soluble copper contents of sediments taken at 10 monitoring points of irrigation water quality in the ARIS area vary between 90 and 180 ppm. These sediments contain soluble lead of less than 10 ppm, zinc of 30 to 70 ppm and cadmium with a level of trace.

2.4 Crop Survey

At the respective monitoring paddy fields, four plots were selected for observation purpose. These plots are irrigated under plot-to-plot condition. The first plot is located adjacent to the inlet from watercourse or settling basin. The last plot connects to the drainage channel through the outlet. Three hills of rice plant were selected in the inlet portion of each plot and were observed once a week in terms of plant height and number of tillers. In parallel with the monitoring works on crop growth, interview survey was done to collect information on farming practices of farmers who managed the monitoring paddy fields. After harvesting, these observed hills were separated into root, stem, leaf and grain for heavy metal and nutrient analysis.

The yield survey was performed by cutting method. For this purpose, all the hills grown in an area of 1 m^2 were cut at inlet, center and outlet portions of each plot under a series of plot-plot irrigation in the respective monitoring paddy fields and in some of paddy fields at which the random soil sampling was made. After counting number of tillers of all hills, six hills with an average number of tillers in each cutting spot were chosen for estimating yield and analyzing yield components.

Throughout the field monitoring period, the observed rice plants in each plot of the monitoring paddy field in the ADRIS area showed flourishing and similar growing condition with a total productive tillers of 25 to 45 for the dry season and 15 to 35 for the wet season. In the ARIS area, on the other hand, differences in crop management practices done by farmers and rice varieties used were reflected in the growing condition of observed rice plants. In general, observed rice plants selected near by the settling basin showed poor growing condition. Especially, if sand and silt flew into the main paddy fields passing through the settling basin, observed rice plants in the first plot showed delay in the early stage of growth compared with the crop growing condition of the second plots onward. The maximum number of tillers was 35 for the dry season paddy and 30 for wet season paddy, both of which were below the number of tillers of the rice plant observed in the ADRIS area.

According to the results of yield survey undertaken in the dry season, as shown

in Table V-4, paddy yields of the monitoring paddy fields in the ARIS area varied from 1.4 to 6.1 ton/ha with an average of 3.8 ton/ha. In the ADRIS area, the paddy yields were between 4.3 and 8.1 ton/ha with an average of 6.1 ton/ha. The average paddy yields of eight places in the ARIS area had the variation of 0.6 to 2.1 ton/ha at inlet portions and 2.4 to 4.0 ton/ha at outlet portions. The difference in yield suggests that rice plants grown at the inlet portion of paddy field is prohibited from normal elongation of root due to poor physical environment of root zone like compact sandy layer and poor aeration. The similar tendency is found in the results of yield survey of wet season paddy as shown in Table V-5. In the ADRIS area, the range of paddy yields was between 1.6 and 3.2 ton/ha and the average yield was 2.4 ton/ha. In the ARIS area, paddy yields varied from 2.4 to 5.2 tons/ha with an average of 3.2 ton/ha at the monitoring point near to the intake dam and ranged from 3.5 to 5.8 ton/ha having the average yield of 4.2 ton/ha at the downstream monitoring point. The results of yield survey at 18 places in the ARIS area indicated that the average paddy yields were between 2.2 and 3.2 ton/ha at inlet portions and from 2.5 to 4.2 ton/ha at outlet portions.
and 3.2 ton/ha at inlet portions and from 2.5 to 4.2 ton/ha at outlet portions.

Through the review of the results of laboratory tests, no correlation between nutrient uptake by rice plant and location of observed rice plants was found. There is a notable difference in uptaking copper by observed rice plants between the ARIS and ADRIS areas. Also, the uptaking of copper varies seasonally in the same monitoring paddy fields, namely more copper is absorbed by rice plants grown in the dry season compared with the copper contents of the wet season rice plant. Good correlation is found with respect to soluble copper contents of surface soils and uptake of copper by observed rice plant in the respective monitoring paddy fields in the ARIS area. As shown in Table V-6, the average copper concentration in a leaf of the dry season rice plant is 50 ppm in the ARIS area and 5 ppm in the ADRIS area, while that of the wet season rice plant is 40 ppm in the ARIS area and 5 ppm in the ADRIS area.

Among other heavy metals, it is well known that cadmium contained in brown rice affects adversely human beings. It was clarified through the laboratory tests that the cadmium concentration in brown rice harvested in the ARIS area was below 0.02 ppm on an average with the exceptional maximum of 0.04 ppm. This fact means that there is no harmful problem in quality of rice produced in the ARIS area from the viewpoint of human health.

3. Selection of Problem Heavy Metals

Throughout the field observation works and laboratory tests, it is pointed out that the main problem in the ARIS area is the inflow of sediments containing copper to some extent so far as irrigation water is diverted from the Agno River having the present level of water quality. As these sediments comprise coarse sands, however, most of sediments can be controlled by intruding river water into a settling basin. Hence decline in the inflow of sediments to paddy fields results in reduction of copper to be accumulated in paddy soils under the present situation.

The projected quality of released water from the proposed San Roque dam suggests that the future irrigation water will not contain coarse sediments like the present one and, on the contrary, will become rich in very fine suspended solid contents. It is considered that such a very fine suspended solid is hardly settled even though the water is at rest and also shows the same behaviour of water. Further, the projected water quality indicates the existence of copper in this very fine suspended solid to some extent.

In due consideration of the findings throughout the field observation and laboratory works as well as the projection of reservoir water quality in the future, copper is selected for the further evaluation study.

4. Assessment of Future Quality of Irrigation Water

4.1 Projected Water Quality

The new water resources to be developed by constructing the proposed San Roque dam will make it possible to supply irrigation water throughout the year to the proposed San Roque irrigation development area of 70,800 ha. The water to be impounded in the reservoir of the proposed San Roque dam will be released downstream through the power waterways and spillway to the Agno River. There is no tributaries flown in the main stream of the Agno River downstream from the proposed San Roque dam up to the existing ARIS intake dam to be reshaped and upgraded in the future. As all of water demanded for irrigating 70,800 ha are planned to be diverted from the existing ARIS intake dam site, the future quality of irrigation water can be considered to be same as the projected quality of released water from the proposed San Roque dam in the Study.

According to the projected water quality, dissolved copper concentration will range between 0.002 and 0.009 mg/l. In the future, all of sand and silt will be settled in the reservoir of the proposed San Roque dam, though these are directly transported by irrigation water to the ARIS area at present. In the future, however, a very fine suspended solid with a particle size of less than 5 μ will be discharged downstream with the outflow from the proposed San Roque dam. The results of projection indicate that suspended solid concentration of water released from the proposed San Roque dam will decline from 1,600 mg/l at present to 720 mg/l in the future. But, such a very fine suspended solid will not controlled by passing irrigation water through any type of settling basin and thus spreading to the whole service areas to be benefited under the proposed San Roque irrigation development. The future copper concentration of the suspended solid is projected to be 140 ppm as soluble copper and 520 ppm as extractable copper with a possibility of translocation from soils to rice plants.

4.2 Methodology of Evaluation

In comparison with the limit allowed over which dissolved copper concentration of irrigation water may affect harmfully rice plants in terms of physiological disorder of crop growth, projected level of dissolved copper concentration is low to a considerable extent. In the Study, therefore, the dissolved copper is considered as a kind of pollutant load to cummulative copper in soils. Thus, sources of pollutant load in the proposed San Roque irrigation development area consist of copper contained in the very fine suspended solid and dissolved copper of irrigation water.

The annual inflow of suspended solid dissolved copper to paddy fields can be calculated by multiplying the annual diversion water requirement by suspended solid concentration and dissolved copper concentration, respectively, of irrigation water. Then, by applying the copper contents of suspended solid, the annual copper load to the paddy field can be estimated.

As the suspended solid is very fine, it can be deemed that this suspended solid is carried away to some extent to drainage channels directly from canals or through paddy fields. Thus, the rate of remaining suspended solid on paddy fields is assumed to be 55% for paddy field and 50% of upland field against the total inflow of suspended solid. This assumption was made taking into consideration the irrigation efficiency given in the ELC Feasibility Report.

4.3 Irrigation Plan

According to the ELC Feasibility Report, a combination of reshaping and upgrading works of the existing ARIS intake dam is proposed to integrate irrigation water diversion from the Agno River for covering the total service area of 70,800 ha in the future. In addition to the ARIS and ADRIS areas, the proposed San Roque irrigation development area includes the existing LARIS area as well as the ARIS Extension area of which paddy fields have no irrigation water sources and facilities at present.

The future cropping patterns proposed in the ELC Feasibility Report comprise the following seven types; (a) double cropping of rice, (b) rice followed by cotton to be grown as the dry season crop, (c) rice followed by tobacco, (d) rice followed by one of cash crops like mongo, corn and peanuts, (e) rice followed by two crops of vegetables (f) triple cropping of vegetables and (g) perennial cropping of sugarcane. Based on the results of land capability classification study, the different cropping pattern is proposed for the respective components of San Roque irrigation development area as shown in Table V-7.

By referring to the unit irrigation water requirement employed in the ELC Feasibility Report and the results of hydrologic review in the Study, irrigation diversion requirements for each of seven proposed cropping patterns and four irrigation components were estimated on the basis of basin rainfall record for 21 years judged to be reliable.

4.4 Accumulation of Copper in Soils

As mentioned in the above, the following factors were obtained; namely, (1) irrigation diversion requirements for the ARIS, ADRIS, LARIS and ARIS Extention areas, (2) dissolved copper and suspended solid concentrations of irrigation water, (3) copper contents of suspended solid and (4) the accumulation ratio of suspended solid in paddy soils. On the basis of these factors, the annual copper load per 1 ha of paddy field is estimated for each of the four irrigation components.

The annual irrigation diversion requirements, as shown in Table V-8, vary to a little extent by the irrigation component which has the different proposed cropping pattern. As summarized in Table V-9, therefore, the annual copper load to paddy fields in each irrigation component is estimated to be 1,150 to 1,350 g/ha. Furthermore, in case that the future reservoir water quality is projected in the worst manner, the annual copper load is estimated to increase to 1,650 to 1,950 g/ha.

As pointed out, the very fine suspended solid is considered to spread over the whole irrigated paddy fields even though irrigation water passes through a settling basin. The copper contained in this suspended solid will have a largest share of the total copper load estimated in the above. Except for the outflow from paddy fields to drainage channels through the outlet, the suspended solid will remain after being transported to paddy fields. If the copper together with all of the remaining suspended solid is accumulated in surface paddy soils neglecting absorption by rice plants and loss by deep percolation of irrigated water, this accumulated copper will be mixed with the surface paddy soils by tillage done in the initial stage of every crop season. In case that tillage depth is assumed to be 15 cm, hence, soluble copper concentration of surface paddy soils will increase by around 0.8 ppm every year.

It is well known through the preceding findings in Japan, reduction of crop yield influenced by copper contained in soils will usually occur when the soluble copper concentration of surface soils exceeds a level of 125 ppm. Following this, the period of time approximately required for reaching the above limits allowed is estimated to be about 120 years for the ARIS area and around 160 years for other three irrigation components such as ADRIS, LARIS and ARIS Extention. If estimation is done taking into account the projected water quality in the worst manner, it will take about 75 years until the soluble copper concentration of soils in the ARIS area attains to 125 ppm.

Actually, a part of soluble copper in surface soils reachs subsurface soils by percolation of irrigation water. Also rice straws absorbing copper accumulated in surface soils to some extent are taken out from the paddy field after harvesting. Hence the copper contents of surface soils will become lower than the estimated level of accumulation and the period of time will also become longer than the aforementioned estimate.

5. Conclusion

Based on the ELC's Feasibility Study, it is projected that the released water from the proposed San Roque dam will have a large amount of very fine suspended solid containing copper if all of mine tailings are discharged to the Agno River system and impounded in the reservoir of the proposed San Roque dam. This water having such characteristics in water quality is provided to the proposed San Roque irrigation development area in the future. As a result, copper will accumulate in paddy soils to the whole beneficial areas through the spread of very fine suspended solid together with irrigation water. After 120 to 160 years, thus, copper concentration of soils will reach the limits allowed over which copper determines the cause of crop yield reduction. This estimated period exceeds over the project evaluation period of 50 years which is set up in the ELC's Feasibility Study.

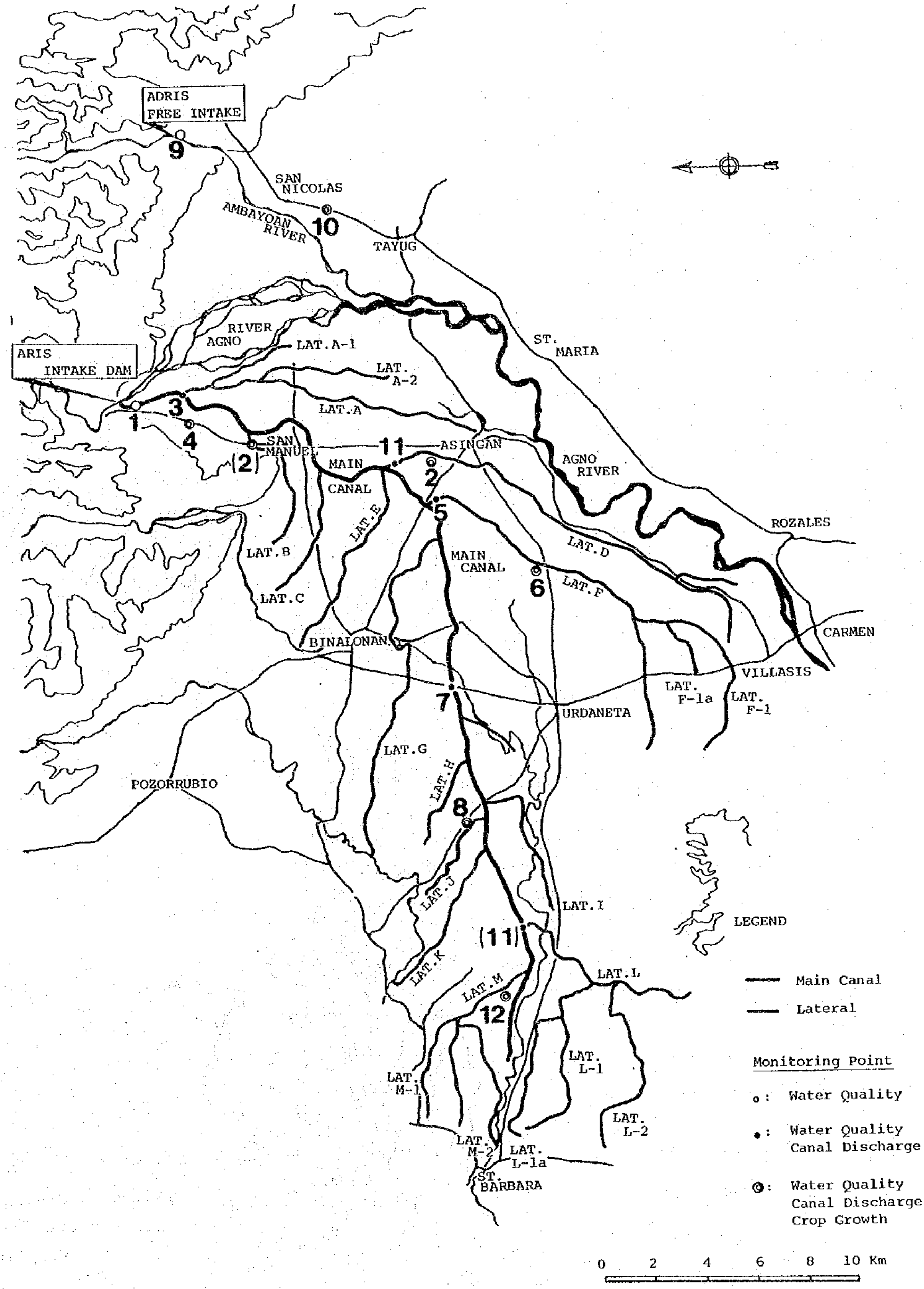

Fig. V-1 Location Map of Monitoring Points for Irrigation Water Quality

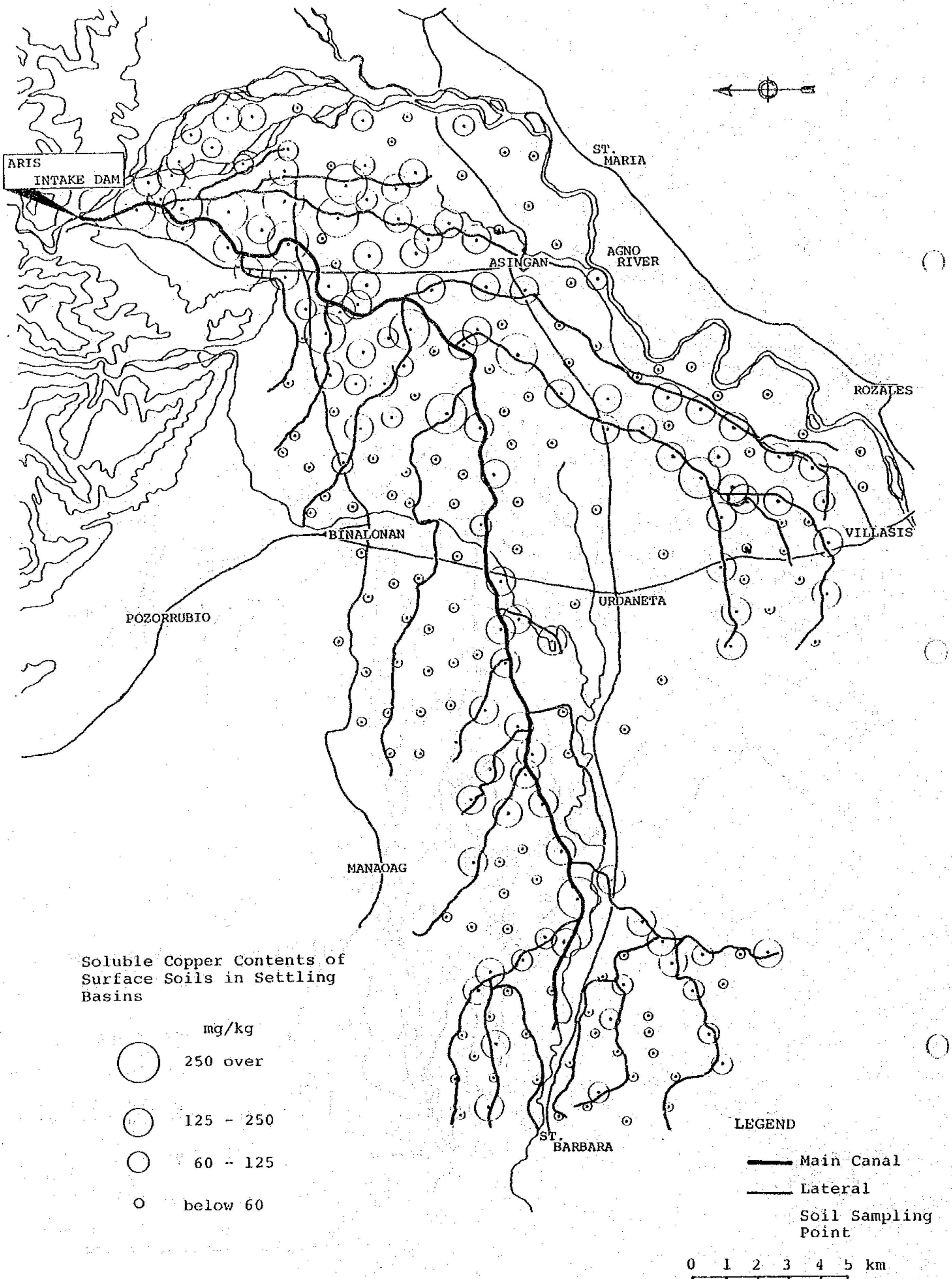

Fig. V-2 Soluble Copper Contents of Surface Soils in ARIS

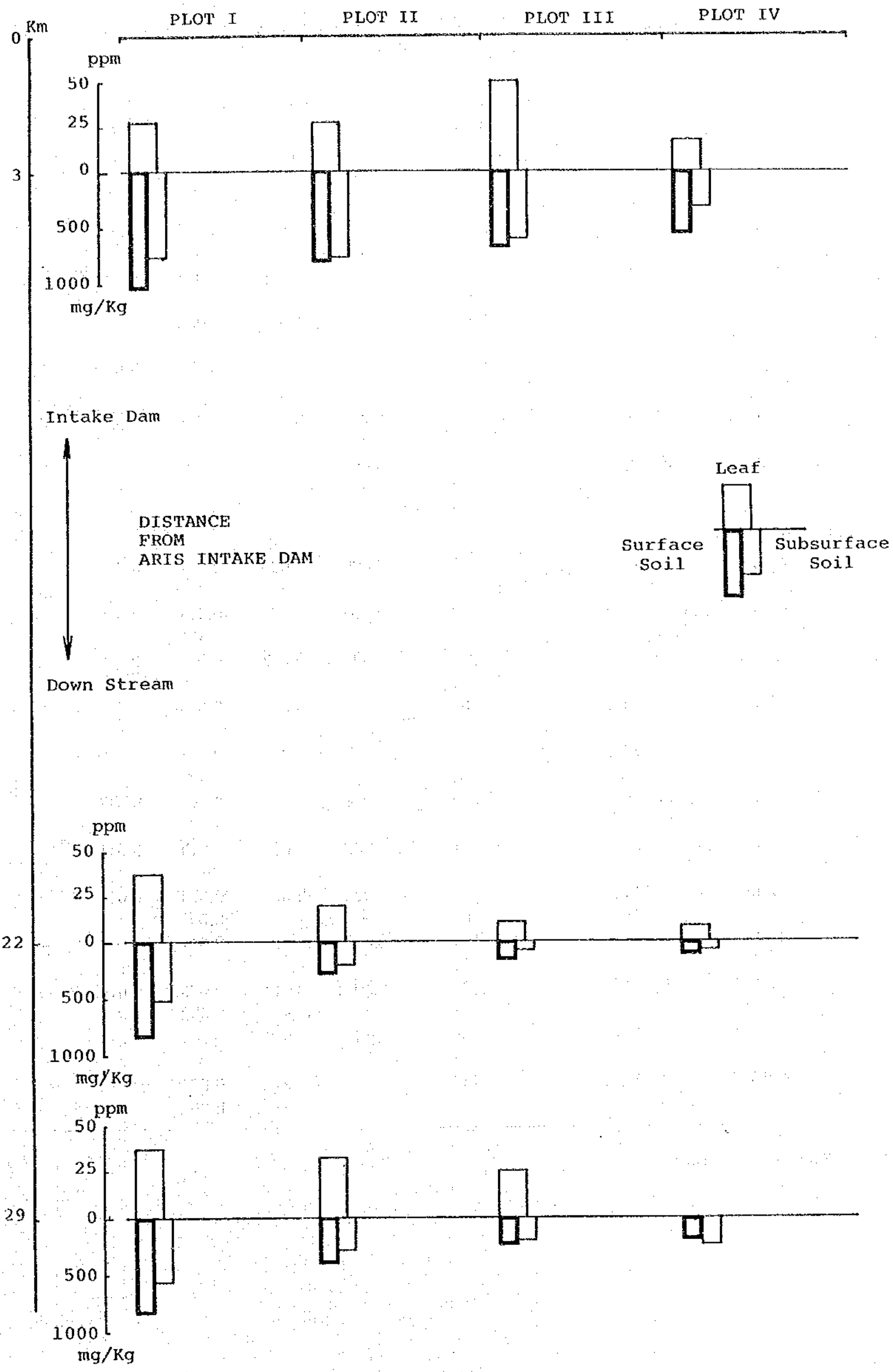

Fig. V-3 Horizontal Distribution of Copper Concentration of Rice Plant Leaf and Soluble Copper Contents of Paddy Soils

Table V-1 SUMMARIZED RESULTS OF LABORATORY TESTS ON DRY AND WET SEASON WATER SAMPLES

Unit: mg/l

Monitoring Point	Suspended Solid	Dissolved Heavy Metals				
		Cu	Pb	Zn	Cd	As
(1) Dry Season						
ARIS No. 1 Max.	2,150	0.015	0.020	0.065	0.004	+
	222	+	+	+	+	+
ARIS No. 2 Max.	425	0.013	0.019	0.025	0.003	0.024
	154	+	+	+	+	+
ARIS No. 3 Max.	1,130	0.015	0.020	0.048	0.003	0.016
	145	+	+	+	+	+
ARIS No. 4 Max.	1,970	0.014	0.022	0.007	0.003	0.016
	228	+	+	+	+	+
ADRIS No. 9 Max.	523	0.005	0.030	0.007	0.003	0.016
	2	+	+	+	+	+
ADRIS No. 10 Max.	63	0.005	0.026	0.009	+	+
	11	+	+	+	+	+
(2) Wet Season						
ARIS No. 1 Max.	8,317	0.009	0.020	0.034	0.010	—
	53	+	+	+	+	—
ARIS No. 2 Max.	3,084	0.019	0.020	0.013	0.008	—
	175	+	+	+	+	—
ARIS No. 3 Max.	2,295	0.008	0.038	0.024	0.010	—
	42	+	+	+	+	—
ARIS No. 4 Max.	2,680	0.014	0.037	0.024	0.010	—
	39	+	+	+	+	—
ARIS No. 5 Max.	5,568	0.009	0.020	0.023	0.010	—
	60	+	+	+	+	—
ARIS No. 6 Max.	1,696	0.010	0.012	0.015	0.011	—
	84	+	+	0.001	+	—
ARIS No. 7 Max.	3,581	0.009	0.018	0.019	0.011	—
	143	+	+	+	+	—
ARIS No. 8 Max.	1,568	0.026	0.026	0.024	0.011	—
	65	+	+	0.001	+	—
ARIS No. 11 Max.	2,547	0.009	0.018	0.014	0.010	—
	11	+	+	+	+	—
ARIS No. 12 Max.	2,372	0.005	0.015	0.015	0.010	—
	171	+	+	0.002	+	—
ADRIS No. 9 Max.	748	0.007	0.013	0.011	0.011	—
	3	+	+	+	+	—
ADRIS No. 10 Max.	459	+	+	0.019	0.012	—
	9	+	+	0.001	+	—

Remarks; + : Trace

Table V-2 COMPARISON OF EXTRACTABLE COPPER CONTENTS IN SOILS

Unit: mg/kg dry soil

Pit No.	Present Land Use Condition	Soil Layer				
		I	II	III	IV	V
7	Gentle slope of hill in ARIS fallow land	29.6	33.4	60.9	56.8	—
4	Irrigated paddy field in ARIS	474.0	571.2	83.0	31.2	30.6
1	Rainfed paddy field in upstream of ARIS	45.2	72.1	65.2	39.8	57.6
5	Rainfed paddy field in downstream of ARIS	102.8	83.8	74.8	71.6	63.5
6	Rainfed paddy field in ARIS Extension	46.4	55.2	54.6	61.0	40.0
10	Irrigated paddy field in ADRIS	38.2	34.2	38.2	41.9	44.2

Table V-3 VARIATION OF SOLUBLE HEAVY METAL CONTENTS OF PADDY SOILS TAKEN AT INLET PORTION OF OR SETTLING BASIN IN PADDY FIELDS OF ARIS

Unit: mg/kg dry soil

Location	No. of Samples	Soluble Heavy Metal				
		Cu	Pb	Zn	Cd	As
Along Main Canal	22					
Maximum		287.4	13.2	36.6	0.5	22.3
Minimum		23.1	1.3	3.4	0.1*	0.9
Along Laterals A to E	84					
Maximum		352.2	6.6	42.6	0.5	92.0
Minimum		6.7	0.3*	0.9	0.1*	0.3
Along lateral F	36					
Maximum		281.4	9.0	31.9	0.6	8.4
Minimum		6.6	0.3*	2.2	0.1*	0.3
Along laterals G to K	48					
Maximum		285.5	4.7	32.8	0.2	7.6
Minimum		0.1	0.3*	0.1*	0.1*	0.6
Along Laterals L and M	50					
Maximum		156.7	8.3	27.8	0.4	9.6
Minimum		0.7	1.0	0.5	0.1*	0.5

Remarks; 0.3* : Below 0.3 mg/kg dry soil
0.1* : Below 0.1 mg/kg dry soil

Table V-4 RESULTS OF YIELD SURVEY FOR DRY SEASON CROP IN ARIS AND ADRIS

Monitoring No.	No. of Panicles per Hill	No. of Grains per Panicle	Percent of Ripened Grains (%)	Weight of 1,000 Grains (g)	Weight of 1,000 Ripened Grains (g)	Average Unit Yield (ton/ha)
ARIS No. 2	15.2	50.2	70.6	16.0	20.2	3.3
ARIS No. 4	17.5	86.6	61.7	16.1	22.3	4.5
ADRIS No. 10	25.4	70.4	60.9	16.2	22.3	6.1
ADRIS 8 spots						
Inlet	12.3	49.7	57.5	15.9	22.6	2.1
Outlet	16.1	61.3	65.1	18.3	23.4	3.3

Table V-5 RESULTS OF YIELD SURVEY FOR WET SEASON CROP IN ARIS AND ADRIS

Monitoring No.	No. of Panicles per Hill	No. of Grains per Panicle	Percent of Ripened Grains (%)	Weight of 1,000 Grains (g)	Weight of 1,000 Ripened Grains (g)	Average Unit Yield (ton/ha)
ARIS No. 2	15.7	50.1	78.7	21.5	25.5	4.2
ARIS No. 4	18.5	62.2	75.1	17.7	21.1	3.9
ARIS No. 6	11.9	80.2	60.0	17.4	24.2	3.2
ARIS No. 8	14.8	96.2	67.6	15.6	19.9	4.1
ARIS No. 12	10.8	84.7	79.0	13.0	20.8	4.8
ADRIS No. 10	23.0	49.0	43.0	17.8	20.5	2.4
ARIS 18 spots						
Inlet	14.4	54.6	70.6	18.3	21.6	3.1
Outlet	16.5	60.9	75.5	19.1	23.1	4.1

Table V-6 **COPPER CONCENTRATION OF LEAF OF RICE PLANT INA RIS AND ADRIS**

Unit: ppm

Monitoring Point No.	Planting Season	Plot No.					
		I'	II'	I	II	III	IV
ARIS No. 2	Dry	50.5	170.5	75.5	33.8	35.8	23.3
	Wet	—	—	49.4	10.8	12.1	13.9
ARIS No. 4	Dry	—	—	26.5	94.8	26.0	17.5
	Wet	—	—	28.7	27.5	48.8	17.8
ARIS No. 6	Wet	—	—	36.4	19.5	10.9	8.6
ARIS No. 8	Wet	—	—	36.6	32.6	26.1	—
ARIS No.12	Wet	—	—	9.6	9.8	10.8	17.2
ADRIS No.10	Dry	—	—	5.3	7.8	3.8	3.5
	Wet	—	—	8.0	5.3	7.1	6.1

Table V-7 **PROPOSED CROPPING PATTERN BY SYSTEM UNDER SAN ROQUE MULTIPURPOSE PROJECT**

Cropping Pattern	ARIS		ARIS Extension		ADRIS		LARIS	
	%	ha	%	ha	%	ha	%	ha
1. Paddy/Paddy	47	12,620	35	8,300	25	1,900	36	4,550
2. Paddy/Tabacco	8	2,150	9	2,130	19	1,440	18	2,280
3. Paddy/Cotton	16	4,300	28	6,640	21	1,600	12	2,660
4. Paddy/Corn	17	4,560	17	4,030	17	1,300	17	2,150
5. Paddy/Vegetables (2 crops)	3	800	5	1,180	14	1,060	3	380
6. Vegetables (3 crops)	1	270	1	240	4	300	1	130
7. Sugarcane	8	2,150	5	1,180	—	—	4	500
Total	100	26,850	100	23,700	100	7,600	100	12,650

Table V-8 AVERAGE MONTHLY IRRIGATION DIVERSION REQUIREMENT

Unit: m³/ha

Month	ARIS	ARIS Extension	ADRIS	LARIS
January	4,087	3,814	3,303	3,808
February	3,386	3,317	3,032	3,333
March	2,136	2,094	2,011	2,109
April	715	648	668	621
May	388	310	291	254
June	1,527	1,568	1,416	1,539
July	1,548	1,662	1,569	1,673
August	1,054	1,035	958	1,083
September	577	577	534	609
October	444	464	470	486
November	1,052	818	597	803
December	2,283	1,993	1,609	1,982
Annual	19,199	18,302	16,458	18,300

Table V-9 AVERAGE MONTHLY ACCUMULATION OF SOLUBLE COPPER ON PADDY FIELD

Unit: g/ha

Month	ARIS		ARIS-Extension		ADRIS		LARIS	
	Normal Case	Worst Case	Normal Case	Worst Case	Normal Case	Worst Case	Normal Case	Worst Case
Jan.	226	317	211	295	183	255	211	295
Feb.	178	281	175	275	160	252	175	277
Mar.	145	286	142	280	136	268	143	281
Apr.	140	162	126	147	130	151	121	141
May	46	72	37	58	35	54	30	48
June	141	219	145	225	131	203	142	218
July	142	168	152	180	144	170	153	181
Aug.	77	83	75	83	70	77	79	85
Sept.	17	38	17	39	16	36	18	40
Oct.	17	24	18	24	18	25	18	27
Nov.	62	78	48	59	35	43	48	60
Dec.	159	193	139	167	112	135	138	167
Annual	1,350	1,921	1,286	1,832	1,169	1,670	1,277	1,819

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