SECTOR D

TABLES

Table 2.1-1 Relation between Cost and Effectiveness (Sewage System)

Area	Effectiveness (ton/day)	Cost (Mill. US$)	Unit Cost (Mill. US$/ton/day)	Economic Priority
El Consejo	0.01	0.57	59.0	6
Las Tejerias	0.02	0.75	37.5	5
Cúa	0.27	3.08	11.4	4
Charallave	0.21	2.28	10.1	3
Ocumare del Tuy	2.71	2.13	0.79	1
S. F. de Yare	0.55	0.48	0.87	2
El Consejo	2.30*	0.57	0.24	2
Las Tejerias	4.07*	0.75	0.18	1

* Effectiveness to Boca de Cagua

Table 3.2-1 Existing Pipes in Ocumare Urban Area

Diameter (mm)	Length (m)	Remarks
Secondary	(52,650)	
457	2,000	ϕ 18 inch
508	43,900	ϕ 20 inch
635	6,750	ϕ 25 inch
Main	(10,100)	
762	2,525	ϕ 30 inch
965	4,275	ϕ 38 inch
1168	750	ϕ 46 inch
1346	1,950	ϕ 53 inch
1753	600	ϕ 69 inch
Total	62,750	

Table 3.2-2 Density of Existing Secondary Pipes in Ocumare Urban Area

Area	Length (m)				Area (ha)	Density (m/ha)
	ϕ 475	ϕ 508	ϕ 635	Total		
A	0	3,375	700	4,075	38.2	107
B	0	2,850	525	3,375	24.1	140
C	0	17,125	3,025	20,150	161.4	125
D	2,000	20,550	2,500	25,050	356.0	70
Total	2,000	43,900	6,750	52,650	580.0	91

Table 3.3-1 Wastewater Discharge Per Capita and Number of Employees by Industrial Category

CIIU	Category	Per Capita Discharge	No. of Employees				
			1995	2000	2003	2005	2010
31100	Nourishing product factory except soft drinks	2.01	0	0	0	0	0
31111	Slaughtering cattle, pigs, sheep, horses and rabbits	2.01	0	0	0	0	0
31112	Farms of chicken and other animals except domestic animals	2.01	0	0	0	0	0
31113	Preparation and manufacture of meat	2.01	0	0	0	0	0
31121	Milk pasteurization and bottling	2.01	0	0	0	0	0
31173	Biscuits, shortcake and noodles	2.01	0	0	0	0	0
31221	Production of animal food	2.01	0	0	0	0	0
31311	Distillation, rectify and blend of alcohol	0.97	440	590	724	814	1,153
31341	Production of soft drinks	0.97	0	0	0	0	0
31342	Bottling and gasification of natural mineral water	0.97	0	0	0	0	0
32111	Preparation of textile	2.43	0	0	0	0	0
32112	Spinning, weaving and finishing of wool and mixed fibers	2.43	0	0	0	0	0
32113	Spinning, weaving and finishing of cotton, artificial and mixed fibers	2.43	54	64	73	78	101
32311	Tannery and repair of leather	1.43	0	0	0	0	0
32321	Industry to prepare tanning leather	1.43	0	0	0	0	0
35131	Synthetic resins, plastic materials and artificial fibers	2.50	0	0	0	0	0
35135	Synthetic resins, plastic materials and artificial fibers except glass	2.50	103	124	144	156	205
35211	Manufacturing of paint, varnishes and shellac	0.09	0	0	0	0	0
35231	Manufacture of soap and cleaning products	0.09	0	0	0	0	0
35234	Manufacture of perfumes and cosmetics	0.09	0	0	0	0	0
35291	Manufacture of various chemical products	0.92	67	85	101	111	152
35292	Adhesives, alus, priming for clothes	0.92	0	0	0	0	0
35295	Manufacture of adhesive materials, glue, gelatin and gum	0.92	0	0	0	0	0
36200	Mud, porcelain stuff factory	0.45	0	0	0	0	0
36201	Production of glass and glass fiber	0.67	0	0	0	0	0
3699	Manufacture of other non- metallic products	0.99	178	204	228	244	304
37102	Manufacture of iron and steel without pig metal and without rolling	0.26	0	0	0	0	0
37201	Basic industry of aluminum	1.44	0	0	0	0	0
38191	Manufacture of metallic products, not specified, except machinery	0.26	0	0	0	0	0
38193	Factory of nickel plate	0.26	78	93	106	114	147
38431	Car (automobile) factory	0.24	0	0	0	0	0
38433	Automobile spare parts factory	0.24	0	0	0	0	0
	Total	-	920	1,160	1,375	1,518	2,061

Table 3.3-2 Wastewater Discharge Per Capita in Various Studies

No.	Target Year	Wastewater Discharge per Capita	Reference
A	2010	250 ltr/day)	Plan Rector para la Cuenca Alta y Media del Río Tuy (1995, Michael Schlegel)
B	2010	272 ltr/day	Analisis de Sensibilidad para el Modelaje de Calidad de Agua (RIOS) del Río Tuy
C	1995	By a coefficient of return of 0.8 - • Ocumare del Tuy 298×0.8=238.4 ltr/day • Las Tejerías 258×0.8=206.4 ltr/day	Actualizacion de Proyectos de Inversion Ambiental en la Cuenca del Río Tuy y su Area de Influencia (1994, Efren Guedez)
	2010	By a coefficient of return of 0.8 - • Ocumare del Tuy 528.9×0.8=476.0 ltr/day • Las Tejerías 461.6×0.8=369.3 ltr/day	

Table 3.4-1 Main Drainage Pipes

No.	Length (m)	Diameter (mm)	Remarks
1	4,650	381~1067	Right Bank (Ocumare)
2	1,750	457	-do-
3	1,750	381~457	-do-
4	1,950	457	-do-
5	750	457	-do-
6	9,000	381~533	-do-
7	500	305	-do-
8	2,500	381~610	-do-
9	2,250	381~457	-do-
10	6,080	305~1067	Left Bank (Santa Barbara)
11	2,100	305	-do-
12	6,625	457~762	Left Bank (Piloncito)
13	2,000	381	-do-

Table 3.4-2 Secondary Drainage Pipes (ϕ400 mm)

Land Use	Area (ha)	Density (m/ha)	Length (m)
Commercial District	63	70	4,410
Residential District	696	60	41,760
New Residential District	1,650	40	66,000
Industrial District	576	120	69,120
Total	2,985	-	181,290

Table 4.2-1 Existing Pipes in Las Tejerías

Diameter (mm)	Length (m)	Remarks
200	10,980	
300	1,700	

Table 4.2-2 Density of Existing Secondary Pipes in Las Tejerías

Area	Length (m)	Area (ha)	Density (m/ha)
	ϕ 200		
A	2,250	14.0	161
B	2,050	12.0	171
Total	4,300	26.0	165

Table 4.3-1 Wastewater Discharge Per Capita and Number of Employees by Industrial Category

CIIU	Category	Per Capita Discharge	No. of Employees				
			1995	2000	2003	2005	2010
31100	Nourishing product factory except soft drinks	2.01	0	0	0	0	0
31111	Slaughtering cattle, pigs, sheep, horses and rabbits	2.01	45	56	66	73	99
31112	Farms of chicken and other animals except domestic animals	2.01	0	0	0	0	0
31113	Preparation and manufacture of meat	2.01	259	324	382	320	567
31121	Milk pasteurization and bottling	2.01	0	0	0	0	0
31173	Biscuits, shortcake and noodles	2.01	0	0	0	0	0
31221	Production of animal food	2.01	39	49	57	63	85
31311	Distillation, rectify and blend of alcohol	0.97	0	0	0	0	0
31341	Production of soft drinks	0.97	0	0	0	0	0
31342	Bottling and gasification of natural mineral water	0.97	0	0	0	0	0
32111	Preparation of textile	2.43	253	299	340	367	471
32112	Spinning, weaving and finishing of wool and mixed fibers	2.43	0	0	0	0	0
32113	Spinning, weaving and finishing of cotton, artificial and mixed fibers	2.43	606	716	814	880	1,129
32311	Tannery and repair of leather	1.43	0	0	0	0	0
32321	Industry to prepare tanning leather	1.43	0	0	0	0	0
35131	Synthetic resins, plastic materials and artificial fibers	2.50	0	0	0	0	0
35135	Synthetic resins, plastic materials and artificial fibers except glass	2.50	146	176	204	222	291
35211	Manufacturing of paint, varnishes and shellac	0.09	11	15	19	22	32
35231	Manufacture of soap and cleaning products	0.09	0	0	0	0	0
35234	Manufacture of perfumes and cosmetics	0.09	9	13	16	18	26
35291	Manufacture of various chemical products	0.92	100	127	150	166	226
35292	Adhesives, alus, priming for clothes	0.92	0	0	0	0	0
35295	Manufacture of adhesive materials, glue, gelatin and gum	0.92	0	0	0	0	0
36200	Mud, porcelain stuff factory	0.45	0	0	0	0	0
36201	Production of glass and glass fiber	0.67	0	0	0	0	0
3699	Manufacture of other non- metallic products	0.99	0	0	0	0	0
37102	Manufacture of iron and steel without pig metal and without rolling	0.26	0	0	0	0	0
37201	Basic industry of aluminum	1.44	0	0	0	0	0
38191	Manufacture of metallic products, not specified, except machinery	0.26	205	243	277	300	387
38193	Factory of nickel plate	0.26	356	422	482	521	671
38431	Car (automobile) factory	0.24	412	541	656	733	1,025
38433	Automobile spare parts factory	0.24	0	0	0	0	0
	Total	-	2,441	2,981	3,465	3,787	5,011

Table 4.4-1 Main Drainage Pipes

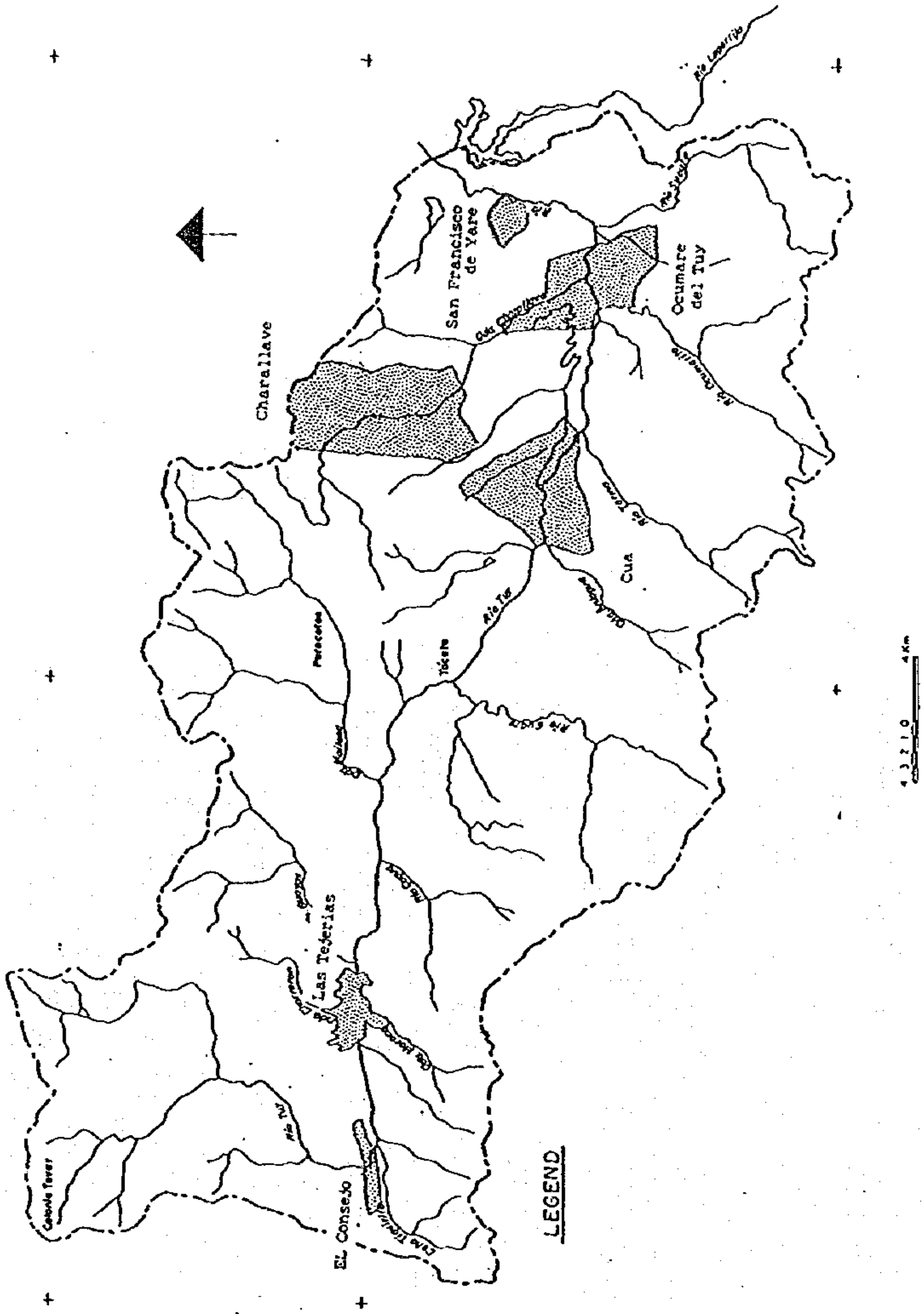
No.	Length (m)	Diameter (mm)	Remarks
1	3,325	450~800	Main (West)
2	800	300~450	Main (East)
3	700	300	Santo Domingo
4	400	200	Tinapuey
5	700	200	Canada
6	1,500	450	Barrio Beisboll
7	920	300	Mamon
8	750	300	Jabillos
9	2,545	350~600	Qda. Morocopo
10	750	300	
11	1,500	400~500	Zona Industrial
12	2,000	400~500	-do-

Table 4.4-2 Secondary Drainage Pipes (ϕ400 mm)

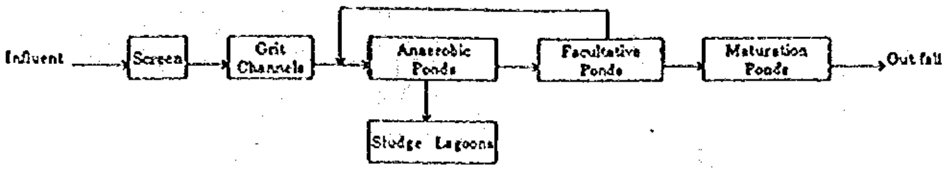
Land Use	Area (ha)	Density (m/ha)	Length (m)
Commercial District	35	85	2,975
Residential District	189	80	15,120
New Residential District	89	100	8,900
Industrial District	103	160	16,480
Total	416	-	43,475

SECTOR D

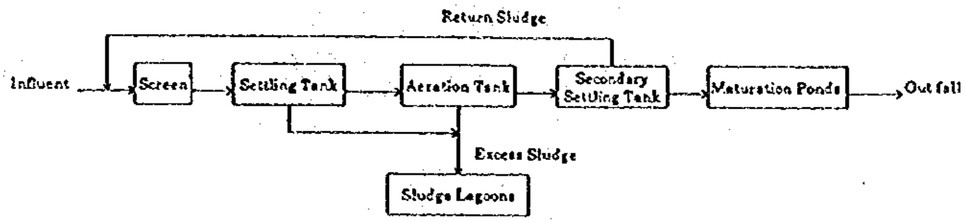
FIGURES



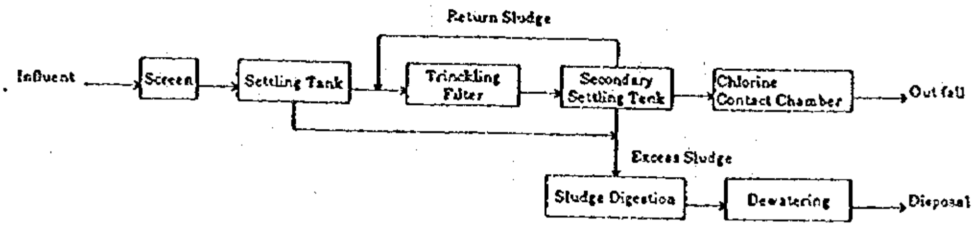
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.2.1-1
JAPAN INTERNATIONAL COOPERATION AGENCY	Area Covered by Public Sewage System



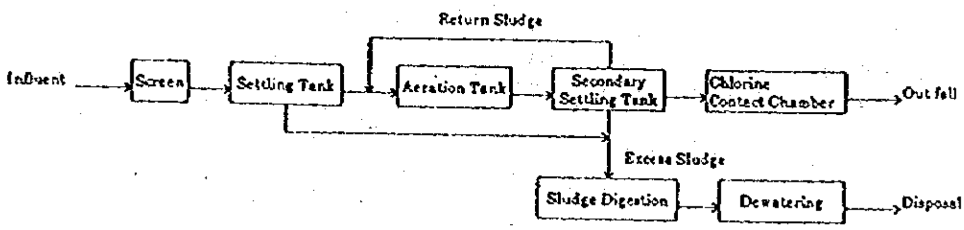
Flow sheet of Stabilization Pond System



Flow sheet of Simplified Activate Sludge Process



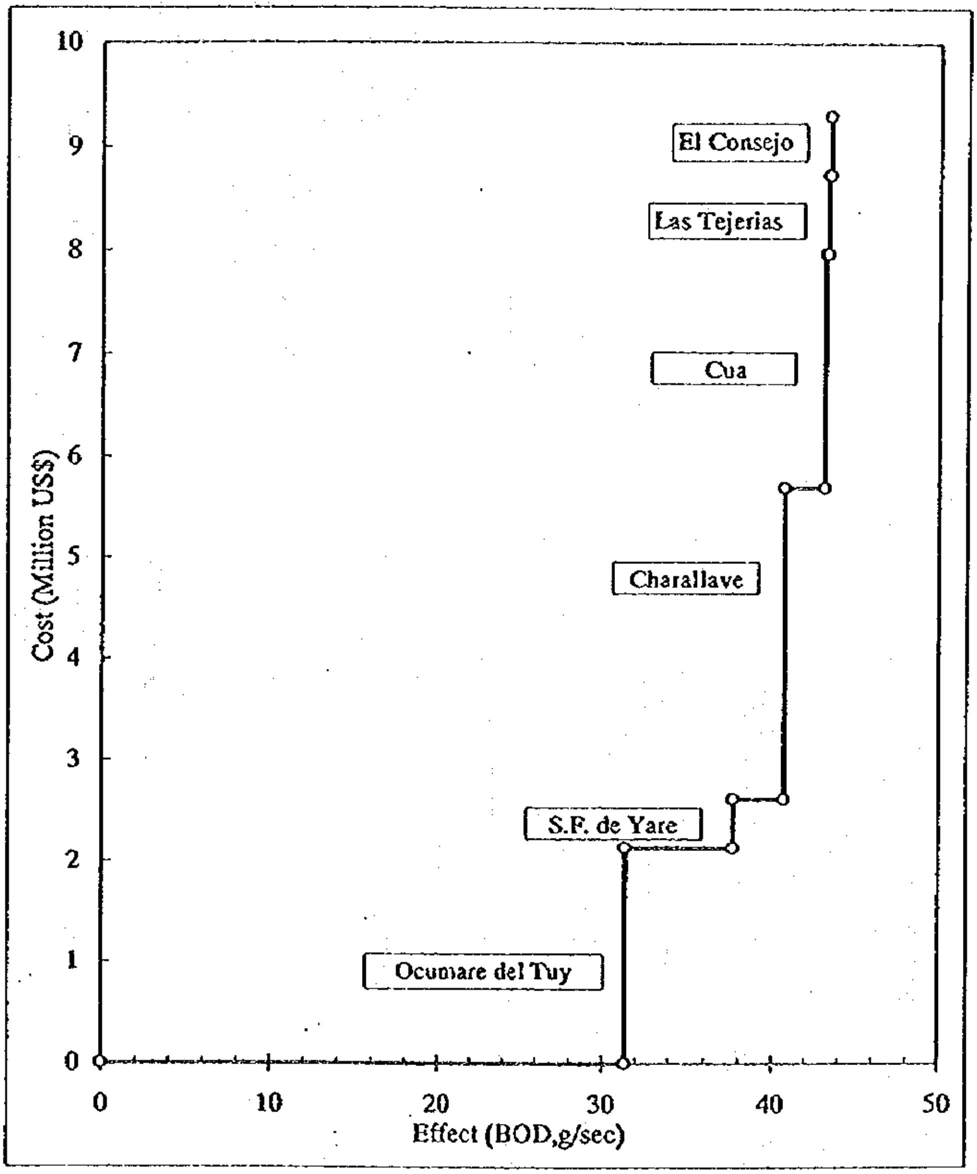
Flow sheet of Trickling Filter Process



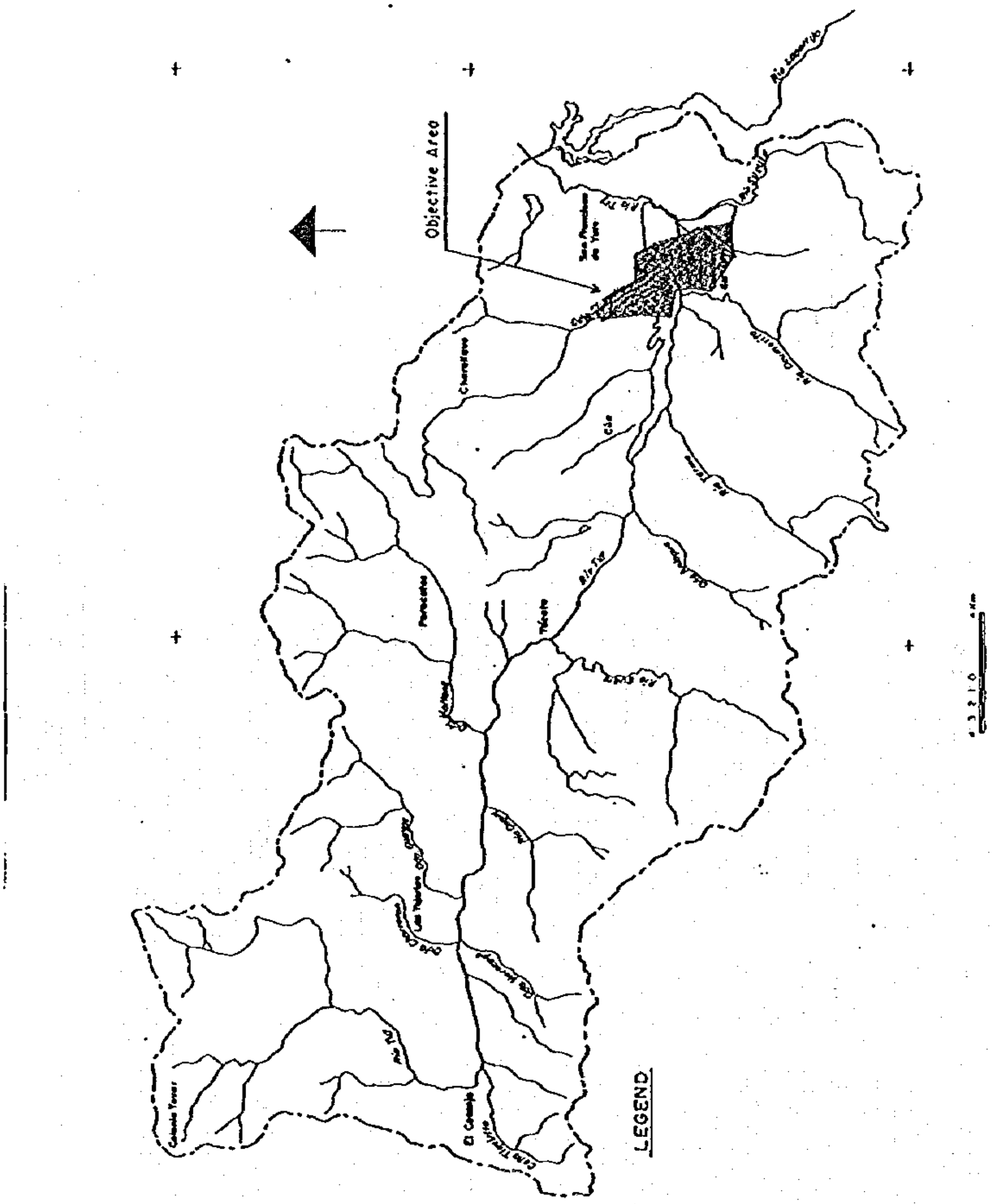
Flow sheet of Conventional Activated Sludge Process

THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.2.1-2 Flow Sheet of Sewage Treatment Process
JAPAN INTERNATIONAL COOPERATION AGENCY	

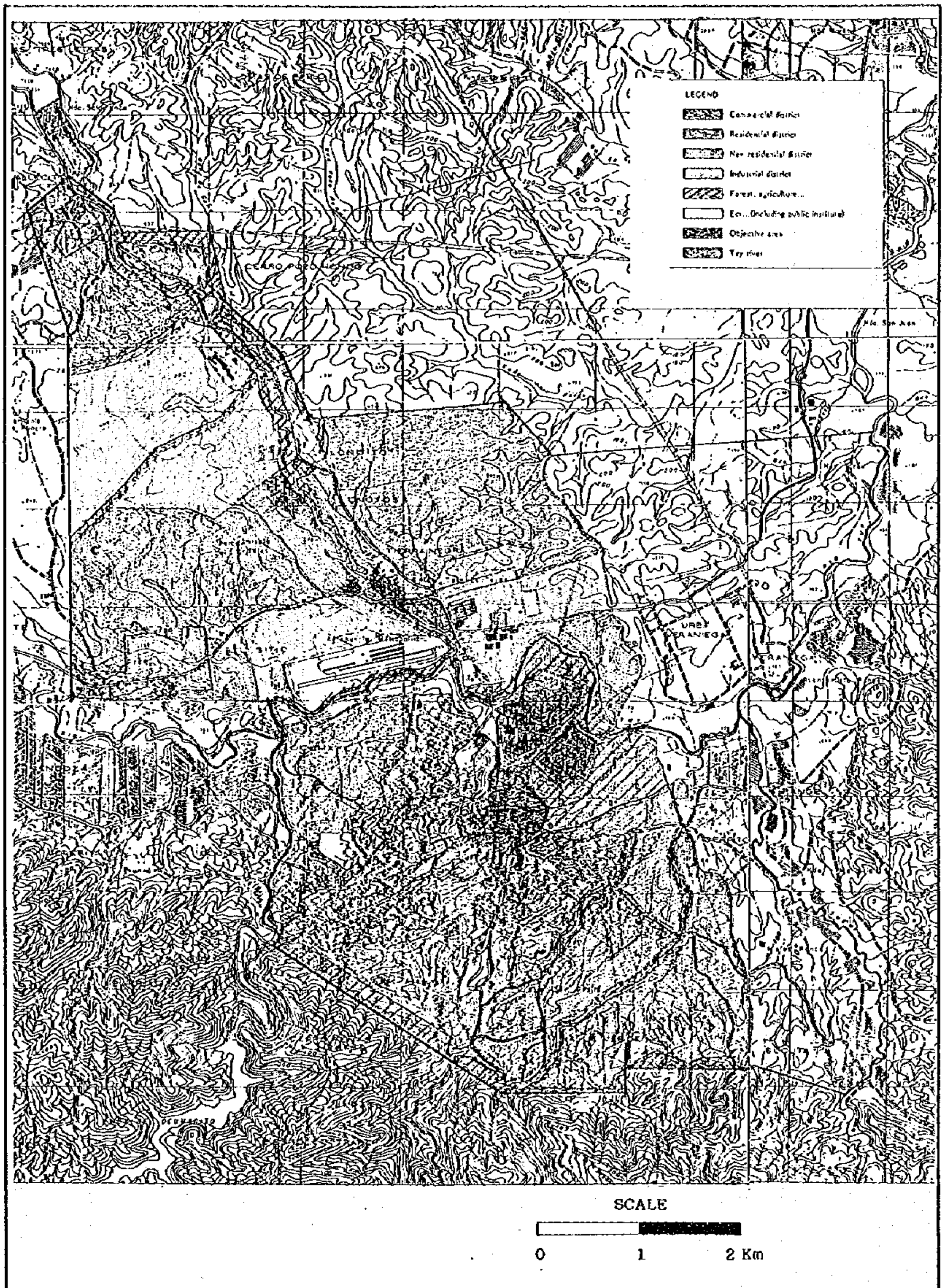
Sewer: Effect and Cost



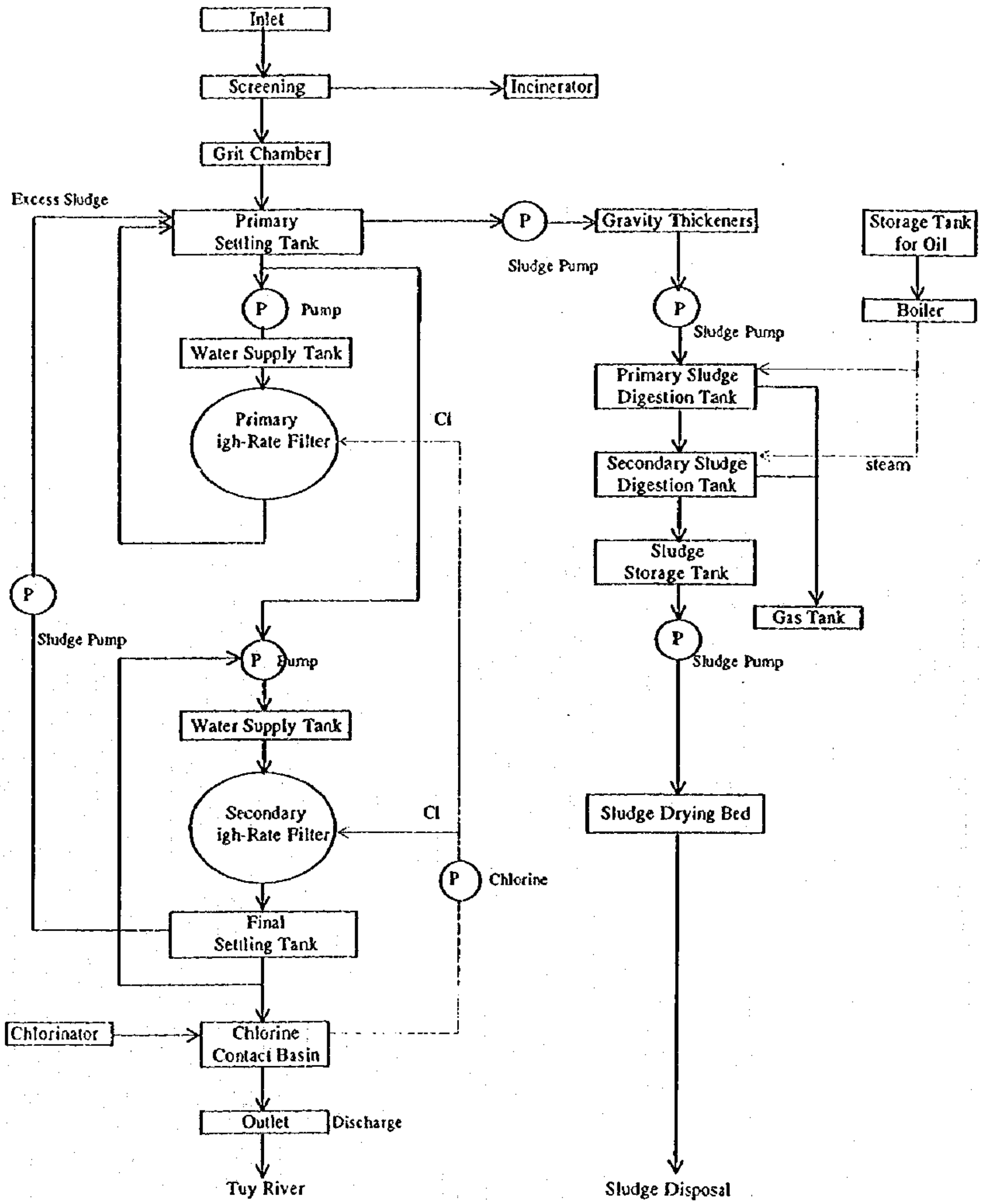
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.2.1-3 Effect and Cost of Wastewater Treatment by Sewage System
JAPAN INTERNATIONAL COOPERATION AGENCY	



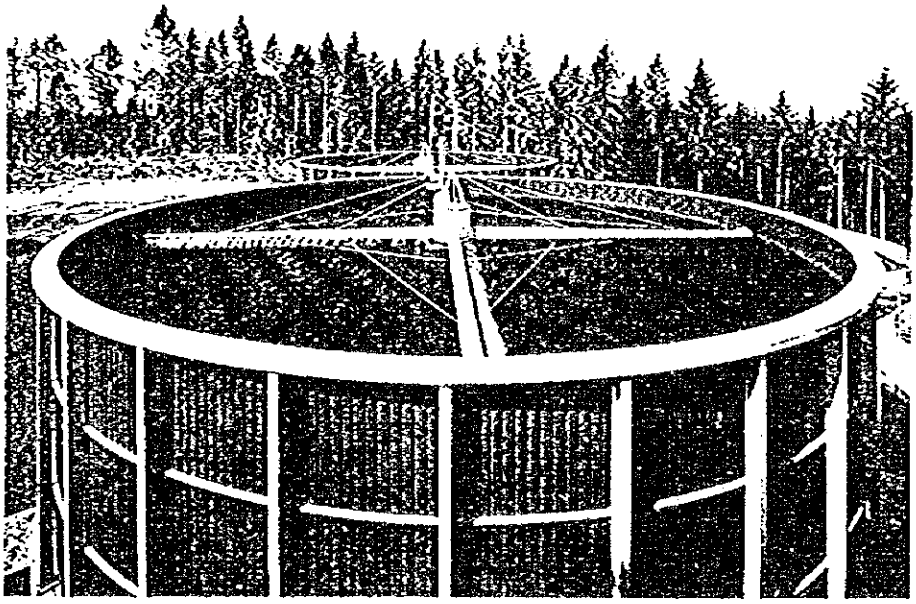
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.3.1-1 Location Map of Ocumare del Tuy Sewage System
JAPAN INTERNATIONAL COOPERATION AGENCY	

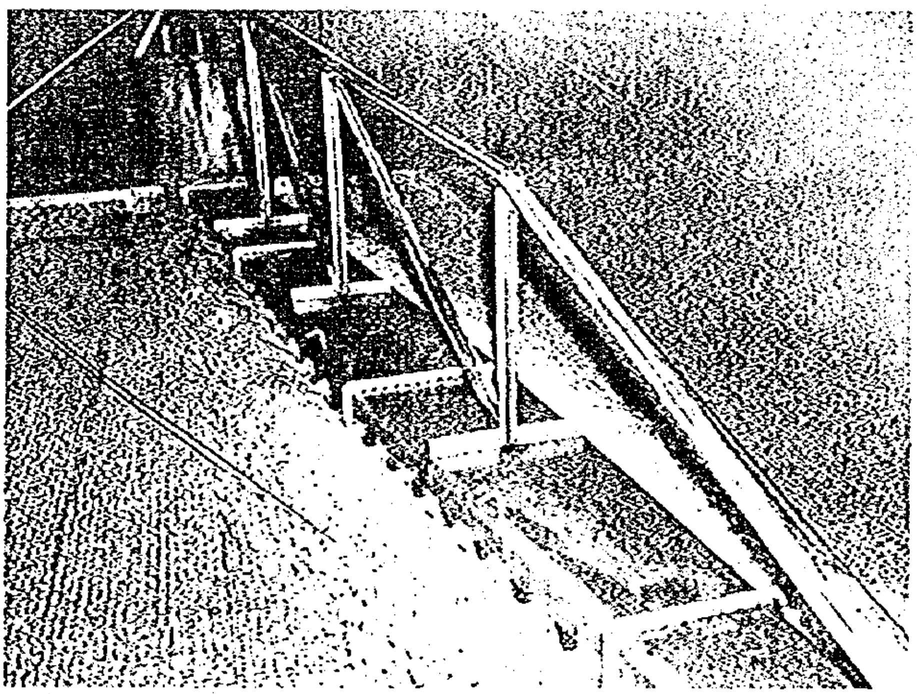


THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 3.2-1 Land Use Map in Future
JAPAN INTERNATIONAL COOPERATION AGENCY	

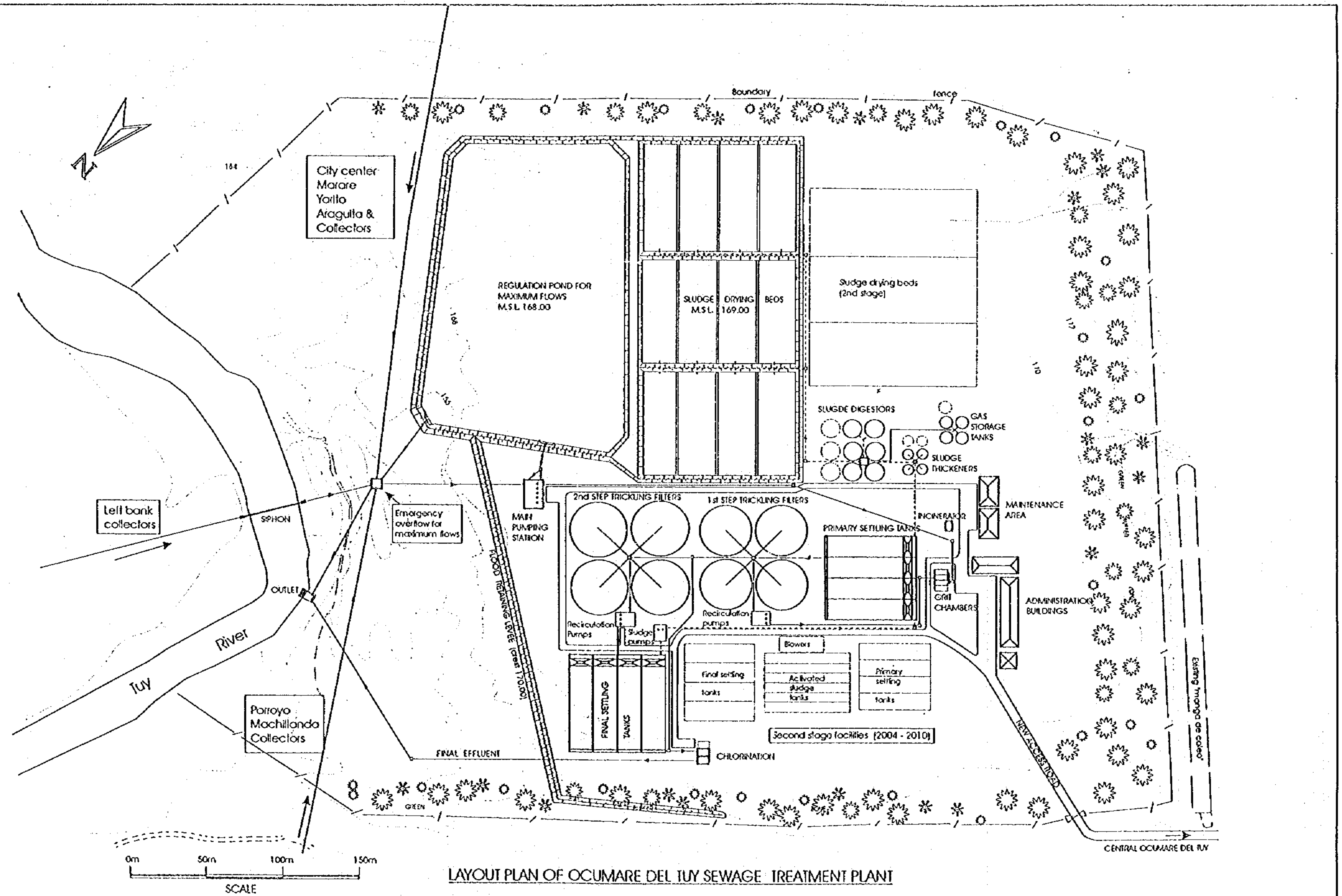


THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.3.4-1
JAPAN INTERNATIONAL COOPERATION AGENCY	Flowchart of Trickling Filter Method

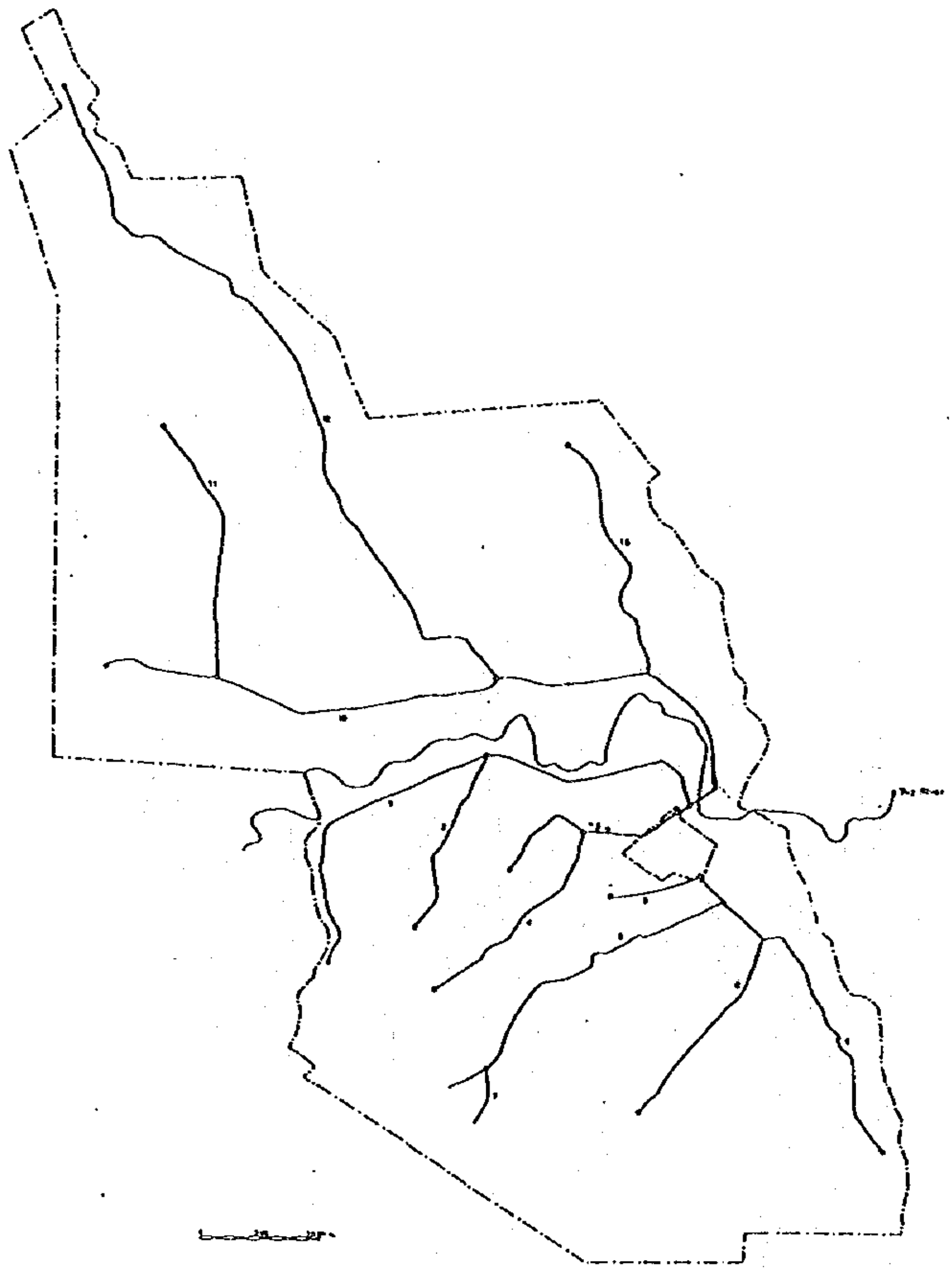




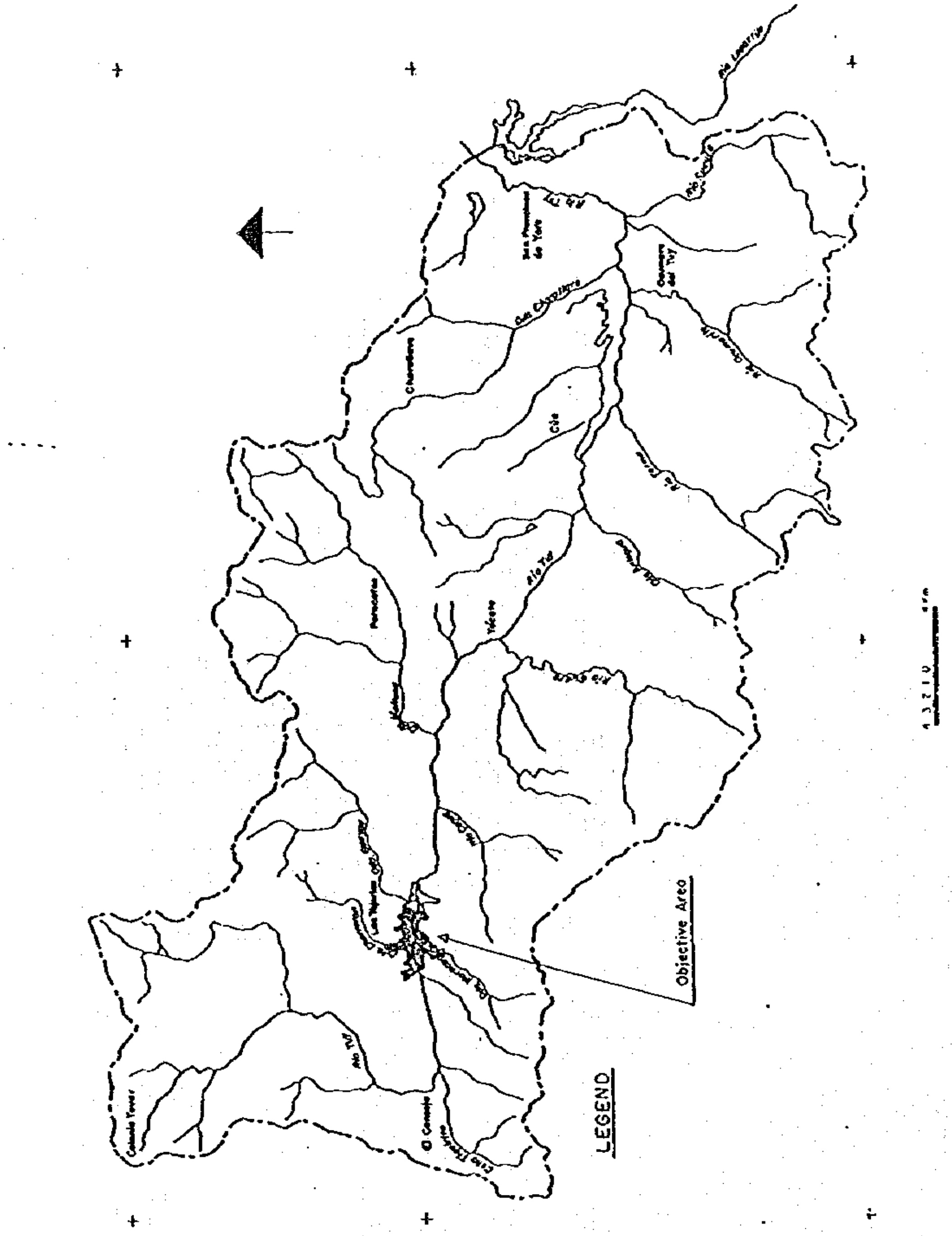
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.3.4-2 Examples of Trickling Filter Method
JAPAN INTERNATIONAL COOPERATION AGENCY	



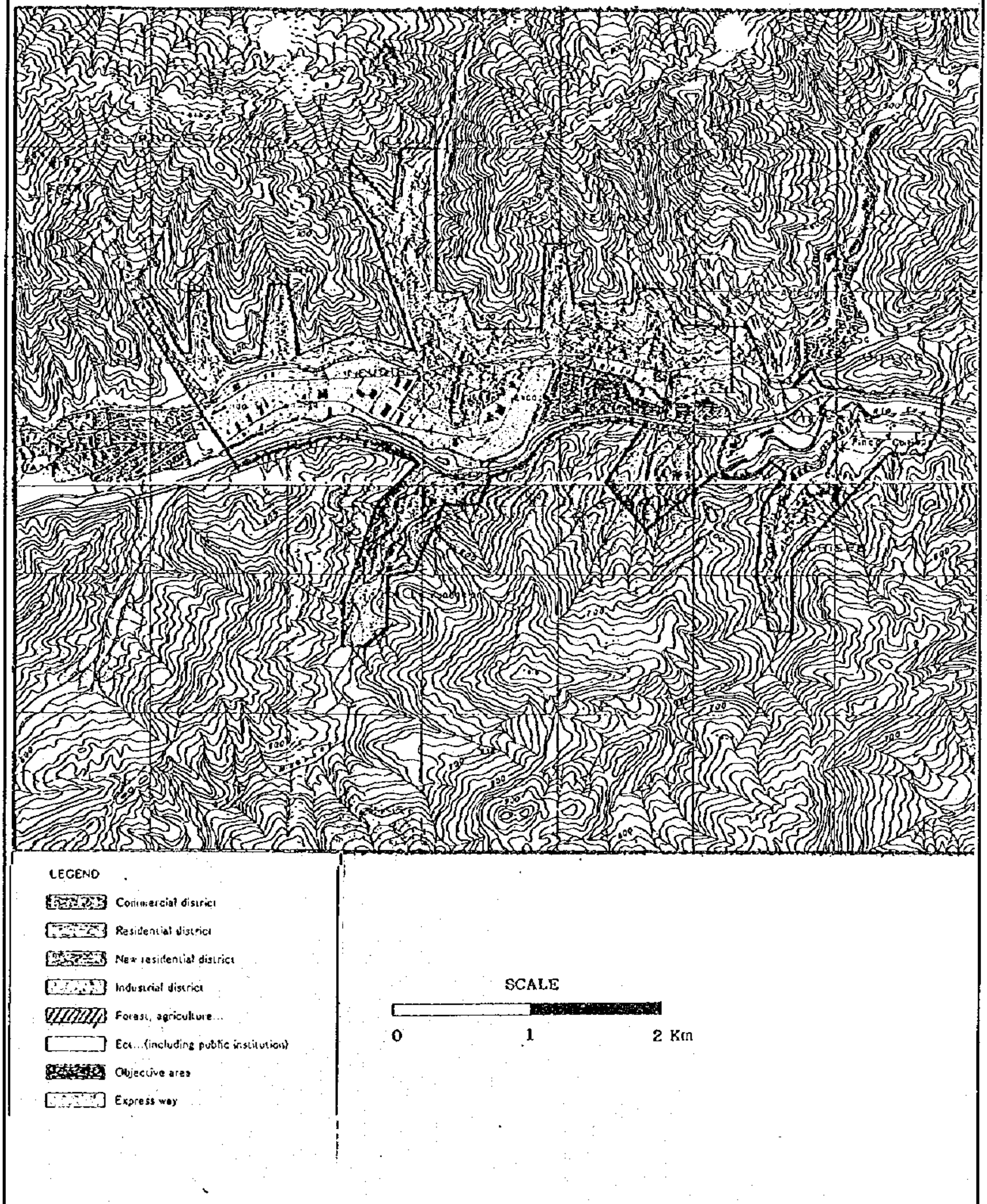
THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 3.4-3 Ocumare del Tuy Sewage Treatment Plant
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.3.4-4 Ocumare del Tuy Main Drainage Pipe Network
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.4.1-1 Location Map of Las Tejerias Sewage System
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON
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STREAM OF THE TUY RIVER BASIN
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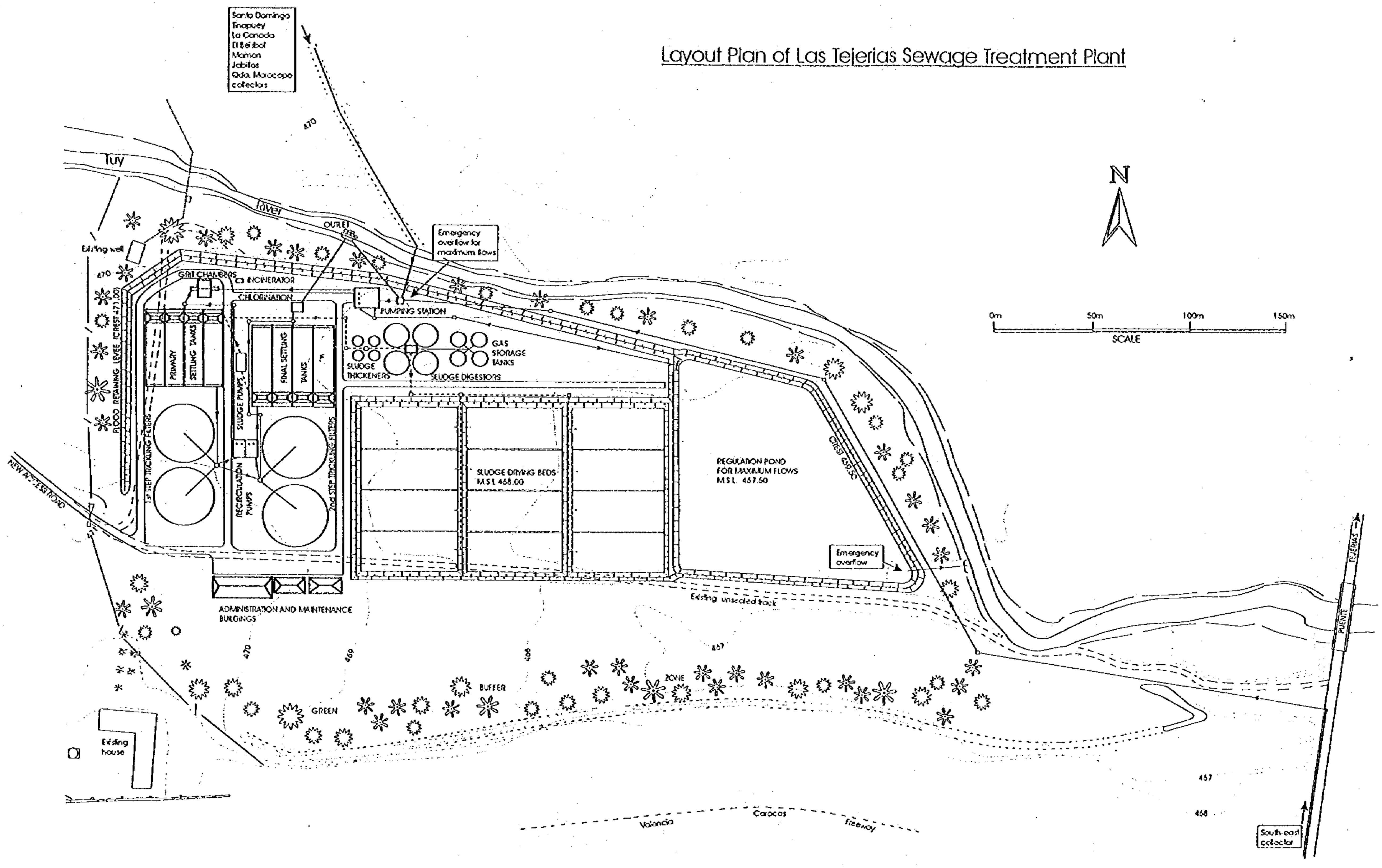
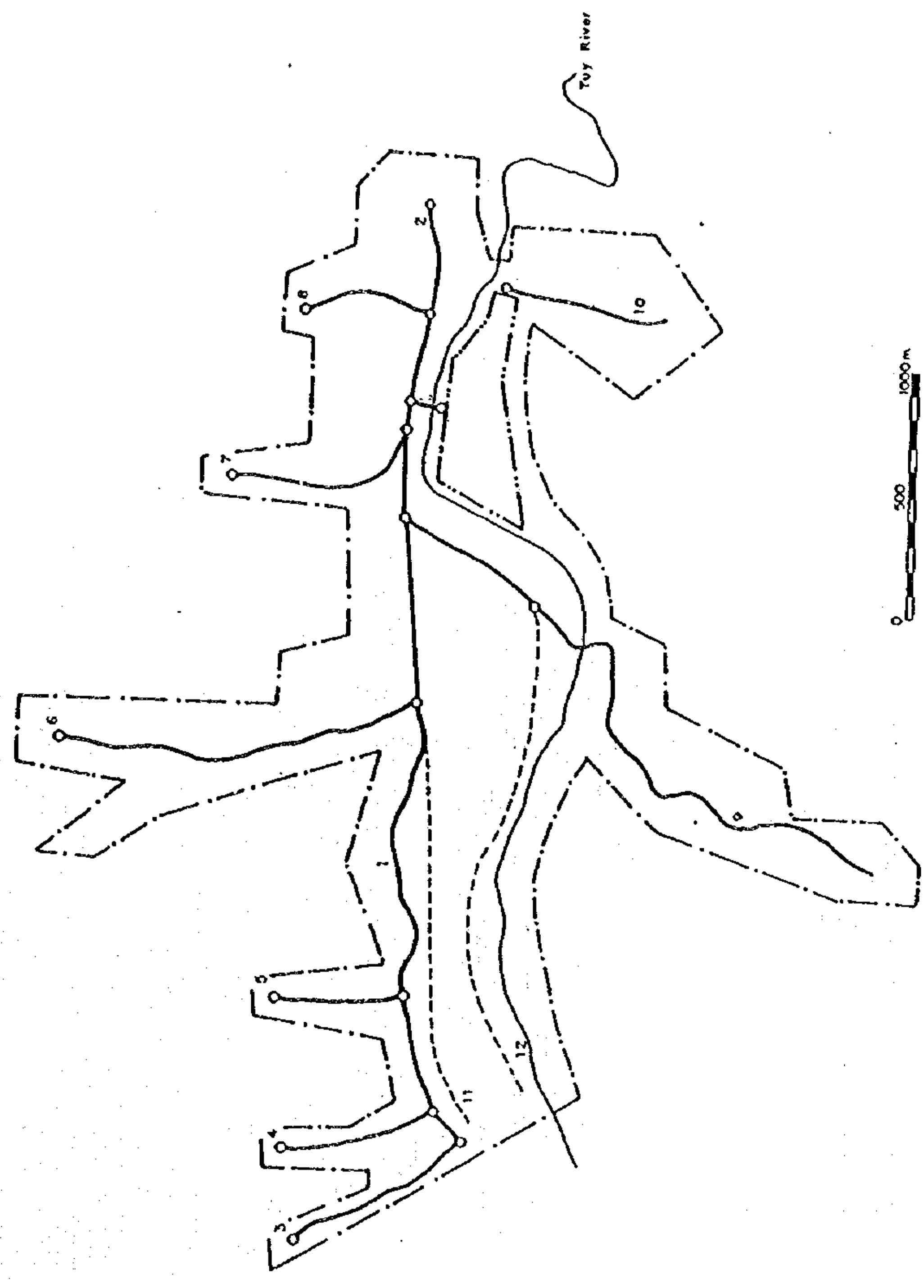
Fig. 4.2-1 Land Use Map in Future



THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig. 4.4-1 Las Tejerías Sewage Treatment Plant
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN IN THE REPUBLIC OF VENEZUELA	Fig.4.4-2. Las Tejerias Main Drainage Pipe Network
JAPAN INTERNATIONAL COOPERATION AGENCY	

SECTOR E

TURBID WATER TREATMENT

THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF
THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN

SECTOR E: TURBID WATER TREATMENT

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SECTOR E: TURBID WATER TREATMENT

1. SURVEY AND ANALYSIS ON TURBID WATER

1.1 General

The turbidity represents muddy or turbid condition of water with solid particles such as wash load and suspended load and organic substances caused by natural or artificial activities on a river basin. On the Tuy River basin, wash load and suspended load are caused by two reasons: One is natural surface erosion by rainfall and another is humans industrial activities, one of which is particularly at sand quarries, dredging of the riverbed and washing of fine aggregate. The origin of organic substances is the waste of factories, livestock farms and residences.

The surface erosion produces fine soil particles, chiefly triggered by rainfall in the rainy season. This fine soil is accumulated into a large volume as to dominate the total sediment volume; The surface erosion is the main reason of turbid water.

In addition, the turbid water from the plants at sand quarries and the wastewater with organic substances from various activities are discharged into the Tuy River all year round and become conspicuous in the dry season.

The turbidity is expressed by the degree of visual sensation; One degree is the same turbid condition as 1 liter of water including 1 milligram of Kaolin (1 mg/*l*), which is influenced by the diameter of a solid content. Then the density of suspended solids (SS) directly and generally expresses turbid condition. Therefore, in this section, SS is used to express the turbid condition.

This section presents the fundamentals to clarify the magnitude of turbidity and its relation to river discharge.

1.2 Cause of Turbid Water

On the Tuy River basin, the obvious causes of turbid water are the wastewater due to human activities and sediment partly due to erosion, and these are individually examined as follows:

(1) Wastewater of Human Activities

As identified in the water quality analyses in Sector A, some factories frequently discharge large quantities of organic pollutants including organic suspended solids and the plants at sand quarries discharge a large quantity of turbid water due to dredging of the riverbed and washing of fine aggregate.

SS of the dry season is observed 494g/s at Toma de Agua (site of intake) against the total discharge SS load of 2,761 g/s from field survey in February, 1996 as shown in Fig. 1.3-2 of Sector A. The total suspended solids (SS) load from human activities is 159 ton/day which is calculated from total SS discharge of 2761 g/s in consideration with the working hours for 16 hours of factories.

About 70 % of the above SS load is from the draining and washing operations at sand quarries because 176m^3/day of fine solid, which is 10% of daily production volume (raw content), is discharged as calculated follows:

$$Ws = 176\ (m^3/day) \times (1-0.75) \times 2.49 = 109\ (ton/day)$$

The solid particles of 109 ton/day from sand quarries are discharged into the middle reaches, at Qda. Maitana and the stretch along the Tuy River between El Conde and Colonia Mendoza. The organic SS pollution load which amounts up to 50 ton/day is mainly detected in the upper reaches, at Caño Tiquirito and Qda. Guayas,

Pollution loads causing turbidity are detected throughout the year. In the dry season, however, these pollution loads partially become less as flow in the Tuy River, some of which are deposited on the riverbed due to the dissipated transporting forces of the river, or which is regarded as a natural purification effect. As a result, the turbidity is not severe at the water intake point in the dry season.

In contrast, in the rainy season, the SS will increase due to accumulated deposition on the riverbed with the pollutants produced by daily activities of factories, though natural water discharge also increases.

As suggested in the Sector A, it is further necessary to examine the pollution condition by these increased loads in the rainy season, but it is worth trying a basic estimation, assuming that throughout the dry season the deposited load is discharged in the rainy season when river discharge reaches a certain level; The typical discharge of each season is low water discharge 1.9 m^3/sec and ninety-five-day water discharge 10.3 m^3/s from discharge duration curve, as follows:

Season	Pollution Load (SS) from Factories (1) (ton/day)	Purification Effect (2) (ton/day)	Balance (Pollution Load at water Intake) (1)-(2)=(3) (ton/day)	Water Discharge (4) (m^3/sec)	Water Quality (3)/(4) (mg/l)
Dry	159.1	130.6	28.5	1.9	174
Rainy	159.1	-130.6	289.7	10.3	326

(2) Natural Sediment Production

Sediment from the basin generally consists of three types of loads depending on the grain size and the relation of their volume for the Tuy River is empirically put in Fig. 1.2-1, which shows the portion of each sediment load deposited in dam reservoirs and the table next is the physical properties of such loads.

Item	Suspended Solids		Bed load
	Wash load	Suspended load	
Diameter (mm)	d < 0.1	0.1 < d <1	1 < d
Volume (%)	85	12	3
Porosity	0.75	0.4	0.3
Solid Volume(%)	21	7	2

Suspended solid is composed of wash load and suspended load. It is difficult to separate clearly the cause of production of each load but wash load as fine particle is attempted to be mainly defined as a product of natural surface erosion due to a storm and suspended load as coarse particle is by bank erosion and collapse. In this study, wash load is calculated by Universal Soil Loss Equation (USLE) and suspended load is calculated by the volume rate between wash load and suspended load.

Precise calculation of the amount of sediment depends on the complexity of the surface erosion mechanism and technically, in general for the estimation, two methods are adopted: (1) estimation based on the experimental equation and (2) estimation based on the observed data.

The estimation by these two methods are discussed in the following sub-sections:

1.3 Estimation of Suspended Solid by Experimental Equation and Observed Data

(1) Estimation by Experimental Equation

(a) Experimental Equation

The suspended solid discharge volume down stream is obtained by the following equation:

$$V = A \times SDR / Sr / (1-\lambda) \times R$$

Where,

V : Suspended Solid Discharge Volume (m^3/year)
A : Soil Loss weight (Wash Load) (ton/year)
SDR: Sediment Delivery Ratio
Sr: Specific Gravity (2.49 ton/m^3)
λ : Porosity (0.75)
R : Volume Rate of Suspended Solid and Wash Load (0.97:0.85)

In this equation, soil loss (A) and sediment delivery ratio (SDR) are obtained in the following manner:

(b) Soil Loss (A)

The calculating area is cover with meshes of 1000 m by 1000 m size (1 km^2). and it was divided into 2,150 (included Lagartijo Dam basin) and the soil loss is calculated on each mesh. The result of soil loss is summarized major 14 sub-basins as shown in Fig. 1.3-1.

Soil loss caused by surface erosion is calculated using the following Universal Soil Loss Equation (USLE) :

$$A = R \times K \times LS \times C \times P$$

Where,

- A : Soil loss in ton/ha/year
- R : Rainfall Factor
- K : Soil erodibility factor (using the soil map)
- L, S : Slope length factor and slope gradient factor
- C,P : Cropping management factor (C) and Erosion control practice factor(P) (using land use-vegetation map)

To decide the coefficient of factors, vegetation map, soil map and isohyetal map are collected from Environmental Information System of Tuy River Basin (MARNER) and Ministry of Urban Development.

(i) Rainfall Factor R

The rainfall (R) factor is calculated with original record of the Cúa automatic rainfall station from 1991 to 1995 collected more completely than others stations. The R factor is explained by the Wischmer's erosion index, meaning the total energy of rainstorm times as below;

$$R = \Sigma E/100 \times I_{30}$$

where

- I_{30} : Maximum intensity over 30 minuets
- E : Kinetic energy of rain (Joules/m^2/cm)
  $E = 210.2 + 89 \log I$
- I : Average rainfall intensity of the considered period in cm/hr

The average yearly R factor at the Cúa automatic gauging station is calculated to 312 Joules/m^2/year.

The others R factors on each mesh are calculated with a good correlation between the average yearly R factor and the average annual rainfall times the 2-year 1-hour rainfall amount, times the 2-year 24-hour rainfall amount as the following equation:

$$R = f(P \times I_1^{2yr} \times I_{24}^{2yr})$$

where

P :Annual Rainfall
I_1^{2yr} :1 hour rainfall intensity with 2-year return period
I_{24}^{2yr} : 24 hours rainfall intensity with 2-year return period

To use above equation, Isohyetal maps of the annual rainfall, 1 hour and 24 hour intensity with 2 year return period is obtained from the hydrological study section. R values was established as shown in Fig. 1.3-2.

(ii) Soil Erodibility Factor K

The soil map shows the distribution of 8 soil types in accordance of the appropriateness to the agriculture in the study area. The classification of soil is shown as follow;

Class 1: appropriated to cultivation without restriction
Class 2: appropriated to cultivation with moderate restriction
Class 3: appropriated to cultivation with some restriction
Class 4: appropriated to cultivation with restriction
Class 5: inadequate to cultivation, appropriated to permannt vegetation, without erosion
Class 6: inadequate to cultivation, appropriated to permannt vegetation, with erosion
Class 7: inadequate to cultivation, appropriated to permannt vegetation, with erosion and some restriction
Class 8: inadequate to agriculture

The area of class 7 is distributed more than 80 % of the study area. In view of this condition, the soil samples were taken from 6 points, one is class 2 and 5 are class 7 as shown in Fig. 1.3-3 and mechanical analysis was performed. The result of analysis was shown in Fig 1.3-4 as the grain size accumulation curve. The characteristic of soils is very sandy.

The K factor is decided from the soil-erodibility nomograph and data on such soil factors as particle size. K factor of class 2 to class 7 ranges from 0.155 to 0.130 as shown in Fig 1.3-5

(iii) Slope Length and Slope Gradient Factor LS

L factor is 1000 m as same as the side of mesh and S factor is using the topographic map scale 1/25,000 as shown in Fig. 1.3-6. LS factor was calculated using the below mentioned formula represented in the FAO Conservation Guide 1, guidelines for watershed management (1977).

$$LS = (\lambda / 22.1)^{0.6} + (S / 9)^{1.4}$$

where,

λ = Slope length (m)

S = Slope gradient (%)

(iv) Cropping Management Factor C

The values of C factor is decided considering land use-vegetation categories, which is shown in Fig. 1.3-7, and percent ground cover.

The value of C factor for natural secondary forest was chosen by taking into consideration forest condition and degree of coverage it provides for the land. The value was 0.005 chosen for forest.

The value of 0.01 was given for bush with a coverage of more than 70 %. The value of 0.015 to 0.025 (with a coverage of 30 - 60 %) were chosen for Sabana which has a low canopy coverage. Because, in the dry season, the leaves fall and in the beginning of rainfall season the raindrops hit directly surface. The values of 0.025 was given to grass land with trees coverage of lower than 30 %. The value of 0.02 was applied for agriculture land. Table 1.3-1 is used as the choosing C factor values for in this study area.

(v) Management Practice Factor P

This ratio is decided in consideration with contouring, strip cropping or terracing to that with straight-row farming, up and down slope.

From the field survey, Almost study area is without soil conservation activity, then values of P factor was applied 1.0 expect where is used for agriculture land with soil conservation and town area. P factor values adapted for this study are shown in Table 1.3-1.

(c) Sediment Delivery Ratio (SDR)

The soil loss from erosion yield to the sediment yield of a torrent is expressed the Sediment Delivery Ratio (SDR) which varies with drainage basin size. In this study the Sediment Delivery Ratio was used with the table of Morgan (1980) which is shown in Table 1.3-2.

(d) Calculation Results

The results of the soil loss volume and the discharge volume of suspended solid are shown in Table 1.3-3. According to this table, annual suspended solid is 564,773 m^3/year (304m^3/km^2/year), flowing down to the water intake point.

The soil loss volume is influenced by the land cover or land use condition. Table 1.3-4 shows the relation between discharge volume of suspended solids and land use. Grassland on steep slopes is used as pasture land and it becomes bare by burning at the end of every dry season to sprout anew for livestock consumption. Therefore, the grassland has the highest soil loss potential in the study area.

(2) Estimation of Sediment Based on Observed Data

As the observed data which can be used for the sedimentation volume from the basin, following data sets are available: The volume of suspended solid at Hda. Tazón and in Lagartijo reservoir. The following relation can be obtained from such data:

(a) Suspended Solids at Hda. Tazón

The data of annual suspended solid volume at Hda. Tazón from 1947 to 1964 is shown in the report "*Tuy en Tazón Informe Hidrologico de la Cuenca*" (1966). According to the report annual average suspended solid volume is calculated as 301 m^3/km^2/year at Hda. Tazón. (Refer to Table 1.3-5)

(b) Suspended Solids in Lagartijo Reservoir

Lagartijo dam with a catchment area of 286 km^2, which is located in the Lagartijo River (a tributary of the Tuy River) basin, was constructed in 1962, 34 years ago. The sediment volume was surveyed by the Study Team in a manner of measurement of the water depth down to sediment surface. The survey results are shown in Fig. 1.3-8. From the survey results, the sediment volume in the reservoir is estimated at 2,745,600 m^3. Ninety seven percent of sediment volume, 2,663,230 m^3 corresponding to 274 m^3/km^2/year, is suspended solid volume: 2,663,230 m^3/ 286 km^2 / 34 years.

(3) Appropriateness of the Experimental Equation

It is possible to confirm appropriateness of the experimental equation by the comparison of sediment volumes between calculation value and observation value. As shown in the table below, the calculation value broadly corresponds to the observed value, and thus the experimental equation was confirmed appropriate.

Point or Basin	Calculation value by Experimental Equation	Observed Value
Tazon, Tuy River	360 m^3/km^2/year	301 m^3/km^2/year(1947-1964)
Lagartijo basin	283 m^3/km^2/year	274 m^3/km^2/year (1990)

The observed value at Tazón is 20% smaller than the calculation value. This difference is caused by the developing process of the area between 2 periods, from 1947 to 1964 and 1990. Increment 20% of SS for 25-years is adaptable rate from the preview calculation of SS in 2010 with the future land conversion. Apart from this, Lagartijo basin planned to be a national park has not been developed and soil loss condition has remained stable in the same period.

Therefore, the calculated value is adopted for the estimation of sediment from the basin in this study.

1.4 Relation between SS and Discharge

In general, the relation between SS and discharge is expressed in the following equation:

$$SS = \alpha \times Q^n$$

Where,

Q : Runoff discharge (m^3/s)
α and n : Coefficient

To examine this relation, observed data at Hda. Barrios and Hda. Tazón from 1967 to 1973 are adopted.

Fig. 1.4-1 shows the relation between SS and monthly maximum discharge at Had. Barrios and Hda. Tazón on a diagram with logarithmic axes. According to this figure, the following relations at 2 points can be obtained:

$SS = 63 \times Q^{1.1}$ (mg/l) or $6.3 \times 10^{-5} Q^{1.1}$ (t/m^3) (Had. Barrios)

$SS = 67 \times Q^{1.1}$ (mg/l) or $6.7 \times 10^{-5} Q^{1.1}$ (t/m^3) (Hda. Tazón)

Where,

Q : Discharge (m^3/s)

The actual SS coefficient is increased more 20% from 1967 by the social development in the areas along the upper stream. And according the next two conditions, SS and sediment volume has the relationship between tributaries;

1. The specific discharge of tributaries on the Tuy River basin is same:

$$\frac{SS_1 Q_1}{A_1} : \frac{SS_2 Q_2}{A_2} = Vu_1 : Vu_2 \quad \text{then} \quad SS_1 : SS_2 = Vu_1 : Vu_2$$

2. Difference of SS between tributaries is influenced only α coefficient of each tributary:

$$SS_1 : SS_2 = \alpha_1 Q^{1.1} : \alpha_2 Q^{1.1}$$

Thus, $Vu_1 : Vu_2 = \alpha_1 : \alpha_2$

Therefore, the actual SS at Toma de Agua (site of intake) is calculated from SS of Hda. Tazón as follows:

$$SS = 67 \times 1.2 \times 303 / 360 \times Q^{1.1} = 67 \times Q^{1.1} \quad (mg/l)$$

1.5 Turbidity in Tuy River Basin

1.5.1 Present Condition

In the former sub-sections, 1.2 and 1.4, SS volume which causes turbidity in Tuy River basin was examined as summarized below:

- SS load from factories : 159.1 (ton/day) × 300 (days) = 47,730 (ton/year)

- SS load from river basin : 221 (ton/km²/year) × 1,857 km² = 410,000 (ton/year)

The differences between the pollution loads with their production and discharging are summarized in the table below; The total SS production volume from factories are 1/8 of that from river basin and thus the major origins of SS production is concluded to be from the river basin.

Source of SS load	Time of Production	Discharge in dry season	Discharge in rainy season
Factories	throughout the year	most of the production is deposited on the way of river course	all production amount and deposited ones are discharged
Basin	rainy season	-	all the production amount are discharged

Besides this, Fig. 1.5-1 shows the SS duration curve at the water intake point. The total SS is the one from the river basin plus the other from factories. This total SS has to be below the standard limit. In other words, water quality of 75% of samples should satisfy the water quality standard limit (SS = 750mg/l) when the water quality examination is performed 1 time per 1 month.

SS for a 25% daily discharge in annual duration curve is 900mg/l from river basin and that from factories is 330mg/l. Therefore, the actual SS of 1230 mg/l of the Tuy river at water intake point does not satisfy the standard limit.

1.5.2 Future Condition

In the Tuy River basin, population increase and the development progress. Thus, the land coverage condition will be changed by deforestation. The land coverage is the factors that affects the volume of sediment production. Then, the sediment production from the basin will be increased.

For the baseline projection, the population increase in the year 2010 is established 3 cases, high, standard and low projection. A ratio of this population increase converts into change of land use condition of future, and sediment volume of each tributary is calculated as presented in Table 1.5-1.

Projected sediment volume at the Intake in the year 2010 will increase from 113% to 130%, between the cases of low to high projection. The sediment production volume of the standard case increases 120% and it is equivalent the increase of SS values until 1080mg/l against the present SS condition of 900mg/l.

2. IDENTIFICATION OF KEY ISSUES AND PROBLEMS

Turbidity is also an important factor of water pollution in the Tuy River. Turbidity in the Tuy River creates aesthetically unfavorable environmental conditions. The high turbidity in the Tuy occurs mainly during the rainy seasons when the total load of suspended solids becomes high. The load of suspended solids in the year 2010 at Toma de Água is projected from the baseline projection as follows;

Projected SS in Year 2010

Point	SS (mg/ℓ)
Toma de Agua (water intake site)	1,080

Note: SS is approximately three times Turbidity in NTU, according to test results of the study. SS is of the value for the discharge of 91-day discharge

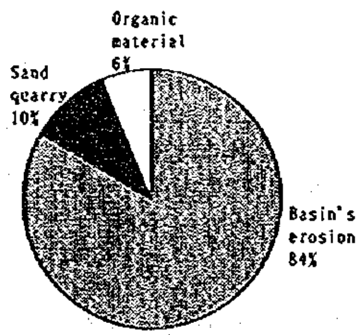
High turbidity causes trouble at the intake. High turbidity caused suspension of water intake shared 11 times (31%) of a total suspension of 36 times on average from 1993-95. The number of times that high turbidity caused operation suspension of the intake is the highest of the causes. It also causes higher annual operation costs of the pre-treatment facility.

2.1 Pollution Source and Spatial Distribution

Production Source

Turbidity of the Tuy River originates from sand quarries, sheet erosion in all areas of the catchment basin, bank erosion of rivers, and from human related activities in the basin, e.g., land reclamation, road construction, as well as from organic pollution. Turbidity is discussed here using suspended solids. The source of SS production load is broadly divided into three; erosion, sand quarries, and organic pollution. Erosion includes sheet erosion in all the areas of the catchment basin, bank erosion of rivers, and from human related activities in the basin, e.g., land reclamation, road construction. The projected composition in the year 2000 is as follows:

SS Production Load



Of the annual amount of total suspended solids, those from basin's erosion make up 84%; sand quarries contribute 10%; and the share of organic material in the composition of SS is comparatively low at 6%.

Spatial Distribution

The sediment production volume is calculated by a 1×1-km mesh as presented in Fig. 2.2-1. As seen in the illustration, the production is comparatively low in the moderately undulated areas of Charallave, Cúa, San Francisco de Yare and in the catchment of the Guare River basin. In other mountainous areas, no distinguishable differences were identified: the production occurs throughout the basin.

Major sand quarries are located in the Qda. Maitana basin. One quarry is equipped with a settling basin and the other without. In the Qda. Maitana, turbidity is very high during the dry season when the river has almost dried up. The turbidity of Qda. Maitana in February, 1996, according to the results of water quality test, was extremely high at 14,800 NTU (SS of approx. 32,000 mg/ℓ).

2.2 Technical Measures Adopted and Their Status

To the pollution sources identified above, some measures have already been applied. In this section, technical measures already adopted are identified and the status of these measures are confirmed for planning.

As discussed before, turbid water originates, chiefly, from erosion over the entire basin and sand quarries. Of these, sand quarries are considered as industrial wastewater and the other is natural condition (though the destruction of the basin is due to human activities).

Sand Quarries

Wastewater from sand quarries is from flushing water. In the case of sand quarries along the Qda. Maitana, 20 to 25 ℓ/sec of water is used. One site is equipped with two sand settling ponds and these are used alternatively. Overflow water from the settling ponds flows to the river. In the other case, there are no sand settling ponds and high concentrations of suspended solids flow (SS>10,000mg/l) into the Tuy River.

Erosion in the Basin

For the erosion in the basin, no measure has been implemented so far. Some river bank protection works have been conducted along the Tuy River, but these are mainly for the protection of bridges and not to protect the river from bank erosion.

Measure at Utilization Site

As a measure at the water intake of Hidrocapital, a pre-treatment facility has been introduced and is presently operated.

3. MASTER PLAN STUDY ON REDUCTION OF TURBIDITY

3.1 Strategies for Application of Countermeasures

Turbidity is one of the most important factors regarding water pollution in the Tuy River. The major sources are erosion in the basin including those related to human activities and industrial activity (sand quarries).

Watershed management is an alternative to reduce wash load production in the basin. This should be considered in a long range program. Sand settling ponds shall also be taken into consideration to reduce turbid water inflow from tributaries. A sand settling pond for the purpose of treating water before pre-treatment shall be studied as a measure to cope with the highly turbid water for intake at Toma de Agua. The following should be considered for measures.

- Reforestation
- Sand settling ponds for tributaries
- Introduction of measures for erosion and sediment discharge protection especially for upland crop lands and grass lands
- Definition of appropriate land use
- Measures to prevent forest fires
- A sand settling pond before pre-treatment at Toma de Agua

Demarcation of the work with the department for watershed management in MARNR should be conducted.

3.2 Alternative Study Cases

For basin erosion that results in high turbidity of river water, the following considerations are taken:

- To secure water quantity and thus reduce the frequency of suspension of water intake due to high turbidity from the water supply viewpoint.
- To improve water quality from the environmental viewpoint.

To reduce the turbidity resulting from land development, it is also necessary to restrict the land utilization including shrub and forest firing. The restriction of the land utilization is dealt with institutional measures, especially in monitoring system which discussed later.

3.3 Reduction of Turbidity to Secure Water Quantity

As discussed in setting the target, the necessity to reduce turbidity that is mainly caused by suspended solids (SS) is from the following two reasons: (1) to secure water supply quantity and (2) to improve water quality from the environmental viewpoint. In this context, the optimum measure is examined in two cases: Case 1, to secure water quantity, and Case 2, to improve water quality. In the former case, the target is to decrease the frequency of suspension of intake at the water intake point through the reduction of high turbidity which emerges in flood time, while in the latter case, the target is to reduce turbidity under normal flow conditions over the entire basin.

3.3.1 Applicable Measures

Judging from the river conditions, the following measures against high turbidity are proposed to be taken to secure water quantity:

For SS from basin erosion:

- Reforestation to reduce soil erosion from exposed areas.
- Sand settling ponds to reduce suspended solids in turbid water of tributaries.
- Sand settling pond to reduce suspended solids at the water intake point.

For SS from factories:

- Factory treatment plants.

Among these applicable measures, the study on optimum measures puts emphasis on soil erosion as the turbidity problem is mainly caused by soil erosion. It also examines factory treatment plants to control other effluents together with turbidity. Because, if SS from factory is controlled under the water quality standard for factory wastewater (SS = 80 mg/l), it's quantity can be negligible volume compared with SS from the basin.

3.3.2 Outline of Measures and Effectiveness

(1) Reforestation

It is identified that soil erosion in the basin is due to logging operations and land development, and one of the effective measures to control soil erosion is reforestation.

To examine this measure's effectiveness, the production of suspended solids at each tributary is calculated for each tributary area to be reforested excluding the present forested, bush and urban areas. Calculation is performed using the experimental "Universal Soil Loss Equation" discussed in the section 1, and the results are shown in Table 3.3-1.

In the results, the three most efficient tributaries are selected. SS reduction volume per unit area of reforestation at each tributary and the reduction rate of actual total SS volume at the water intake point are as shown in following table (refer to Fig. 3.3-1):

Tributary	Reforestation Area km^2	SS Reduction Volume m^3/year/km^2	Reduction Rate %
Qda. Maitana	40	672	4.8
Qda. Guayas	16	616	1.7
Cagua River	46	579	4.7

The effectiveness of reforestation is considered in three cases, cumulatively combining the areas of the above tributaries for higher efficiency.

(2) Sand Settling Pond on Tributaries

The function of the sand settling ponds is to settle thus reducing suspended solids in diverted water and to return less turbid water to the river. Such ponds are proposed to be provided on four tributaries which are heavy contributors of sediments upstream, namely, upper Tuy River, Qda. Guayas, Qda. Maitana and Guare River.(Refer to Fig. 3.3-2.)

To evaluate the effectiveness, the discharge is prepared by the annual duration curve explained in the section 1.3, and the pond size is examined in the following three cases (refer to Fig.3.3-3):

Case 1	70% of discharge volume is diverted from tributaries to the pond.
Case 2	60% of discharge volume is diverted from tributaries to the pond.
Case 3	50% of discharge volume is diverted from tributaries to the pond.

The effectiveness of the sand settling pond is as shown in Table 3.3-2.

(3) The Case of Sediment Settling Pond for the Pretreatment Plant

To reduce turbidity at the water intake point, the sand settling pond is considered to be provided near the water intake point. This measure is designed to flush out the sediment from the pond utilizing the flushing force of the flow by operating the gate at the pond.(Refer to Fig. 3.3-3.)

To evaluate the effectiveness, the following cases of pond size are taken into consideration:

Case	Settling Pond Size (m)			Reduction Rate of SS (%)
	Length	Width	Depth	
1	130	40	3.1	47.4
2	100	40	3.3	45.5
3	70	40	3.6	42.9

In these cases, 40 m of width and 1 m of effective depth are fixed to keep the flow velocity lower than 0.2 m/s. Depth in the above table includes the sediment deposited depth and the effective depth.

(4) The Case of Sand Settling Pond Before the Intake for the Qda. Seca Reservoir

On the other hand for the above measure, Hidrocapital is planning to use a part of the Qda. Seca reservoir as a sedimentation and oxidation pond by providing a dike inside the reservoir to cope with high turbid and polluted water of the Tuy River as shown in Fig. 3.3-4.

In this connection, it is necessary to confirm the advantage of the sand settling pond proposed before the intake. Herein, the economic comparison between two measures, sand settling pond before the intake and Qda. Seca is examined.

To evaluate the effectiveness, the following cases of pond size are taken into consideration:

Case	Settling Pond Size (m^2)	Reduction Rate of SS(%)
1	3,000	48
2	5,000	71
3	7,000	79

Considering the maximum water level and the cleaning of the sand settling pond, the depth is set at 6.5~7.0m with inclining bottom.

The sediment volume to be dredged is calculated applying the monthly discharge data from 1993 to 1978 assuming the different reservoir size : 3,000 m^2, 5,000 m^2 or 7,000 m^2.

Table 3.3-3 shows SS and sediment volumes settled in the three cases of the pond size. Their annual sediment flowing into the pond is estimated at 235,140 m^3, while the settled sediment volumes for three sizes of ponds are estimated 113,420 m^3, 166,060 $m^3$and 185,930 m^3.

3.3.3 Comparison of Alternatives

Table 3.3-4 shows the economic comparison of alternatives in a manner of Cost-Benefit ratio (B/C) and net present value (B-C). In this table, the benefit and cost are considered, as follows:

(1) Benefit

- Reduction of necessary maintenance cost to reduce the turbidity for water supply at the existing pre-treatment facility.
- Increase of water supply volume resulting from the decrease of frequency of water intake suspension due to high turbidity.

(2) Cost

- The cost required includes the initial cost and the operation and maintenance cost for each case.

In the case of sand settling pond before the intake and in the Qda. Seca Reservoir, the economic comparison is calculated with the initial cost and the operation and maintenance cost for both cases.

Based on the table, the optimum measure is the construction of a sand settling pond before the water intake point.

3.4 Reduction of Turbidity to Improve Water Quality from the Environmental Viewpoint

3.4.1 Applicable Measures

The measures to reduce turbidity from the environmental viewpoint are the following two cases which were narrowed down from the measures considered in Case 1. The sand settling pond at the water intake point is eliminated, because it is only effective to assure water quantity but not the environmental impacts.

- Reforestation to reduce soil erosion in the waste area.
- Sand settling pond to reduce suspended solids in turbid water in tributaries.

3.4.2 Optimum Measures

The outline of the two measures and their costs are the same as in Case 1 above, but the benefits are evaluated from the environmental viewpoint.

However, from the environmental aspect it is difficult to calculate the benefit to improve turbidity in monetary terms. Therefore, the optimum measure is selected by the comparison of costs to reduce the volume of turbidity.

Fig. 3.4-1 shows the relation between the unit cost and the reduction volume of the two measures. According to the figure, there is a turning point in the advantage and disadvantage of unit cost between the two measures. Reforestation is economically advantageous when the SS reduction volume is below 60,000 m^3, while the sand settling pond is advantageous when the reduction volume is 60,000 m^3 and above.

At present, turbidity is estimated at less than 900 mg/ℓ for a 25% daily discharge in annual duration curve and this value will increase to 1,080 mg/ℓ at the year of 2010 due to future land development. However, the target for the year of 2010 is set at 750 mg/ℓ.

Under this circumstances, it is necessary to introduce the measures of reforestation and sand settling ponds to reduce turbidity from 1,080 mg/ℓ to 750 mg/ℓ. The reduction volume of 330 mg/ℓ is shared among the reforestation and sand settling ponds, i.e., 110 mg/ℓ by reforestation and 220 mg/ℓ by the sand settling pond in four tributaries.

3.5 Sensitivity Analysis

In this subsection, the cost of measure in cases of low and high projection is calculated as the sensitivity analysis. The projected sediment volume at the intake in the year 2010 is calculated to increase from 113% (SS=270mg/l) to 130% as well as fluctuation of the population between the cases of low and high projection.

In the case of the low projection, the countermeasure is composed reforestation of 10,200 has and 3 settling ponds in tributaries. The annual cost, which is initial cost by 0.11 plus maintenance cost, is US$ 2,377,210/year

In the case of the high projection, the countermeasure is composed reforestation of 10,200 has and 5 settling ponds in tributaries. The annual cost is US$ 3,841,333/year

4. FEASIBILITY STUDY OF COUNTERMEASURE FOR TURBIDITY

4.1 Feasibility Study on Sand Settling Pond at Intake

The main cause of increase in turbidity of the Tuy River is the expansion of development and deforestation areas in the basin. The increase in turbidity causes the problem on the pre-treatment and the intake at San Antonio de Yare.

In the master plan, a sand settling pond along the right river bank before the intake is proposed to dislodge the sediment load to two plants, 1) the pre-treatment plant at Toma de Agua and 2) the Qda. Seca reservoir as a sedimentation and oxidation pond which Hidrocapital is planning.

Therefore, the objective for utilization of the sand settling pond before the intake is to cut down the free settling sediment to 0.02 mm in size before the intake

4.1.1 Result of Additional Turbidity Study

To confirm the effectiveness of the proposed sand settling pond, sediment properties of the Tuy River were examined in this feasibility study. Besides this, sediment depth was measured and samples were taken in the pre-treatment ponds. Other samples of turbid water of the Tuy River were collected in front of the intake and their settled solids were tested in a laboratory.

Fig. 4.1-1 shows the sediment depth and sampling points in the five pre-treatment ponds (one pond was cleaned). The sediment in each pre-treatment pond forms a flat and plain surface for 20 m from the inlet to the outlet.

Moisture and mechanical analyses were applied to the samples. The moisture ranges from 76 to 124%, and it becomes higher toward the outlet.

Fig. 4.1-2 shows the result of the mechanical analysis. Sediment size ranges from 0.008 mm to 0.04 mm and fine particles increase toward the outlet.

To compare the grain curves of sediment of the pre-treatment pond and the suspended solids of the Tuy River, the mean grain of sediment of the pre-treatment pond is calculated with the sediment volume, moisture ratio and grain curve of each sample. The two grain curves obviously resemble each other, as in Fig. 4.1-2.

Table 4.1-1 shows the actual cleaning time and sediment volume in the pre-treatment pond in 1996. The total sediment volume was 117,000 m^3/year and the mean intake volume was 3.2 m^3/s. If the main intake volume increases to 5.6 m^3/s as descried in the report of "*Incremento de la Extracciún de la Toma II de San Antonio en el Rio Tuy , y Compensaciún en el Embalse Quebrada Seca, Edo.Miranda*", the sediment volume will increase to 204,750 m^3/year. Furthermore, considering the elimination capacity as 90% of the pre-treatment pond, the calculated SS volume 235,100 m^3/year in the previous section is thought adequate.

4.1.2 Confirmation of Prerequisite for Planning

The sand settling pond is designed as follows:

- The trace of a falling particle is expressed in the vector of current horizontal velocity v and falling velocity w;
- When falling velocity from an inlet to an outlet of pond is set as w_o, the particle of w ($> w_o$) entirely settles. And, the eliminating rate E of particle of w ($< w_o$) is expressed as the rate of w/w_o;
- If the detention time t_o of particle in pond is reflected as L/v, then the relation of inflow volume Q to pond and w_o is as expressed in the following equation:

$$w_o = \frac{h_o}{t_o} = \frac{h_o}{L/v} = \frac{Q}{LB} = \frac{Q}{A}$$

where

L : Length of settling pond
B : Breadth of settling pond
h_o : Depth of settling pond
A : Water surface area of settling pond

- The particle eliminated in the settling pond is unrelated to depth by the water surface area of settling pond. The elimination rate E of particle having a falling velocity w is expressed in the following equation.

$$E = \frac{h}{h_o} = \frac{wt_o}{w_o t_o} = \frac{w}{w_o} = \frac{w}{Q/A}$$

where

t_o : settling time

- The falling velocity of a particle is calculated by the Stokes Formula, and Fig. 4.1-3 shows the relation between particle size and falling velocity.

$$w = \left(\frac{1}{18} \cdot \frac{\rho_s - \rho}{\rho w_o} \cdot g\right)^{1.0} v^{-1.0} d^2$$

where

ρ : Density of water
v : Coefficient of kinematics viscosity
d : Diameter

4.1.3 Optimization Study

The particle elimination rate E, whose falling velocity is w, is expressed in the above formula and it will be subject to the intake volume (Q) and water surface area (A) of the settling pond.

Design maximum volume at intake is proposed at 8.72 m^3/s with 8 pumps in the report of "*Incremento de la Extracciún de la Toma II de San Antonio en el Rio Tuy, y Compensaciún en el Embalse Quebrada Seca, Edo.Miranda*". The discharge volumes of dry, rainfall season and main are 2.93 m^3/s, 6.42 m^3/s and 5.61 m^3/s, respectively.

Then, the elimination rate E is calculated for different water surface areas (A) of settling pond. As a result, Fig. 4.1-4 shows the elimination rate curve of each settling pond size. To optimize the settling pond size on the efficient curve, the turning point at A=5,000 m^2 which is the maximum available space at the site is observed that the elimination rate reduces as 70 % when enlargement of size larger than A=5,000 m^2; This is ineffective. In this way, the settling pond size is decided A=5,000 m^2.

4.1.4 Design Features

The design requires the maximum and normal water levels at the intake of the sand settling pond.

The Tuy River Basin does not have a concrete plan for flood control. In this proposed plan, the capacity of the sand settling pond is designed for the flood of 10-year return period whose discharge Q is 525.3 m^3/s, as in the report named "*Impacto Morfologico del Trasvase de Aguas del Lago de Valencia al Rio Tuy*" (López, J. L., 1992).

The maximum and normal water levels are calculated as follows:

- The water level, which is calculated by the overflow equation, at the intake weir is the starting point for the upstream, and
- The water level at the intake of sand settling pond is calculated at 5 cross sections in the upstream of the actual weir by non-uniform flow equation.

The maximum and normal water levels are calculated at EL. 135.5 m and EL. 133.3 m, as in Fig. 4.1-5.

4.1.5 Preliminary Design

The intake of sand settling pond is located at 650 m upstream from the actual weir of the intake. The topographic condition determines 50 m wide and 100 m long for the sand settling pond.

The pond should be deeper than 3 m so as to reduce the current velocity, and sediment storage volume for 1 week ensures 1 m deep.

The bottom of the pond should incline as I = 1/240 which is needed to produce the velocity for flashing settled sediment.

Table 4.1-2 and Fig. 4.1-6 show the Dimension and preliminary design.

4.1.6 Operation and Maintenance

The water level of EL. 132.8 m controls the intake volume, which is as high as the actual intake weir. When the water level lowers than EL. 132.8 m, the intake valve at the pump station shall throttle to reduce the intake volume.

To clean the sand settling pond, the inlet and outlet gates shall be operated. If the sediment is filled with the sediment storage volume, the inlet gate is closed and the outlet gate is opened to drain the sediment off. After the pond becomes empty, the inlet gate is slightly opened and sediment is flashed out. The gate operation is required approximately three times a month.

4.2 Feasibility Study on Reforestation

4.2.1 Reforestation Site Selection

At present, SS is estimated at 900 mg/*l* against the water quality standard of 750 mg/*l* at the water intake point in San Antonio de Yare. This value is estimated to increase to 960 mg/*l* in 2003. To prevent the increment of SS, the target of the short term program is set at 920 mg/l. Therefore, the increment of 40 mg/l in 2003 shall be reduced by the optimum combination of measures.

Reforestation is selected for grassland on steep sloped areas in Qda. Maitana (3,342 ha.). From the result of the Universal Soil Loss Equation, 22,080m^3 of suspended solid is annually reduced by the reforestation.

These are located in separate 2 blocks. Their location and area, named Qda. Santa Maria and Palo Negro are shown in Table 4.2-1 and Fig. 4.2-1.

These 2 blocks are located in the protection zone of Caracas City established in 1992 by the cabinet order. According to the order, expropriation is not necessary for the implementation of reforestation; only permission from the landowners is needed. Table 4.2-2 shows the landowners in the planting area.

4.2.2 Reforestation Operation Plan

(1) Planting Plan

The planting area is mainly separated to fire resistant belt and reforestation area because the grassland and deforestation area in the Study area incidentally burns in every dry season. From the point of fire prevention, 20 m wide forest roads and belts on both sides will act as fire breakers with fire resistant trees. The evergreen tree whose inside is wetter than the deciduous tree in dry season is appropriate to the fire resistant tree. An example is shown in Fig. 4.2-2.

Reforestation has two ways: a single plantation and mixed plantation. The single plantation is generally used to the forest product, while the mixed plantation is applied to an environmental improvement project. In the aim of reforestation in the Study, which is environmental improvement and erosion control, a mixed planting plan is recommended. The mixed plantation expects the following advantages:

- A mixed plantation creates a multi-layered vegetation cover which is desirable for the protection of surface soil against the impact of rain and hence erosion;
- A mixed plantation provides a wide range of resistance to insects and plant diseases in comparison to a mono-culture plantation;

(2) Choice of Tree Types

For the fire resistant belt and mixed planting, the following characteristics short-lists tree types. Those tree types are listed in Table 4.2-3.

- Existing types common in and around study area with the growth capability in degraded sites;
- Leguminous for nitrogen fixation to improve soil condition;
- Fast growth to form a vegetation cover for the area in the shortest possible time; and
- Seedling costs more than cutting. Kinds for logging should be limited in order to reduce the total project cost.

For the fire resistance belt, Cuji, evergreen and medium fire resistant tree, is chosen and will be planted at a distance of 3 m x 3 m (1,110 trees/ha) according to the tree size.

For the mixed plantation, Gliriscidia sp and Bauhinia, larger than other trees, are selected from the list. The mixing rate of two trees is one to one. A planting distance of 2.5 m x 3 m (1,334 trees/ha) will be applied to the mixed planting.

The target reforestation area and the required number of seedlings are shown in Table 4.2-1.

(3) Compartmentalization

The necessary reforestation sites are located in five separate blocks whose area is from 639 ha to 2,675 ha. A plantation area is divided into compartments from 100 to 300 ha for a better plan implementation and management considering human working capacity and natural features.

The compartment of Qda. Santa Maria No. 2 is subdivided into sub-compartments of approx. 200 ha that will function as units with existing access roads and natural features such as streams and ridges forming their boundaries. An example of a suitable area for reforestation divided into compartments is shown in Fig. 4.2-3.

(4) Nursery Plan

There is the existing idle nursery station of MARNR of 0.28 ha located in Qda la Virgen in the north area of Los Teques. This nursery with the seeding facilities will be used for the implementation, although the capacity of this nursery is insufficient and the topographic condition does not allow extension of the area. Therefore, a new nursery is an alternative for mainly potted seedling. The new nursery will be built in a suitable location near project area (refer subsection 4.2.4).

(5) Planting Season

A planting season depends on soil moisture, which is critical to rooting. Thus the period from May (beginning of the rainy season) to the end of September is preferable for the planting season.

4.2.3 Maintenance and Protection Plan

This includes activities such as replanting, fertilizer application and weeding.

(1) Replanting

To assume the target to reduce the surface erosion, replanting needs when seedling withered in a certain level. When mortality rate of planted seedlings is more than 10% which is generally applied in the reforestation plan, replanting will be carried out 2 to 3 months after planting using the same types.

(2) Fertilizer Application

To accelerate the growth of plant which is mainly affected by pH, ion and organic matters, neutralization by lime to acidic soil and both chemical and organic fertilizers will be applied. To know the need of neutralization and fertilizers, the soil pH test, measurement of electric conductivity and soil observation were conducted in the planting area.

A pH value between 6 and 7 has been recorded for the whole planting area, which means that soil slightly tends acidic and does not need lime neutralization .

The electric conductivity test shows dissolution of ion in soil and the need of fertilizer. The measured values are between 0.2 and 1.3 ms/cm. Such value means soils need fertilizers. Ten (10) gr. of NPK fertilizer will be applied.

According to the field observation, the soil of planting area is sandy and does not contain any organic matter. Therefore, 50 gr. of organic fertilizers will be enough.

Fertilizer application will firstly be during tree planting. Fertilizer is mixed with topsoil and put at the bottom of planting hole before planting. If tree grows weak and slowly, the second fertilizer will be applied after the first weeding.

(3) Weeding

To promote the expected growth of seedling, it is necessary to weed unwanted grass which hinders the growth of seedling between planted trees. For that purpose, weeding should be preferably 2 months after planting before applying fertilizer. An area up to 1.0 m wide around tree trunk shall be cleared.

(4) Grazing and Fire Prevention

Cattle grazing is common in the Project Area and this may damage plantations. To protect plantations, a fence is effective but its price is not economical in the area. Therefore it is recommended to promote public education on the reforestation and cooperation to keep their cattle out of plantations.

In the Study area, bush fire is hazardous to reforestation. Local cooperation near plantations is essential. Like grazing, public education and advertisements can be more favored for the prevention of forest fires.

4.2.4 Preliminary Design of Facilities

(1) Nursery

Based on the standards in Venezuela, pots of which size is generally 15 cm length and 10 cm width will be used. Access path will be 0.6 m wide and road width will be 4 m. the nursery area for the reforestation period of 5 years which will require 460,700 seedlings/year is calculated as follows:

One 15 cm long and 10 cm wide pot when filled with soil will have a filled area of 78.5 cm^2. Thus, 127 pots/m^2 of pot bed can be accommodated. Seedlings or pots amounting to 460,700 will be required and 460,700 / 127 = 3,630 m^2 will be for pot bed. A seedbed area 20% of pot bed area which is 730 m^2, is considered. Therefore, pot bed and seedbed areas will be 4,360 m^2. An additional 20% of the bed area will be set aside as a reserve. Hence, the total bed area or productive area will be 5,230 m^2.

Non-productive areas such as access path, road between beds, soil mixing and compost shed, fence and windbreak, working shed, tool shed, etc., will be roughly twice of the productive area. Therefore, the total area of the nursery will be 15,690 m^2 or approximately 1.57 ha for the 5 years.

MARNR has a nursery of 0.28 ha in Los Teques. Therefore, a new nursery of 1.3 ha has to be constructed. A nursery site is chosen at adjacent land to the proposed wastewater treatment plant at Las Tejerías, considering the following points:

- Accessibility for easy mobilization of equipment and manpower;

- Topographic requirement which should be flat and spacious;
- Availability of irrigation water, especially during dry season;
- Climatic adaptability to the reforestation area;

(2) Forest Road

The existing road in the reforestation area will be used as much as possible as forest road. New forest road will be constructed until where the forest distance to reforestation site is 1 km.

The forest road plan is the first activity that will be carried out before actual planting starts. In the Project Area it is estimated that the construction of 1 km of forest road could take some 5 weeks for the section of more than 8% of gradient and some 3 weeks for the flat section.

Forest roads will be constructed to provide suitable access to the areas required for the reforestation and to facilitate operation and maintenance. Planned forest roads will be connected existing secondary and main roads as shown in Fig. 4.2-3. Table 4.2-1 shows the total road length in the planned reforestation areas. When needed, work roads will be extended from planned forest roads to each work unit.

Forest road and access road construction will be implemented in accordance with following specifications:

Road bed width	6.00 meters
Carriage-way width	3.00 meters
Thickness of pavement	0.2 meter
Pavement material	graveled
Slope of pavement	6%
Shoulder width	1.5 meters (ea.)
Slope of shoulder	6%
Longitudinal slope	8% up to 12%
Maximum radius of curvature	30 meters

(3) Planting Plan

This includes staking, digging of holes and out-planting. Staking should be carried out to indicate digging points. It will be conducted after the spacing is decided. A planting hole of 30 cm x 30 cm x 30 cm will be dug. Holes smaller than this size may hamper root development. About 20 to 25 cm height of healthy seedlings with a vigorous growth and 30 cm of tree cuttings will be planted along contour lines.

Planting period is scheduled to be 5 years starting from 1999 in order to follow this schedule, 6 teams are required to accomplish the planting for 668 ha/year, and each should be composed of 23 persons to cover 1 ha/day. Table 4.2-4 is the planting schedule.

SECTOR E

TABLES

Table 1.3-1 "C & P" Values

No.	Area (km²)	C	P
1	Forest	0.005	1.0
2	Bush	0.010	1.0
3	Sab. Bosque	0.015	1.0
4	Sab. Chaparro	0.020	1.0
5	Sab. Abierta	0.025	1.0
6	Grass	0.025	1.0
7	Agriculter	0.020	0.5
8	Town	0.100	0.3

Note : Sab. means Sabana

Table 1.3-2 Sediment Delivery Rate

No.	Area (km²)	SDR
1	0.05	0.580
2	0.1	0.520
3	0.5	0.390
4	1	0.350
5	5	0.250
6	10	0.220
7	50	0.153
8	100	0.127
9	500	0.079
10	1000	0.059

Note : The table of Morgan "1980)

Table 1.3- 3 Soil Loss and Volume of Suspended Solid

Sub-Basin		Area	Soil Loss (Wash Load)			Sediment	Volume of Suspended Solid					
No.	Name	(km²) (1)	(t/year) (2)	%	(t/km²/year) (2)/(1)	Delivery Ratio(3)	(t/year) (2)x(3)/.75=(4)	(t/km²/year) (4)/(1)	(m³/year) (5)	%	(m³/km²/ year) (6)	a SS=aQ²
1	TUY RIVER	238	401271	15.5%	1686	0.11	59088	248	81229	14.4%	341	76
2	Qda. EL SOCORRO	139	195847	7.6%	1409	0.12	31941	230	43910	7.8%	316	70
3	Qda. GUAYAS	136	230214	8.9%	1693	0.12	37657	277	51767	9.2%	381	84
4	CAGUA RIVER	84	175276	6.8%	2087	0.14	31624	376	43474	7.7%	518	114
5	Qda. MAITANA	205	408365	15.8%	1992	0.11	62289	304	85629	15.2%	418	92
6	GUARE RIVER	194	328856	12.7%	1695	0.12	50740	262	69753	12.4%	360	80
UPPER TUY RIVER		996	1739829	67.4%	1747		273341	274	375761	66.5%	377	83
7	Qda. de SACUA	83	104285	4.0%	1256	0.14	18888	228	25965	4.6%	313	69
8	Qda. ANIAGUA	188	216567	8.4%	1152	0.12	33623	179	46221	8.2%	246	54
9	OCUMARITO RIVER	150	243550	9.4%	1624	0.12	39293	262	54016	9.6%	360	80
10	Qda. de MUME	67	16441	0.6%	245	0.14	3160	47	4344	0.8%	65	14
11	Qda. CHARALLAVE	141	103286	4.0%	733	0.12	16812	119	23112	4.1%	164	36
12	SUCUTA RIVER	155	147398	5.7%	951	0.12	23662	153	32528	5.8%	210	46
13	Qda. SECA	77	11091	0.4%	144	0.14	2055	27	2825	0.5%	37	8
MIDDLE TUY RIVER		861	842618	32.6%	979		137493	160	189012	33.5%	220	49
Total		1857	2582447	100.0%	1391		410834	221	564773	100.0%	304	67
14	Lagartijo	294	437396		1488	0.10	60489	206	83154		283	63

Table 1.3-4 Relation Between Discharge Volume of Suspended Solid and Land Use

Suspended Solid Volume of Land Use Category (A) — Unit m³/year

	River	Forest	Bush	Open Sabana	Sab. Chaparro	Sab. with Bush	Grass	Agriculture	Town	Total
1	TUY RIVER	10190 1.8%	26312 4.7%	2293 0.4%	2424 0.4%	22069 3.9%	12838 2.3%	5102 0.9%		81229 14.4%
2	Qda. EL SOCORRO	2407 0.4%	12716 2.3%	690 0.1%	3016 0.5%	10238 1.8%	10777 1.9%	2324 0.4%	1742 0.3%	43910 7.8%
3	Qda. GUAYAS	1875 0.3%	33511 5.9%				11535 2.0%	661 0.1%	4185 0.7%	51767 9.2%
4	CAGUA RIVER	3822 0.7%	5247 0.9%			8194 1.5%	25556 4.5%	655 0.1%	0.0%	43474 7.7%
5	Qda. MAITANA	6283 1.1%	33506 5.9%			3609 0.6%	29915 5.3%	292 0.1%	12021 2.1%	85629 15.2%
6	GUARE RIVER	9027 1.6%	15994 2.8%	659 0.1%			34379 6.1%	9693 1.7%	0.0%	69753 12.4%
	UPPER TUY RIVER	33604 6.0%	127285 22.5%	3642 0.6%	5441 1.0%	44111 7.8%	125000 22.1%	18726 3.3%	17949 3.2%	375761 66.5%
7	Qda. de SACUA	811 0.1%	7404 1.3%	4891 0.9%		11360 2.0%		812 0.1%	687 0.1%	25965 4.6%
8	Qda. ANIAGUA	5464 1.0%	23752 4.2%	293 0.1%			8969 1.6%	7744 1.4%		46221 8.2%
9	OCUMARITO RIVER	8175 1.4%	10425 1.8%				20010 3.5%	12757 2.3%	432 0.1%	54016 9.6%
10	Qda. de MUME	1059 0.2%	1009 0.2%	646 0.1%				406 0.1%	1224 0.2%	4344 0.8%
11	Qda. CHARALLAVE	1883 0.3%	9641 1.7%	331 0.1%		250 0.0%	4143 0.7%	78 0.0%	6786 1.2%	23112 4.1%
12	SUCUTA RIVER	1502 0.3%	4541 0.8%				7949 1.4%	16807 3.0%	184 0.0%	32528 5.8%
13	Qda. SECA	24 0.0%	1816 0.3%	467 0.1%				259 0.0%	259 0.0%	2825 0.5%
	MIDDLE TUY RIVER	18917 3.3%	58588 10.4%	6629 1.2%		11610 2.1%	41071 7.3%	38863 6.9%	9571 1.7%	189012 33.5%
	TOTAL	52521 9.3%	165874 32.9%	10271 1.8%	5441 1.0%	55721 9.9%	166071 29.4%	57589 10.2%	27520 4.9%	564773 100%

Land Use Situation (B) — Unit km²

	River	Forest	Bush	Open Sabana	Sab. Chaparro	Sab. with Bush	Grass	Agriculture	Town	Total
1	TUY RIVER	64 3.4%	84 5%	3 0%	3 0.2%	41 2.2%	15 0.8%	28 1.5%		238 12.8%
2	Qda. EL SOCORRO	15 0.8%	46 2%	3 0%	6 0.3%	27 1.5%	15 0.8%	21 1.1%	6 0.3%	139 7.5%
3	Qda. GUAYAS	13 0.7%	99 5%				13 0.7%	3 0.2%	8 0.4%	136 7.3%
4	CAGUA RIVER	20 1.1%	18 1%			16 0.9%	27 1.5%	3 0.2%	0.0%	84 4.5%
5	Qda. MAITANA	40 2.2%	104 6%			7 0.4%	32 1.7%	1 0.1%	21 1.1%	205 11.0%
6	GUARE RIVER	49 2.6%	53 3%	4 0%			34 1.8%	54 2.9%	0.0%	194 10.5%
	UPPER TUY RIVER	201 10.8%	404 22%	10 1%	9 0.5%	91 4.9%	136 7.3%	110 5.9%	35 1.9%	997 53.7%
7	Qda. de SACUA	5 0.3%	33 2%	6 0%		18 1.0%		10 0.5%	11 0.6%	83 4.5%
8	Qda. ANIAGUA	24 1.3%	100 5%	1 0%			12 0.6%	51 2.7%		188 10.1%
9	OCUMARITO RIVER	25 1.3%	36 2%				23 1.2%	65 3.5%	1 0.1%	150 8.1%
10	Qda. de MUME	7 0.4%	17 1%	10 1%				29 1.6%	4 0.2%	67 3.6%
11	Qda. CHARALLAVE	14 0.8%	95 5%	1 0%		1 0.1%	7 0.4%	4 0.2%	19 1.0%	141 7.6%
12	SUCUTA RIVER	9 0.5%	19 1%				9 0.5%	110 5.9%	7 0.4%	154 8.3%
13	Qda. SECA	1 0.1%	38 2%	6 0%				25 1.3%	7 0.4%	77 4.1%
	MIDDLE TUY RIVER	85 4.6%	338 18%	24 1%		19 1.0%	51 2.7%	294 15.8%	49 2.6%	860 46.3%
	TOTAL	286 15.4%	742 40%	34 2%	9 0.5%	110 5.9%	187 10.1%	404 21.8%	84 4.5%	1857 100%

Unit Suspended Solid Volume on Land Use Categoly (A)/(B)

	River	Forest	Bush	Open Sabana	Sab. Chaparro	Sab. with Bush	Grass	Agriculture	Town	Total
1	TUY RIVER	159	313	764	808	538	856	182		341
2	Qda. EL SOCORRO	160	276	230	503	379	718	111	290	316
3	Qda. GUAYAS	144	338				887	220	523	380
4	CAGUA RIVER	191	292			512	947	218		517
5	Qda. MAITANA	157	322			516	935	292	572	418
6	GUARE RIVER	184	302	165			1011	179		359
	UPPER TUY RIVER	167	315	364	605	485	919	170	513	377
7	Qda. de SACUA	162	224	815		631		81	62	313
8	Qda. ANIAGUA	228	238	293			747	152		246
9	OCUMARITO RIVER	327	290				870	196	432	360
10	Qda. de MUME	151	59	65				14	306	65
11	Qda. CHARALLAVE	134	101	331		250	592	19	357	164
12	SUCUTA RIVER	167	239				883	153	26	211
13	Qda. SECA	24	48	78				10	37	37
	MIDDLE TUY RIVER	223	173	276		611	805	132	195	220
	TOTAL	184	251	302	605	507	888	143	328	304

Table 1.3-5 Suspended Solid Volume at Hda. Tazon

year	Wash Load		Suspended Load		SS Total	
	(m^3)	($m^3/km^2/year$)	(m^3)	($m^3/km^2/year$)	(m^3)	($m^3/km^2/year$)
1947-48	49,890	43.6	7,034	6.2	56,924	49.8
1948-49	218,915	191.5	30,867	27.0	249,782	218.5
1949-50	218,094	190.8	30,751	26.9	248,845	217.7
1950-51	822,788	719.8	116,013	101.5	938,801	821.3
1951-52	597,883	523.1	84,302	73.8	682,185	596.8
1952-53	115,075	100.7	16,226	14.2	131,301	114.9
1953-54	202,610	177.3	28,568	25.0	231,178	202.3
1954-55	255,845	223.8	36,074	31.6	291,919	255.4
1955-56	200,503	175.4	28,271	24.7	228,774	200.2
1956-57	149,067	130.4	21,018	18.4	170,085	148.8
1957-58	75,874	66.4	10,698	9.4	86,572	75.7
1958-59	598,150	523.3	84,339	73.8	682,489	597.1
1959-60	294,463	257.6	41,519	36.3	335,982	293.9
1960-61	587,100	513.6	82,781	72.4	669,881	586.1
1961-62	191,054	167.2	26,939	23.6	217,993	190.7
1962-63	96,529	84.5	13,611	11.9	110,140	96.4
1963-64	462,910	405.0	65,270	57.1	528,180	462.1
Average	302,162	264.4	42,605	37.3	344,767	301.6

Table 3.3-1 Valuation of Suspended Solid Volume by Reforestation

Sub-Basin		Area	Actual	Reforestation			
		(km^2)	SS(m^3/year)	(km^2)	SS(m^3/year)	Effect(m^3/year/km²)	Effect Rate
No.	Name	(A)	(1)	(B)	(2)	((1)-(2))/(B)	((1)-(2))/Total(1)
1	TUY RIVER	238	81229	90	50735	339	5.4%
2	Qda. EL SOCORRO	139	43910	72	24609	268	3.4%
3	Qda. GUAYAS	136	51767	16	41910	616	1.7%
4	CAGUA RIVER	84	43474	46	16839	579	4.7%
5	Qda. MAITANA	205	85629	40	58737	672	4.8%
6	GUARE RIVER	194	69753	92	38786	337	5.5%
UPPER TUY RIVER		996	375761	356	231168	406	25.6%
7	Qda. de SACUA	83	25965	34	14274	344	2.1%
8	Qda. ANIAGUA	188	46221	64	36209	156	1.8%
9	OCUMARITO RIVER	150	54016	88	31982	250	3.9%
10	Qda. de MUME	67	4344	39	3651	18	0.1%
11	Qda. CHARALLAVE	141	23112	13	19338	290	0.7%
12	SUCUTA RIVER	155	32528	119	19861	106	2.2%
13	Qda. SECA	77	2825	31	2340	16	0.1%
MIDDLE TUY RIVER		861	189012	388	127655	158	10.9%
Total		1857	564773	744	358823	277	36.5%

Table 3.3-2 Capacity and Cost of Sand Settling Pond

Case 1	Discharge Cut Rate	Sed. V (m^3 /year)	Cut Sed. V (1)	Dimension W×D×L & Volume (m^3) of Pond	Intal+O/M Cost (US$/year)(2)	Unit Cost (US$)(2)/(1)
Tuy-Hda. Barrios	70%	81,229	40,105	100×2.10×225		
(213km²)		49% cut		36,000	597,352	14.9
Cagua	70%	43,474	24,815	70×1.80×225		
(84km²)		57% cut		22,400	451,751	18.2
Maitana	70%	85,629	41,911	100×2.10×225		
(205km²)		49% cut		38,000	601,060	14.3
Guare	70%	69,753	34,684	100×1.80×225		
(194km²)		50% cut		30,000	555,186	16.0
Total		563,109	141,515	126,400		
(1857km²)		25% cut				

Case 2	Discharge Cut Rate	Sed. V (m^3 /year)	Cut Sed. V (1)	Dimension W×D×L & Volume (m^3) of Pond	Intal+O/M Cost (US$/year)(2)	Unit Cost (US$)(2)/(1)	Priority
Tuy-Hda. Barrios	60%	81,229	34,503	100×1.80×200			
(213km²)		42% cut		36,000	501,304	14.5	2
Cagua	60%	43,474	21,350	70×1.60×200			
(84km²)		49% cut		22,400	386,993	18.1	4
Maitana	60%	85,629	36,055	100×1.90×200			
(205km²)		42% cut		38,000	514,719	14.3	1
Guare	60%	69,753	29,838	100×1.50×200			
(194km²)		43% cut		30,000	464,854	15.6	3
Total		563,109	121,746	126,400			
(1857km²)		22% cut					

Case 3	Cut Rate	Sed. V (m^3 /year)	Cut Sed. V (1)	Dimension W×D×L & Volume (m^3) of Pond	Intal+O/M Cost (US$/year)(2)	Unit Cost (US$)(2)/(1)
Tuy-Hda. Barrios	50%	81,229	29,055	100×1.70×175		
(213km²)		36% cut		29,750	452,055	15.6
Cagua	50%	43,474	17,985	70×1.50×175		
(84km²)		41% cut		18,375	357,235	19.9
Maitana	50%	85,629	30,193	100×1.80×175		
(205km²)		35% cut		31,500	461,630	15.3
Guare	50%	69,753	24,986	100×1.50×175		
(194km²)		36% cut		26,250	423,810	17.0
Total		563,109	102,219	105,875		
(1857km²)		18% cut				

Table 3.3-3 Comparison of Settling Sediment Volume by Sand Settling Pond's Size

Month	Mean Discharge (1939~1978) (m^3/s)	Intake V m^3/s	SS of Tuy mg/l	SS Volume Through the Settling Pond			Settling Sediment Volume (m^3/month) (2)					
							Size of sand Settling Pond					
				t/day	t/month	m^3/month (1)	3000m^2	Gate Operation Time (/month)	5000m^2	Gate Operation Time (/month)	7000m^2	Gate Operation Time (/month)
Jan	7.07	5.7	473	231	7168	10018	5473	1.8	7730	1.5	8282	1.2
Feb	4.19	3.3	280	81	2273	3651	2738	0.9	3144	0.6	3376	0.5
Mar	2.53	2.0	170	30	919	1476	1335	0.4	1314	0.3	1467	0.2
Apr	2.20	1.8	147	22	671	1078	1012	0.3	964	0.2	1087	0.2
May	4.43	3.5	297	91	2822	4534	3306	1.1	3878	0.8	4149	0.6
Jun	14.10	7.0	945	573	17199	27629	12830	4.3	19206	3.8	21595	3.1
Jul	17.57	7.0	1177	714	22143	35572	16518	5.5	24727	4.9	27803	4.0
Aug	17.65	7.0	1182	718	22246	35737	16595	5.5	24842	5.0	27932	4.0
Sep	16.09	7.0	1078	654	19628	31531	14642	4.9	21918	4.4	24645	3.5
Oct	17.93	7.0	1202	729	22606	36315	16863	5.6	25244	5.0	28384	4.1
Nov	13.78	7.0	923	560	16812	27006	12541	4.2	18773	3.8	21109	3.0
Dec	10.17	7.0	682	414	12822	20597	9565	3.2	14318	2.9	16099	2.3
Total						235144	113416	37.8	166059	33.2	185928	26.6
Mean	10.6	5.5	713	402	12276	19595	9451	3.2	13838	2.8	15494	2.2
						(1)/(2) %	48%		71%		79%	

Table 3.3-4 Benefit and Cost of Countermeasure for Turbidity

Case	Size	Reduction Volume of SS (mg/l) (1)	Unit Cost us$/m³ / Effect (8hr/day)	Benefit (US$/year) Intake 0.327	Alumni 0.0062	Total(2)	Cost (US$/year) Initial Cost	OM Cost	Pre-tori OM Cost 0.011	Total(3)	Unit cost (3)/(1)	B-C (2)-(3)	B/C (2)/(3)
Reforestation													
Case 1 (SS= 4.8% cut)	4000ha	46	4.7 m³/s × 1.4 days	62,179	9,854	72,032	330,000	20,000	2,092	352,092	7,641	-280,059	0.20
Case 2 (SS= 6.5% cut)	5600ha	62	4.8 m³/s × 1.7 days	76,728	13,560	90,287	462,000	28,000	2,581	492,581	7,894	-402,294	0.18
Case 3 (SS= 11.2% cut)	10200ha	108	5.0 m³/s × 2.4 days	114,044	24,396	138,440	841,500	51,000	3,836	896,336	8,336	-757,896	0.15
Case 4 (SS= 16.7% cut)	19400ha	160	5.3 m³/s × 3.0 days	148,370	38,175	186,545	1,600,500	97,000	4,991	1,702,491	10,619	-1,515,946	0.11
Sand Settling Pond on 4 Tributaries								5.0					
Case 1 (SS= 6.4% cut)	Maltena=(a)	61	4.8 m³/s × 1.7 days	76,658	13,345	90,003	331,865	180,275	2,579	514,719	8,373.9	-424,716	0.17
Case 2 (SS= 12.5% cut)	(a)+Hda. Barrios=(b)	120	5.1 m³/s × 2.4 days	114,454	27,619	142,074	659,383	352,790	3,850	1,016,023	8,446.5	-873,949	0.14
Case 3 (SS= 17.8% cut)	(b)+Guere=(c)	171	5.3 m³/s × 3.0 days	149,805	41,150	190,955	973,857	501,980	5,039	1,480,877	8,652.1	-1,289,922	0.13
Case 4 (SS= 21.6% cut)	(c)+Cagua=(d)	208	5.5 m³/s × 3.5 days	180,396	51,506	231,902	1,253,072	608,730	6,068	1,867,870	8,999.4	-1,635,968	0.12
Case 5 (SS= 25.6% cut)	(d)+Guayas	246	5.7 m³/s × 4.0 days	212,948	63,043	275,991	1,554,504	720,855	7,163	2,282,522	9,280.2	-2,006,532	0.12
[illegible]								22.4					
Case 1 (SS= 47.4% cut)	40×130m	455	6.6 m³/s × 5.4 days	335,447	136,857	472,305	401,046	58,248	11,284	470,577	1,034.1	1,728	1.00
Case 2 (SS= 45.5% cut)	40×100m	437	6.5 m³/s × 5.1 days	316,941	129,678	446,619	343,500	44,806	10,662	398,968	913.4	47,652	1.12
Case 3 (SS= 42.9% cut)	40×70m	412	6.4 m³/s × 4.8 days	293,110	120,083	413,193	287,178	31,364	9,860	328,402	797.4	84,791	1.26
Sand Settling Pond before Intake of Qda. Seca			Settling Sediment Vollume (m³/year)	Sedinentation Pond in Qda. Seca Initial Cost	OMCost 36/m³	Total(2)	Sedinentation Pond before Intake Initial Cost	OM Cost		Total(3)	Unit cost (3)/(1)	(2)-(3)	(2)/(3)
Case 1 (SS= 48.0% cut)	3000m²	461	113420	3,730	680,520	684,250	587,710	18,900	-	606,610	1,316.4	77,640	1.13
Case 2 (SS= 71.0% cut)	5000m²	682	166060	4,660	996,360	1,001,020	687,010	16,600	-	703,610	1,032.3	297,410	1.42
Case 3 (SS= 79.0% cut)	7000m²	758	185930	6,060	1,115,560	1,121,620	-	-	-	-	-	-	-

Table 4.1-1 Sediment Volume in Pre-treatment Pond for 1 Year

Pond No.	Date of Cleaning Pond		Sediment		Total V (m³)
	Start	End	Depth (m)	Volum (m³)	
1	1995/11/20	1995/11/23	1.15	2263	
1	1995/12/28	1995/12/29	1.00	1968	
1	1996/6/17	1996/6/19	1.00	1968	
1	1996/7/15	1996/7/16	1.80	3542	
1	1996/8/8	1996/8/12	1.50	2952	
1	1996/9/18	1996/9/19	1.50	2952	
1	1996/10/7	1996/10/10	1.30	2558	
1	1996/10/28	1995/10/29	1.10	2165	
1	1996/11/18	1996/11/21	1.20	2362	22730
2	1995/11/22	1995/11/22	1.00	1968	
2	1996/1/2	1996/1/3	1.10	2165	
2	1996/6/20	1996/6/21	1.00	1968	
2	1996/7/17	1996/7/18	2.00	3936	
2	1996/8/23	1996/8/28	2.50	4920	
2	1996/9/20	1996/9/23	1.00	1968	
2	1996/10/9	1996/10/11	1.20	2362	
2	1996/10/30	1996/10/31	1.20	2362	
2	1996/11/22	1996/11/23	1.20	2362	24009.6
3	1995/11/24	1995/11/27	1.10	2165	
3	1996/7/8	1996/7/11	1.50	2952	
3	1996/7/19	1996/7/23	1.60	3149	
3	1996/8/29	1996/9/4	2.50	4920	
3	1996/9/25	1996/9/27	1.00	1968	
3	1996/11/1	1996/11/1	1.10	2165	17318.4
4	1995/11/10	1995/11/125	1.00	1968	
4	1996/1/4	1996/1/5	1.00	1968	
4	1996/7/1	1996/7/3	1.20	2362	
4	1996/7/30	1996/7/31	2.00	3936	
4	1996/9/5	1996/9/11	2.00	3936	
4	1996/9/24	1996/9/25	1.00	1968	
4	1996/11/5	1996/11/7	1.30	2558	18696
5	1995/11/16	1995/11/17	1.50	2952	
5	1996/6/27	1996/6/28	1.00	1968	
5	1996/8/6	1996/8/7	1.80	3542	
5	1996/9/30	1996/10/1	1.00	1968	
5	1996/10/22	1996/10/24	1.20	2362	
5	1996/11/8	1996/11/8	1.00	1968	14760
6	1995/11/20	1995/11/20	1.20	2362	
6	1996/6/11	1996/6/13	1.00	1968	
6	1996/8/1	1996/8/6	2.40	4723	
6	1996/9/12	1996/9/18	2.00	3936	
6	1996/10/2	1996/10/4	1.10	2165	
6	1996/10/24	1996/10/25	1.10	2165	
6	1996/11/11	1996/11/11	1.10	2165	19483
Total (Average intake volume = 3.27m³/s					116998

Table 4.1-2 Dimension of Sand Settling Pond

Part	Size		Bottom	
	Length(m)	Width(m)	Height(EL.m)	Inclination
Inlet	30	20	131.5	0
Spreader	25	20~52	131.5~130.5	1/25
Settling Pond	100	52 (25×2)	129.5~129.08	1/240
Intake	20	52~20	129.08~129.0	1/240
Outlet	40	20~10	129.0~128.87	1/240
Channel	20	10	128.87~128.75	1/240
Sediment Charging Volume(m^3)			5,000	

Instrument	Unit
Inlet Gate (2m×2m)	8
Outlet Gate (2m×2m)	8

Table4.2-1 Compartmentalization of Reforestation Area

	Block Name	Co. No.	Area (ha)	Reforestation Area (ha)	Belts of Fire Resistant Trees (ha)	Distance of New Forest road (km)	Total of Existing Road (km)	Mixed Planting	Fire Resistant Trees	Cutting	Seedling
1	Qda. Santa Maria	1	59.1	57.9	1.2		0.3	77218	1333	38609	39942
2		2	1129.2	1077.2	52.0		13.0	1436318	57778	718159	775937
3		3	361.0	355.0	6.0	0.8	0.7	473394	6667	236697	243364
4		4	182.9	156.9	26.0		6.5	209141	28889	104571	133460
5		5	189.5	175.1	14.4		3.6	233470	16000	116735	132735
6		6	362.6	349.4	13.2		3.3	465868	14667	232934	247601
7		7	244.7	224.7	20.0		5.0	299542	22222	149771	171993
8		8	146.2	139.0	7.2		1.8	185371	8000	92686	100686
Sub-total			2675.2	2535.2	140.0	0.8	34.2	3380323	155556	1690161	1845717
9	Palo Negro	1	177.9	173.9	4.0	0.4	0.6	231875	4444	115938	120382
10		2	349.9	333.5	16.4	1.4	2.7	444631	18222	222315	240538
11		3	139.2	130.0	9.2	1.2	1.1	173276	10222	86638	96860
Sub-total			666.9	637.3	29.6	3	4.4	849782	32889	424891	457780
total			3342.2	3172.6	169.6	3.8	38.6	4230105	188444	2115053	2303497
Quantity for 1 year			668.4					846021	37689	423011	460699

Table.4.2-2 Landowner in the Reforestation Area

No.	Area Name	No.	Owner	Observation	ha (aprox.)	Address
1	Qda. Santa Maria	1	No data available	No data available		Unknown
2		2	Sucesion Hermanos Bravos		920	Moscatel Piso 4, Apto. 4 - 2. Los Teques
3		3	No data available	No data available		Unknown
4		4	Sucesion Hermanos Bravos		920	Moscatel Piso 4, Apto. 4 - 2. Los Teques
5		5	Ditto		920	Ditto
6		6	Ditto		920	Ditto
7		7	Ditto		920	Ditto
8		8	No data available	No data available		
9	Palo Negro	1	Instituto Agrario Nacional	Estates belong to Agriculture National	450	Unknown
10		2	Instituto Agrario Nacional	Ditto	450	Ditto
			& Abrahan Malave	Ocampo Farm (Finca Ocampo)	290	Ditto
11		3	Abrahan Malave	Ditto	290	Ditto

Table 4.2-3 Tree Types for Planting

Types (Local Name)		Sowing & Distance (m×m)	Resistance to Fire	Maintenance Required	Annual Growth, Diameter & Height	Cost (Bs)	Selection
Fire Resistant Tree Belt	Alnus Jorulensis (Aliso)	Seed 4×4~4×5	Weak Evergreen.	Laborious	0.5 m/year ϕ=20 cm. Height = 15~20 m	86.14	
	Cuji (Prosopis Julifora)	Seed 3×3 ~ 3×4	Medium Evergreen	Only a little	1 m/year ϕ=8 ~ 15cm Height = ± 3 ~ 5 m	86.14	●
Mixed Planting Area	Bauhinia (Pata e'Vaca)	Seed 3×3 ~ 3×4	Weak Deciduous tree in dry season	Only a little Resist to dry season.	0,5 - 1 mt/year. ϕ= 8 ~15 cm. Height = 4 ~ 7 m	86.14	●
	Cassia Moschata (Caña Fistolo)	Seed 2×2	Weak Deciduous tree in dry season	Only a little.	0,5 mt/year ϕ = 30 cm Height = ± 4 m	86.14	
	Gliriscidia sp (Mataraton)	Cutting or Seed 2×2	Weak Deciduous tree in dry season	Only a little	1 m/year or more. ϕ= 8 ~ 15cm Height = ±3 ~ 4 m	20.54	●

Table4.2-4 Nursery & Planting Activity Schedule for Reforestation

No.	Activity	Month														
		9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
1	Preparation of Nursery															
	- Land cleaning	—														
	- Building of facilities	—	—	—	—											
	- Preparation of soil for pots				—	—										
	- Procurement of seed					—										
2	Procurement of cutting								—							
3	Seeding					—	—	—	—							
4	Planting									—	—	—	—			
5	Weeding											—	—	—	—	—
6	Replanting												—	—	—	

Planting Activity Schedule of Blocks

	Block Name	Year				
		1999	2000	'01	'02	'03
1	Qda. Santa Maria No.1,2-4,4,5 (630ha)	—				
2	Qda. Santa Maria No.2-1,2-2 (707ha)		—			
2	Qda. Santa Maria No.2-3,6,8 (733ha)			—		
4	Qda. Santa Maria No.3,7 (605ha)				—	
5	Palo Negro (667ha)					—