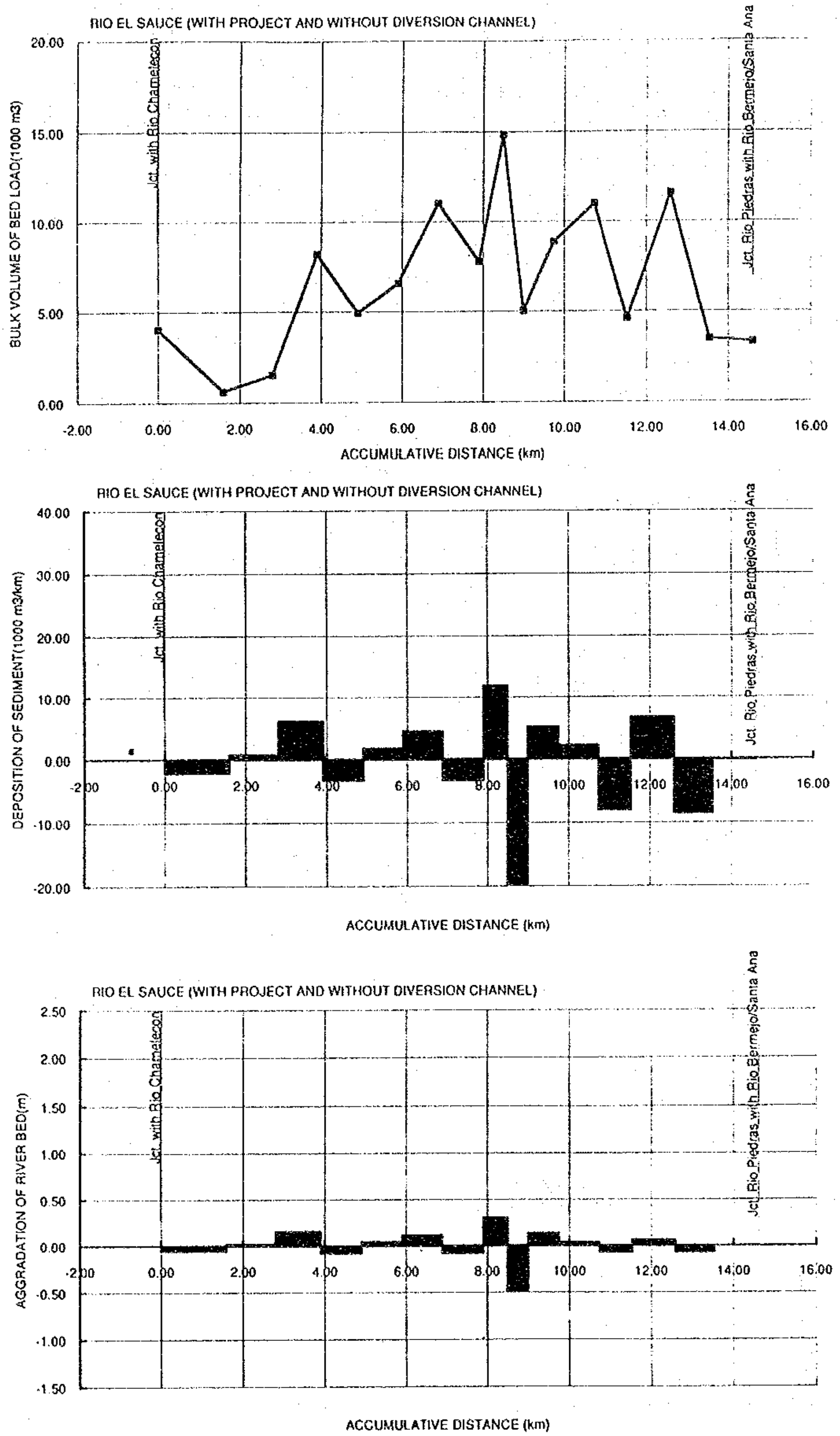


FIG. 8.14 RESULTS OF SEDIMENT SIMULATION OF THE RIO EL SAUCE (CASE 3-2 WITH PROJECT)

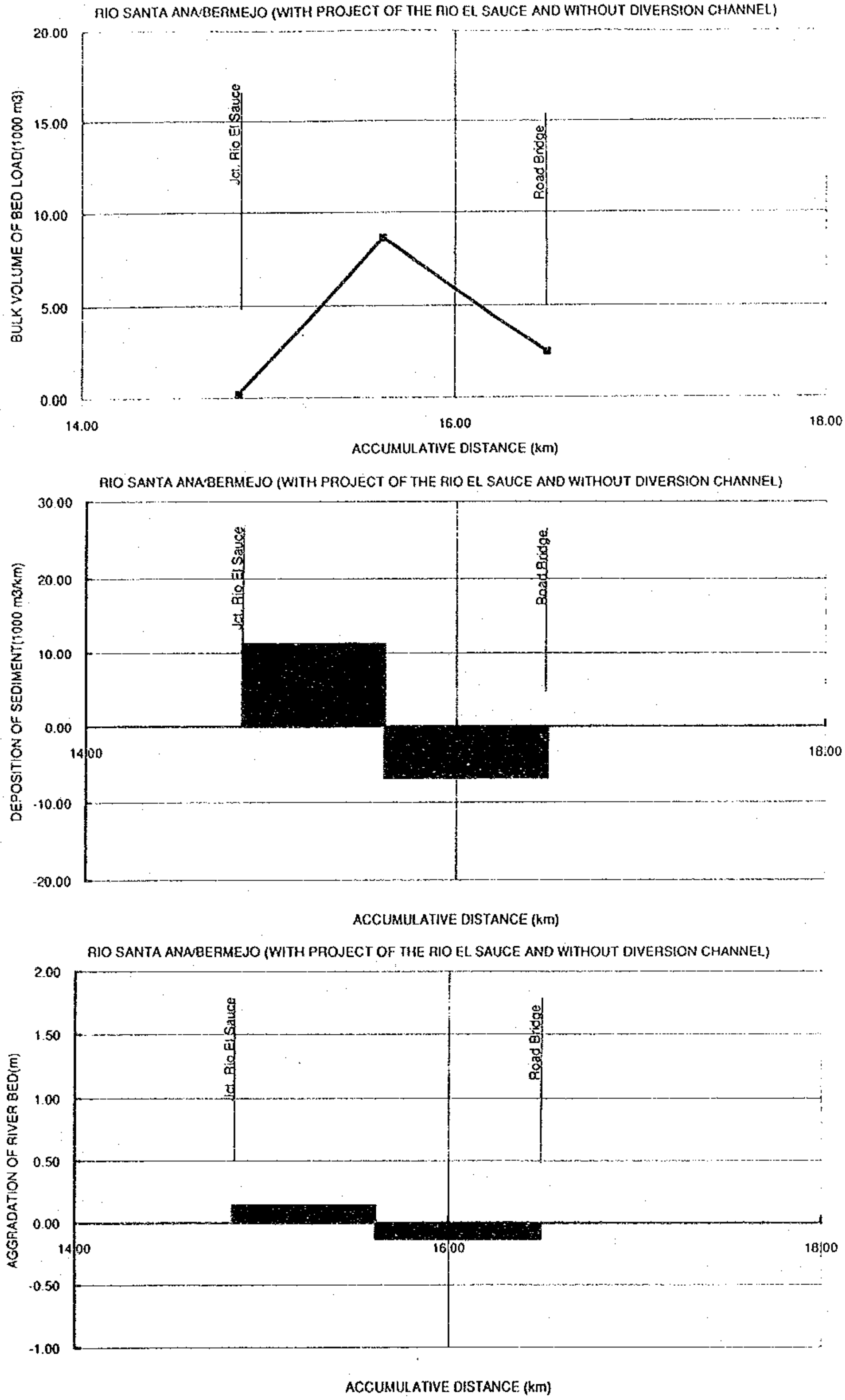


FIG. 8.15 RESULTS OF SEDIMENT SIMULATION OF THE RIO SANTA ANA/BERMEJO (CASE 3-2 WITH PROJECT)

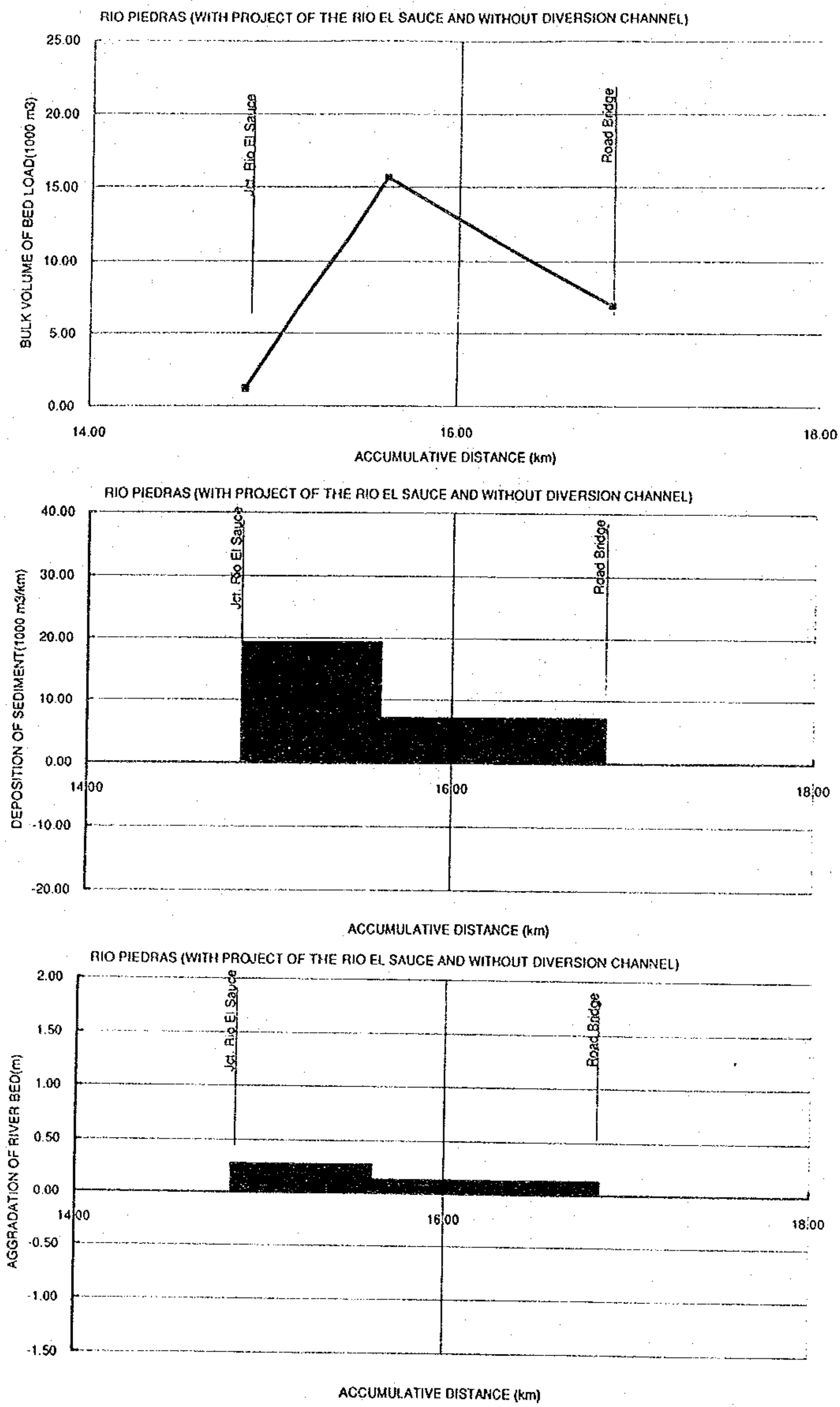


FIG. 8.16 RESULTS OF SEDIMENT SIMULATION OF THE RIO PIEDRAS (CASE 3-2 WITH PROJECT)

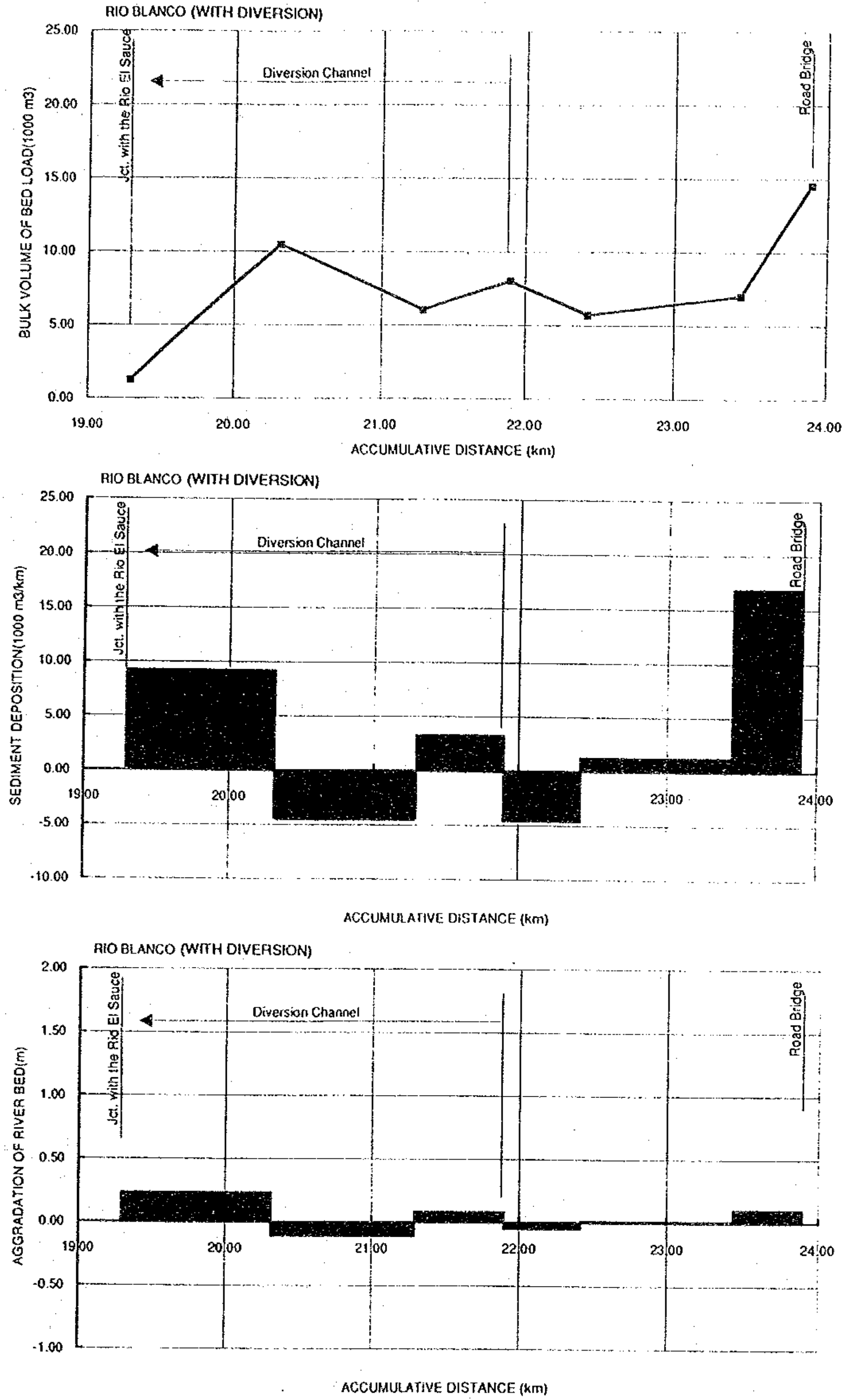


FIG. 8.17 RESULTS OF SEDIMENT SIMULATION OF THE RIO BLANCO (CASE 4-1 WITH DIVERSION)

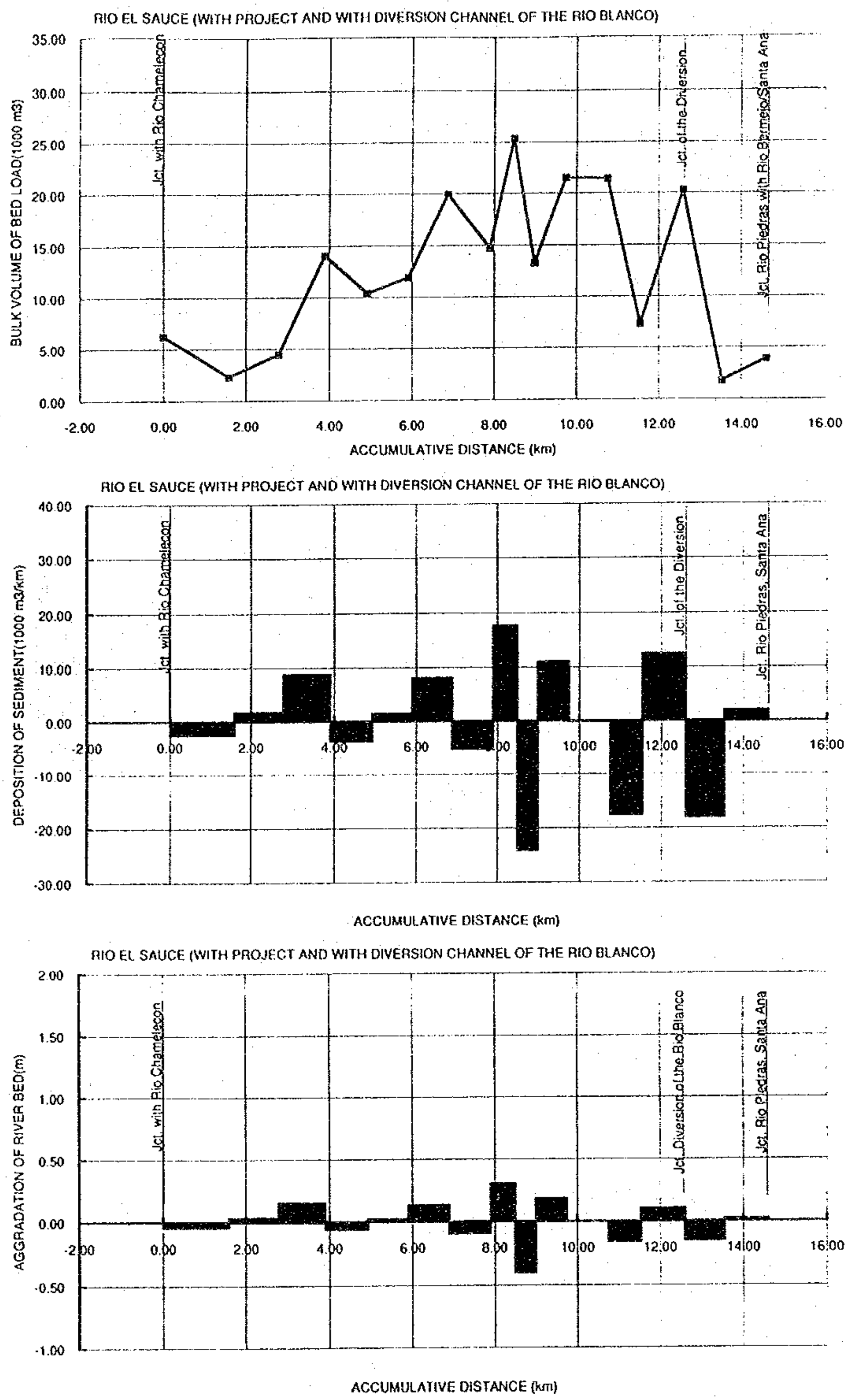


FIG. 8.18 RESULTS OF SEDIMENT SIMULATION OF THE RIO EL SAUCE (CASE 4-1 WITH DIVERSION)

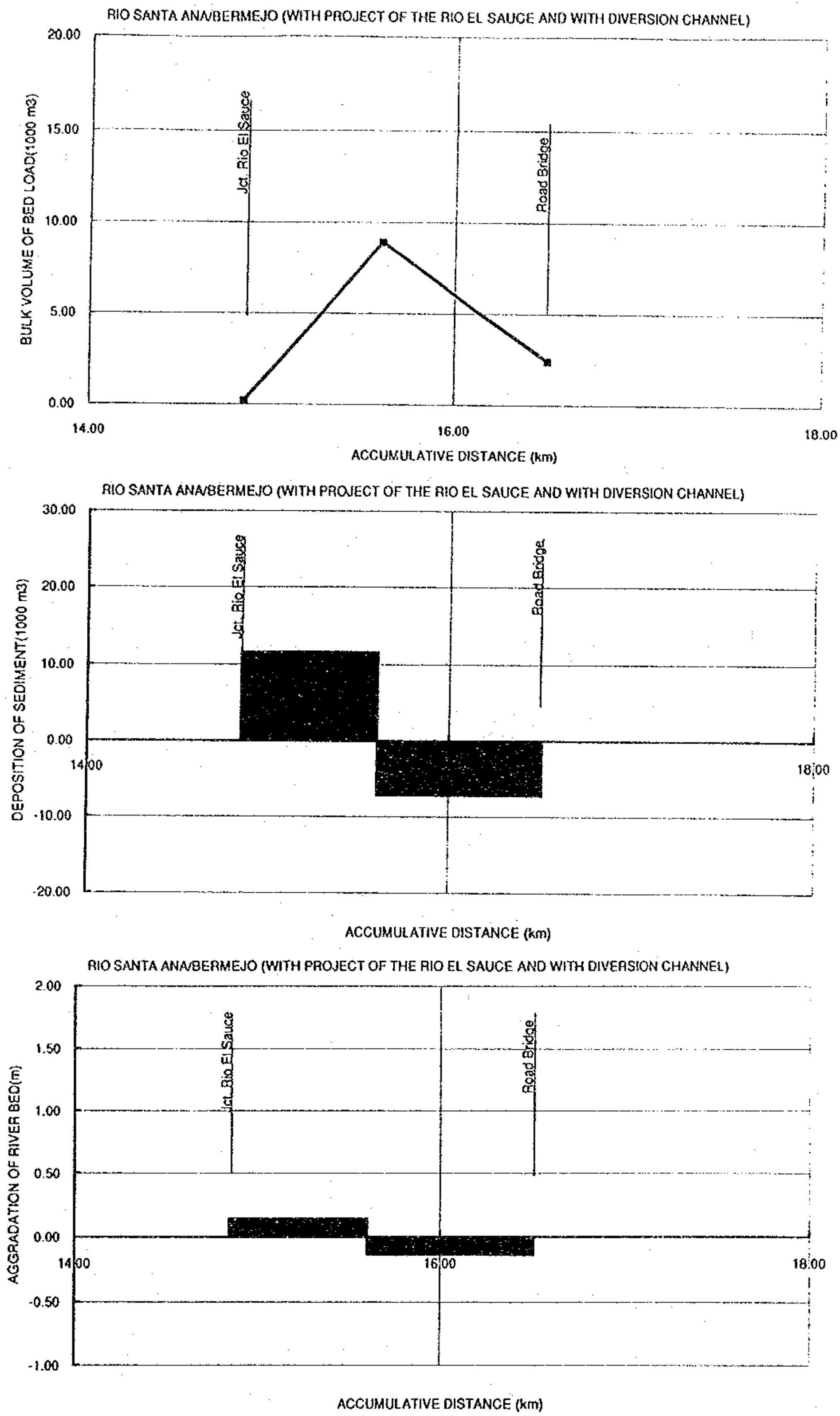


FIG.8.19 RESULTS OF SEDIMENT SIMULATION OF THE RIO SANTA ANA/BERMEJO (CASE 4-1 WITH DIVERSION)

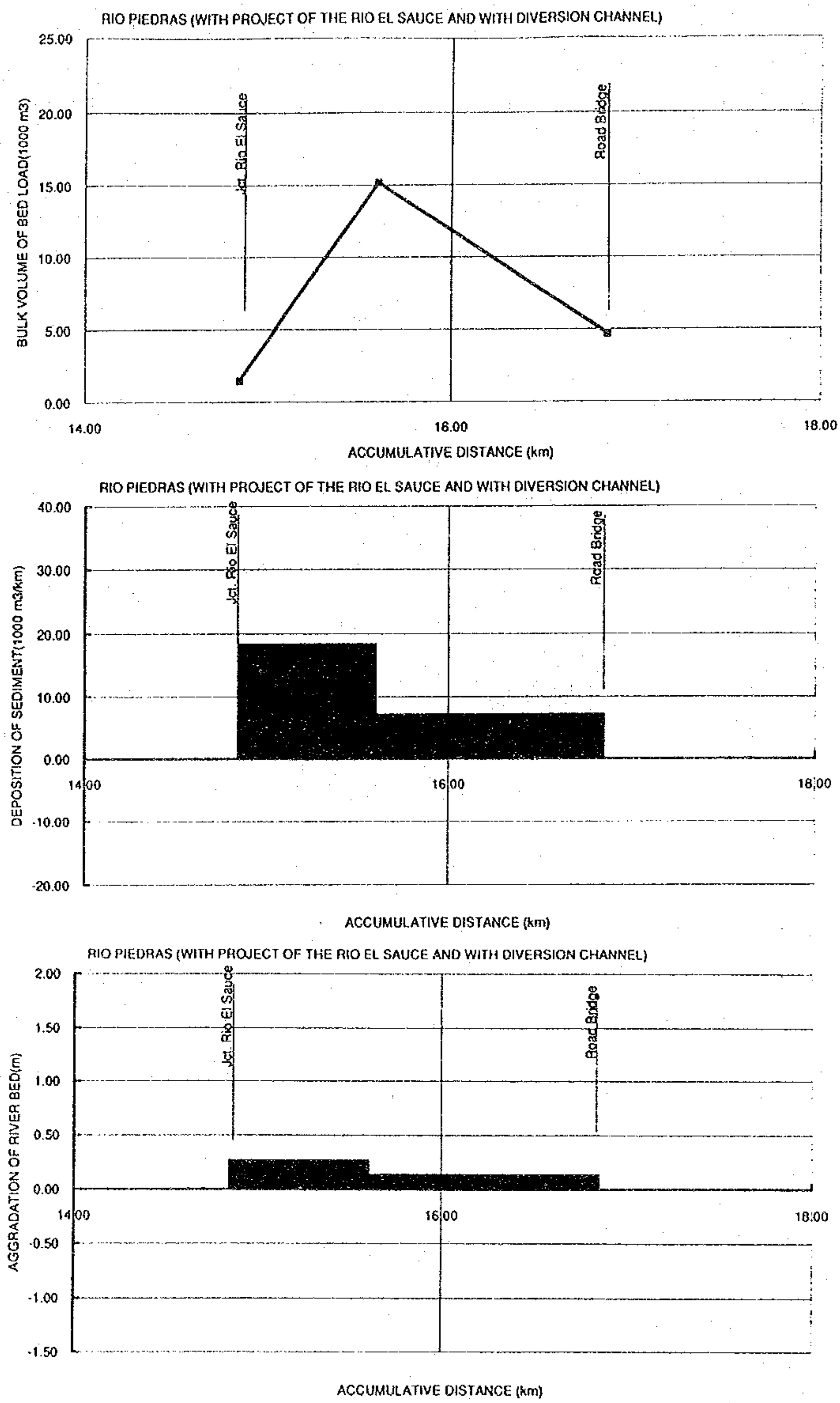


FIG. 8.20 RESULTS OF SEDIMENT SIMULATION OF THE RIO PIEDRAS (CASE 4-1 WITH DIVERSION)

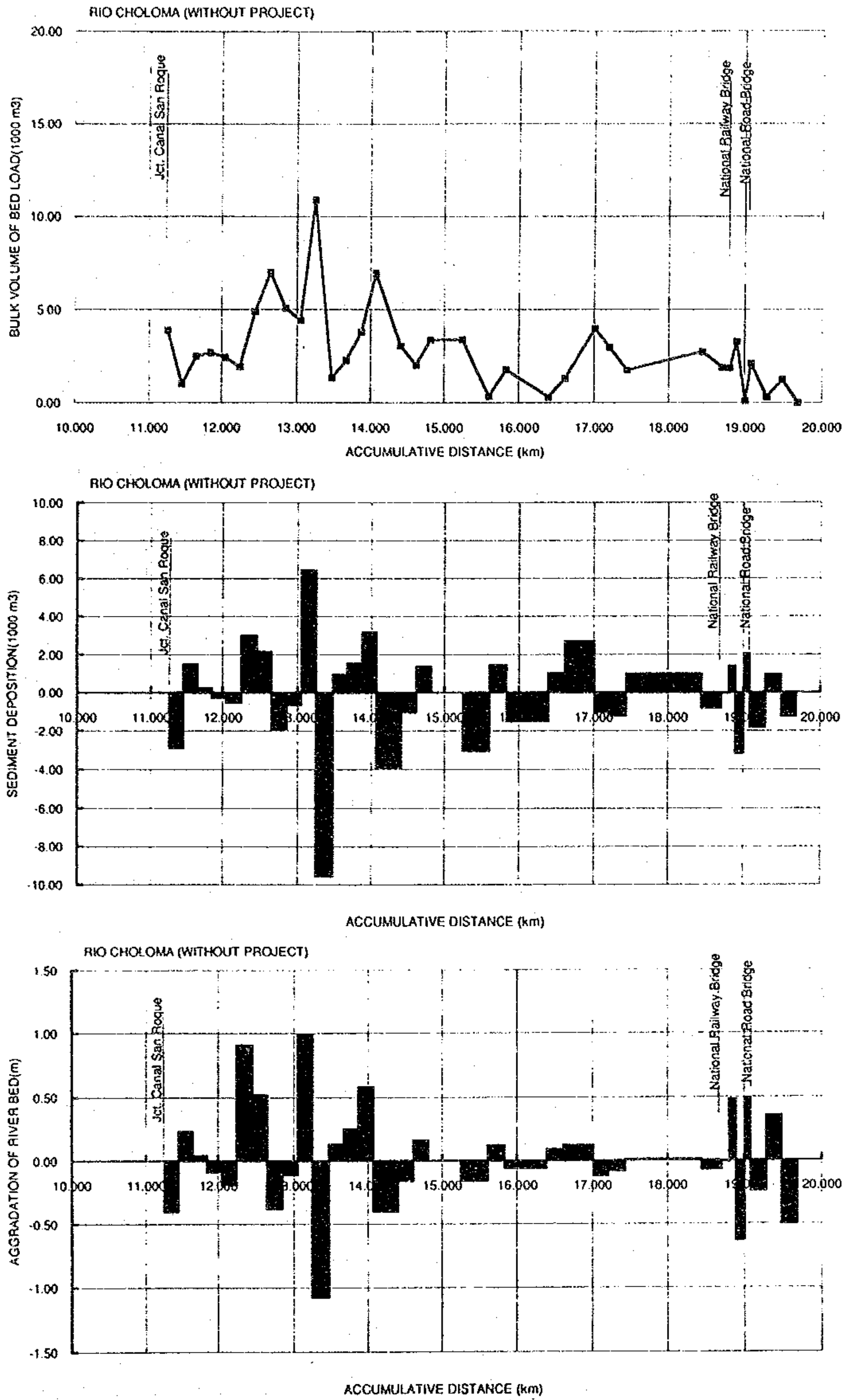


FIG. 8.21 RESULTS OF UPGRADED SEDIMENT SIMULATION OF THE RIO CHOLOMA (CASE 1 WITHOUT PROJECT)

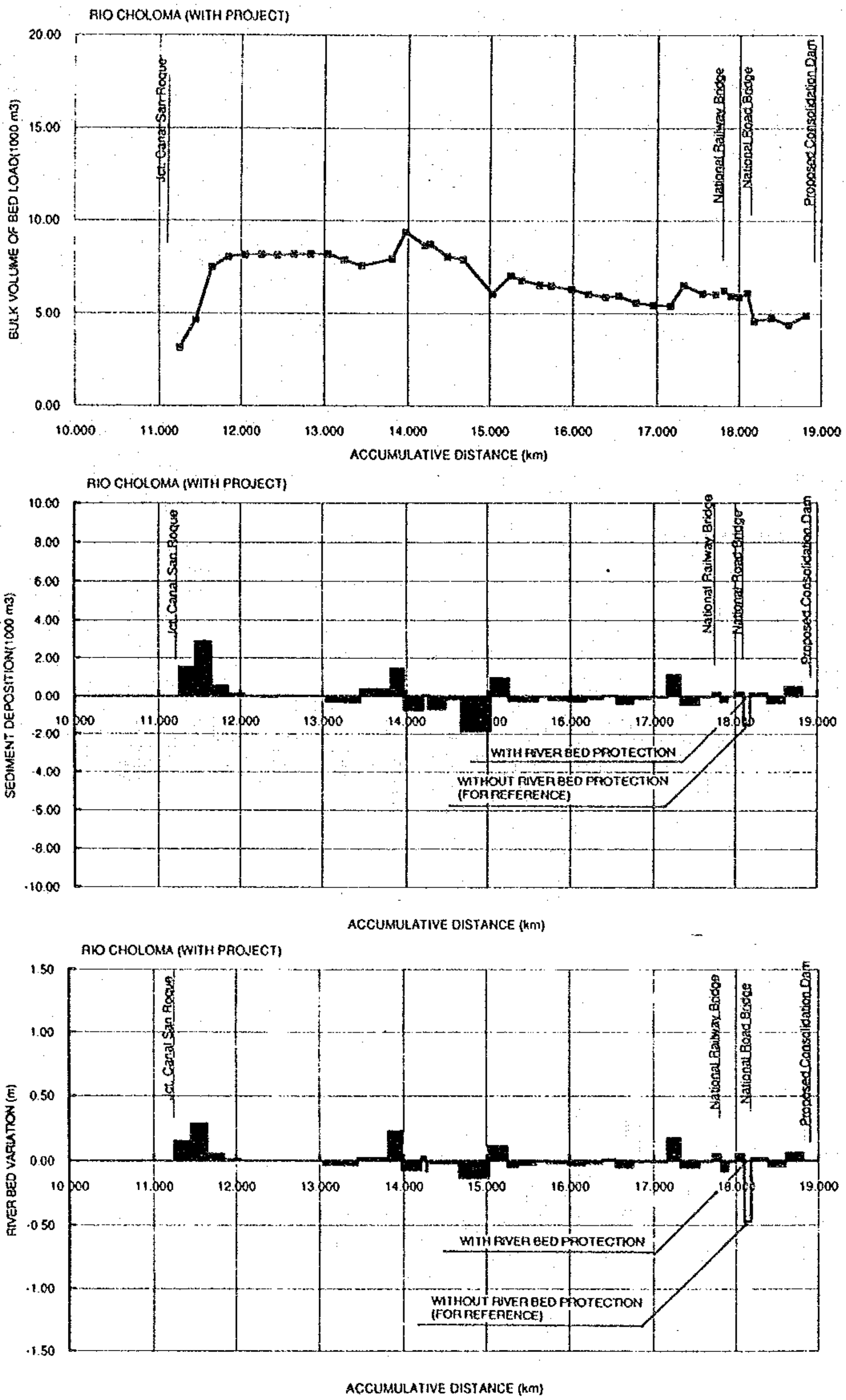


FIG. 8.22 RESULTS OF SEDIMENT SIMULATION OF THE RIO CHOLOMA (F/S-CASE 2 WITH LONG TERM PROJECT)

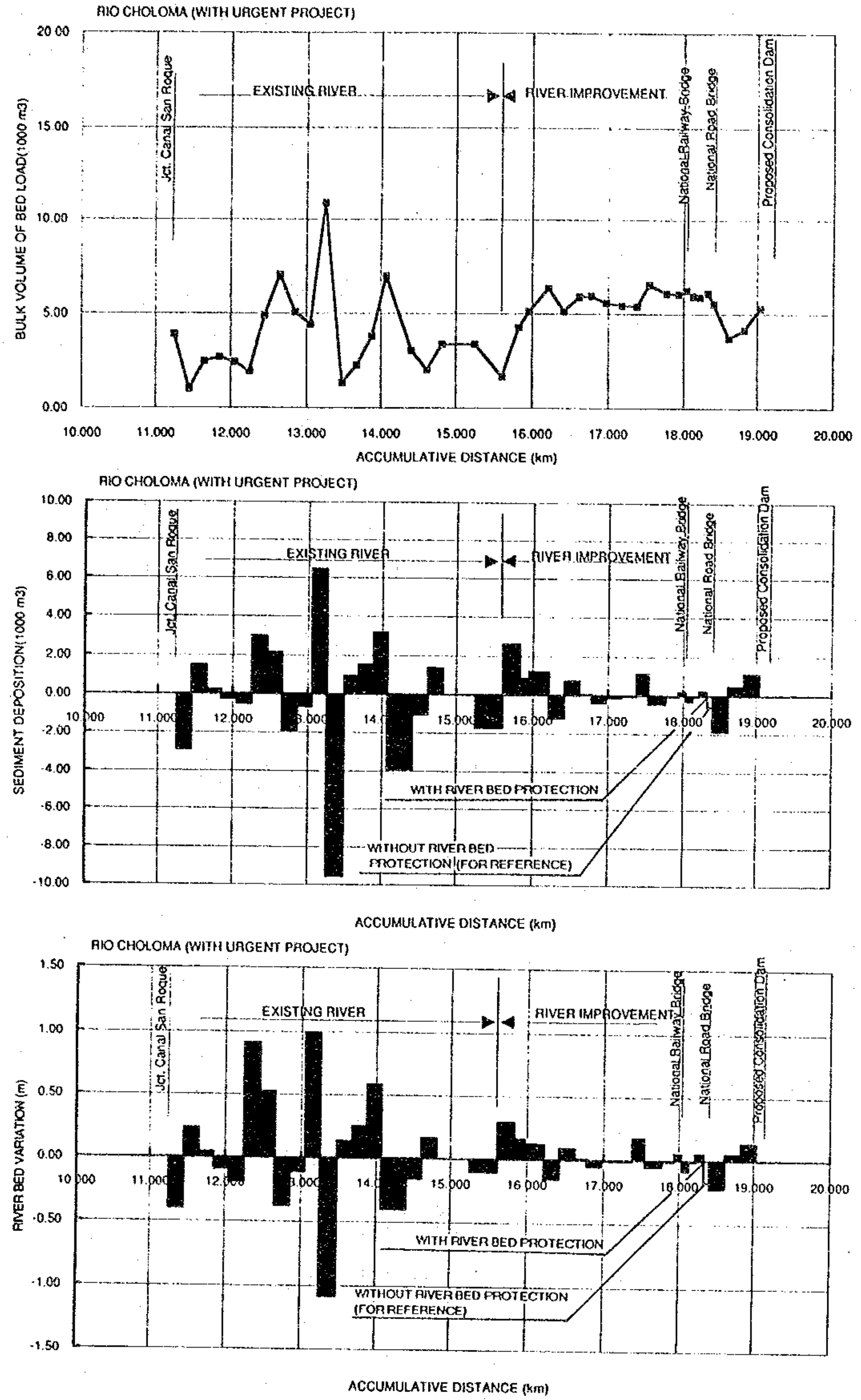


FIG. 8.23 RESULTS OF SEDIMENT SIMULATION OF THE RIO CHOLOMA (F/S-CASE 3 WITH URGENT PROJECT)

FLOOD OF THE RIO CHOLOMA BY THE TORMENTA "GERT" IN 1993
(DESTROYED NATIONAL RAILWAY BRIDGE)

CHAPTER 9
FLOOD MITIGATION MEASURES

CHAPTER 9 FLOOD MITIGATION MEASURES

9.1 General

This chapter deals with the flood mitigation measures for the study area. The study area has severe erosion, sediment and flood problems. The conceptual facility plan against erosion and sediment control measures is given in Chapter 7. According to the Flood and Flood Damage Survey (Chapter 5), the study area has been affected partly by the floods from the pilot rivers and partly by that from of the Rio Chamelecon. After assessing the actual conditions of the pilot rivers such as their conveyance capacities and existing facilities, optimum measures for sediment and flood control were proposed.

After the hurricane Fifi, several studies have been conducted through the years on the flood mitigation in the Sula Valley. There are two studies that are pertinent to the current situation. They are:

a. Obras de Protection Contra Inundaciones, by Sir William Halcrow & Partners in September 1975,

b. 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 Factivilidad y el Diseno de las Obras Hidraulicas Prioritarias para el Desarrollo Integral y Control Inundaciones en el Valle de Sula, by HARZA-CINSA, in November 1980

The Study by William Halcrow & Partners prepared the detailed design for the remedial works of the Rio Blanco and the Rio El Sauce in San Pedro Sula. The Municipality of San Pedro Sula and SECOPT have constructed flood dikes along the Rio Blanco and the Rio El Sauce, and the diversion work of the Rio Chiquito based on their recommendation. However the other works have not been executed by this time.

The study by HARZA-CINSA is the most comprehensive study on the flood control for the Sula Valley. The flood control measures proposed in the master plan have not been implemented yet, except some part of the drainage improvement works. The drainage works carried out, are as follows:

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

- Canal San Roque and (6.4 km),
- Canal Montanuela-San Roque.

These canal construction works, simultaneously with the embankment along the Rio Chamelecon, are very important for flood mitigation in the lower basin of the Rio Choloma. The flood water of the Rio Choloma flows into the Canal San Roque-Cuabanos and drained to the Rio Chamelecon through the Canal Copen-Higuero Cuabanos. These drainage canals will require remedial works in future, because they have not constructed in full scale as proposed in the master plan. Their conveyance capacities of flood waters seem by far small.

9.2 Existing River Conditions

1) River System

The river systems with their watersheds are shown in *Fig.* 9.1. The river distance and longitudinal profile of the main channels are shown in *Figs.* 9.2 (1)~(3) and *Figs.* 9.3 (1)~(3) respectively. The rivers in the study area are very steep in the upper basins, but become gentle in the mid and lower basins within a short distance.

The river length and river bed slope between the confluence and the design control point for the sediment control plan 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

The Rio Blanco had flowed to the Rio Chamelecon through the present river course of the Rio El Sauce and The Rio El Sauce had flowed through the river course of the Rio Chotepe before the hurricane Fifi. However the river courses of the Rio Blanco and the Rio El Sauce were changed to the present river courses during the improvement works after the hurricane Fifi.

2) River Facilities

There are flood mitigation facilities such as embankments and embanked channels constructed along the pilot rivers and the Rio Chamelecon. They are explained below.

a) Embankment along the tributaries

After the hurricane Fifi, embankments (or embanked channels) were constructed by the Municipality of San Pedro Sula and SECOPT. The Rio Blanco and the Rio El Sauce were constructed mostly based on the design by Sir William Halcrow & Partners. The river distances of the embanked channels are summarized as follows:

- Rio Choloma: 5.0 km
- Rio Blanco and it's tributaries 21.2 km
- Rio El Sauce and it's tributaries 44.1 km
- Rio El Sauce(viejo)-Chotepe: 12.7 km

These rivers were improved to have a hydraulic capacity adequate to convey a flood with a frequency of once in 100 years. They seem to have sufficient flow capacities against the flood caused by the hurricane Fifi.

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. The detailed information and the location of facilities are shown in *Table* 9.1 (1)~(2) and *Fig*. 9.4.

b) Embankment along the Rio Chamelecon

There are flood embankments (approximately 54.1 km) along the left bank of the Rio Chamelecon that have been constructed by different agencies i.e., Tela Railroad Company, Municipality of San Pedro Sula, SECOPT and Sula Valley Committee, but still about 5.5 km of the left bank is remaining without embankment. It is not clear whether the existing embankments are high enough against the flood stage or not.

The embankments might not be strong enough against seeping and scouring during floods. Accordingly the height and stability of the existing embankments should be checked and reinforced or rehabilitated, if necessary.

3) Discharge Capacity

The bank high flows of the pilot rivers are calculated by the Manning Formula. The results are summarized as follows;

a) Rio Choloma

The bank high flow of the Rio Choloma is assessed as follows:

- In the river course between the national road bridge and the railway bridge, the bank high flow is larger than 900 m^3/s, but the maximum discharge capacity at the railway bridge is only 170 m^3/s.
- In the river course between the railway bridge and the confluence with the Canal San Roque, the bank high flow capacity is estimated as follows:

Station	Discharge Capacity
11.25~17.00 km	40 ~ 60 m^3/s
17.00~18.70 km	100 ~ 170 m^3/s

b) Rio Blanco

The discharge capacity of the river reaches between the national road bridge and the inlet of Laguna El Carmen decreases from 3,600 m^3/s to 1,600 m^3/s. The Qda. San Agustin, that is located between the outlet of Laguna El Carmen to the Canal San Roque (6.40 km ~ 23.45 km) and flows down through mountainous area, has a discharge capacity more than 2,000 m^3/s. But at the most upstream reach, the discharge capacity is only 460 m^3/s.

c) Rio El Sauce

The discharge capacity of the downstream reach is smaller than those of midstream and upstream reaches. The discharge capacities of the reaches, (0.0 ~ 5.0 km) and (5.0 ~ 14.6 km), are 600 m^3/s and 1,000 ~ 2,000 m^3/s, respectively. The discharge capacity of the Rio Piedras is about 1.200 m^3/s. The discharge capacity of the Rio Santa Ana -Rio Bermejo is about 900 ~ 1,300 m^3/s.

4) Estimation of probable flood stages and inundation area

In order to assess the flood damages by different flood scales, the inundation areas by the probable floods of 2-year, 5-year, 30-year, 50-year and 100-year return periods were estimated as shown in *Table* 9.2 and *Figs*. 9.5. based on the flood stages calculated.