

Marcos and reaching the site and the other runs through Quepos along the sea coast; the latter is the National Highway 239 running from Carudera Harbor, major harbor facing the Pacific Ocean. These roads are paved, but single-lane for each direction, and used for human traffic and transportation of goods from major cities. Area around Quepos is a sightseeing spot centering Manuel Antonio National Park, actively frequented by big buses in good seasons.

As the project area is in the mountains with roads connecting to the site being narrow and steep because of passing through forests, large vehicles have difficulty in traffic; roads going to Villa Nueva, Londres Naranjito and Junta Naranjo, however, are gravel ones, allowing small vehicle traffic.

(3) Education

Most of municipalities around the project area have schools; Londres, Villa Nueva, Esquipulas, Naranjito, Pascua and Paso Real are no exception, but have no educational system for secondary and higher education.

13.2.14 River Utilization

(1) Service Water

There are two springs in Nara in the protected zone on the east side of the Naranjo River downstream from the dam site. One of these (33 liters/sec) supplies water to Esquipulas, Villa Nueva and Naranjito, and the other (6.5 liters/sec) supplies water to Londres and Paso Indios. Part of the town of Londres is on a slope, so individual wells or a different spring is apparently used, and water shortages occur in the dry season.

Like the upper reaches, water for individual dwellings in Paso Real in the middle reaches is obtained from springs.

In Quepos City there are presently three sources of water: two wells near the Paquita River about 1.5 km to the south west of Ceritos (the pumping capacity is 18 liters/sec and 28 liters/sec, respectively, however the amount of water actually drawn off is 45 liters/sec), the La Gallega spring (average outflow is 10 liters/sec), and a well located near Llamaron downstream of the Naranjo River (the pumping capacity is 24 liters/sec, however the amount of water actually drawn off is 15 liters/sec).

Under the future plan for service water facilities in Quepos City, the present two wells are to be increased to provide a capacity of 80 liters/sec, water is to be drawn from the spring in the upper reaches of the Canus River at the rate of 28 liters/sec, and a well is to be dug in the lower reaches of the Naranjo River (across the river from the present water intake well) to provide 30 liters/sec of water (Figure 13-25). As a result of surveys carried out at the above places, it is clear that river water is not used directly for service water, but that there are wells from which the riverbed of the Naranjo River is drawn.

The present population of Quepos is about 12,000. There are about 200,000 tourists a year. Assuming that this figure rises to 30,000 during the dry season and that one person requires 200 liters of water a day, a water supply of 8,400,000 liters/day (97.2 liters persec) is necessary.

This amount of water can be more or less attained if the future plan is added to the present water supply capacity. Depending upon the scale of future tourist development, it maybe necessary to secure new water sources in these areas.

There are also three wells used to supply drinking water to the inhabitants of the palm plantations. At the house near the west end of Estero Garita, there is a well of 4 meters deep, about 15 m away from the high tide line on the shore. The water surface is 3 m from the ground level (the surface of the land is about 1.5 m above the high tide line). The water is slightly salty, and has a salt content of between 500 and 1,000 ppm. Between December and February, the well is dry, however water can apparently be obtained by digging about one meter below the bottom of the well.

The seasonal variation of water level and quality, shown in Table 13-8, are as follows:

- Naranjo River mouth (W-1): There are no significant changes in water levels from February to April, but salinity increases slightly.
- Sea side of Estero Negro (W-2): Water levels vary a little.
- North side of Negraforestal Lagoon (W-3): Water levels vary a little, but tend to increase slightly.
- Rice growing area south of Palma Tica plantation (W-4): Water levels increase.
- Near water intake (W-5): Water levels moves up and down, but show no decreasing trend.
- Quebrada Estero Negro (W-6): Water levels have increasing trend.

(2) **Agricultural Water**

a) **Palm Tica plantation**

Water obtained directly from the river (Figure 13-26) is used for the plantations on the left bank of the lower reaches of the Naranjo River (Table 13-30). Of the total area of 3,500 ha, 600 ha is under irrigation. Water for irrigation is obtained only during the dry season which extends from January to April. During this period, the average amount of water used is 1.43 m³/sec, through 1.8 m³/sec. of water is to be permitted by river water rights, utilization. When the land in this area is irrigated, the quality of the products improves. It is planned to increase the amount the water drawn off by 0.5 m³/second in 1996. It is also planned to irrigate the south end of the Palma Tica plantation in the near future. In this case, the water will be obtained from the Savegre River.

As shown in Figure 13-31, the palm plantations use the water from the Naranjo for irrigation. This water flows through a network of water channels to the mangrove area of Estero Negro. Measurements of flow rate and water quality were carried out on representative water channels from the dry season through the wet season. The results are shown in Table 13-31 ~13-32. The water quality was measured in order to obtain an idea of the source of the water flowing through the water channels and also to obtain a grasp of the nutrient supply situation attendant to variations in the volume of water supplied to the mangroves.

The following results were obtained from the survey. The survey was performed at a total of seven points: water intake point (TOMA) and six water channels in the plantation. Of these, the channel that has St.4 does not lead to the Estero Negro mangroves, but instead goes to the mouth of the river at Savegre in the south (Figure 13-26). The survey was started before the start of the dry season and performed through to the beginning of the wet season. The survey points along the channels were determined using the drawing that indicates the water channels up to Estero Negro on the seas side of the national route, taking into account the way in which the channels converge and tidal behavior, and aiming to eliminate the effects of convergence and tidal behavior. The results are summarized below (Table 13-33, Figure 13-27~13-29).

i) **Change of Flow Volume**

- **At the water intake (TOMA)**

Figure 13-27 shows the changes in flow rate. At the commencement of the survey in September, the flow rate was 0.2 m³/sec, however in December the bottom of the river was visible, and there was no evidence of water in take.

The fact that water was not taken on January 6 of the following year, but flow rate of 1.44 m³/sec. was observed on January 19 indicates that water intake operation started between these two dates. This water intake operation for agricultural use had been conducted since then and up to April 6, final date confirmed; completion date for this operation, however, is not exactly known, although the operation usually ends in the middle of April considering floods according to hearings.

- **St. 6**

A fairly high flow rate of about 1.8 m³/sec was measured at this point in September at the beginning of the survey; however, flow rate dropped as each month passed to find flow reversal at one occasion. Flow rate had been 0.5 to 0.7 m³/sec. since late march. There was no lack of water during the survey.

- **St. 7**

The flow rate at this point during the survey was small, in December the flow of water stopped altogether, and in January this point dried up altogether. This situation remained and unchanged until the last observation in June.

- **St. 8**

The flow rate through this water channel is also small, and the water stopped flowing temporarily in December and also stopped at February.

- **St. 9**

This water channel supplies the most amount of water. At the beginning of the survey, the measured flow rate was about 1.8 m³/sec which, like the flow rate through the channel that has St.6, greatly exceeds the flow rate at the water intake point. Even when the water intake channel from the Naranjo River dried up and the supply of water from the river stopped, water still flowed through the channel. Flow rate fluctuated between 0.4 and 1.3 m³/sec. from

middle of March to early March, but varied between 1.5 and 3.2 m³/sec from late March to early April, showing higher flow rate without any lack of water.

- St. 10

It dried up in January and no water flow continued until the end of the survey.

- St. 4

Flow rate of this channel generally fluctuated between 0.2 and 0.8 m³/sec. without almost no flow interruption. In summary, water from several sources flows through the water channels. The channels are divided into channels, like the channel that has St.4 or St.9, through which water continues to flow even when the water intake point dries up, the channel that has St.8 through which the flow of water stops when the water stagnates, and channels through which the flow of water stops when the intake of water stops and which take time to fill again after the intake of water is resumed.

Between January and April, the intake of water is carried out. The range of the channel network through which water flows is shown in Figure 13-16. The channels through which water does not flow and also the area which is affected by the tide from Estero Negro are shown in Figure 13-16.

The Queb Cacao water channel where water channels converge is a prepared tidal water channel through which a plentiful supply of water flows. Mangroves are distributed about the edge of the water channel near Estero Negro. And there is always water in this water channel, even in the dry season.

On the other hand, the water channel that enters Laguna Negraforestal is presently buried in deposited soil, hence the supply of water is extremely low.

ii) **Quality of water in channels**

A survey of the quality of water taken in and the water in the channels was carried out to determine whether or not this water affects other water in the dry season. The results are summarized below.

- At St.4, the affect of seawater was evident, however there was no affect at other points.

- The water at St.6, 7, 8, 9 and 10 was surface water, and had very similar characteristics during each season. There was no deep underground water mixed with it.

iii) Supply of nutrients

- **TIN**

Figure 13- shows the variation in the amount of TIN supplied. The water channel that supplies the greatest load of TIN is the one that has No.9. Between January and February the load of TIN decreased, but recovered in March. A similar trend can be seen in other water channels as well. The variation in the TIN load was small, however the supply from water channels that have a small flow rate, such as St.6, had relatively large TIN load, and also the supply from the water channel that has St.8, in which there was a large tendency for the water to stagnate, had small TIN load.

- **PO4-P**

Like TIN, the amount of PO4-P load was largest in the water channel that has St.9, and second largest in the water channel that has St.6. With the exception of St.9, there is a tendency for the amount of PO4-P load to decrease when the water intake channel dries up. Within one day after water intake started, the supply of PO4-P load increased sharply (Figure 13-29).

iv) Method of water intake from the Naranjo River in the dry season

As shown in Figure 13-30 , water is taken in using a method whereby a training dike is built by stacking stones on top of each other at an upstream point that faces the opposite bank of the Naranjo River. The water is branched from the water intake channel then taken to the plantation(Figure 13-31). The water supply area in March was surveyed or estimated as shown in Figure 13-16). It was judged that water had started to flow relatively recently because there was little algae on the base stone of the Queb Bartolo water channel from the north that continues on to the shrimp farm near the inlet from the Estero Negro sea.

v) Outflow to Estero Negro

The water from each water channel that converges at the Quec Cacao water channel and is stored there(Figure 13-32), flows over the weir at the confluence point to the Estero Negro as a result of the up and down motion caused by the tide and also the downward flow force due to the fact that the water is stored. At

times when there is relatively little water in the water channels, the tidal action becomes prominent, and particularly in the dry season there is an outflow due to the balance between the tidal fluctuation and the amount of water stored.

b) Plan plantain in FINCA LUZ

Following the mouth of the Naranjo River is a farm (FINCA) that runs a 170 ha palm plantation. In this farm, irrigation water for palm trees is supplied from a pool prepared by damming up channel from November to May.

c) Rice growing, and others

Based on on-site observations and Landsat images, there are prepared ranches, pasture lands, sparse forests and grasslands, as well as rice paddies and cultivated fields along the middle and lower reaches of the Paquita River and the Naranjo River (Figure 13-22).

In Cerritos Village in the middle reaches of the Paquita River, there are rice paddies which appear to use the river water, mainly on low-lying land at a bend in the river. The main crop grown in this area is rice. In addition, beans, corn, yams, mandarins and bananas are grown, and livestock raised. (Table 13-34).

According to the inhabitants, every three or four years, particularly when there is a hurricane or torrential rain in the mountains, this low-lying land is flooded to a depth of about 2 meters.

Flooding due to hurricanes occurs about once every 10 to 20 years. On such occasions, rescue workers are sent in from Quepos. The difference in height between the rice paddies and the surface of the river both in normal times and during heavy rain is not known, however it is known that the difference in height between the rice paddies and the plateau on which the inhabitants live is about 14m, hence it can be said that at present there is no danger to houses or human life.

Because hurricanes and torrential rain in the mountains occur mainly in October, the inhabitants decide when to harvest the rice based on the weather forecast, hence there have been no instances of financial loss due to flooding. However, it is necessary to remove trees and rocks that cover the rice paddies after flooding, hence a financial outlay is necessary to employ labor for this purpose.

In 1978, the current at the mouth of the Paquita River changed, resulting in extensive damage to roads, homes and farms. In order to prevent a re-occurrence of this, a Japanese consultant proposed straightening the river, however because of the astronomical cost that would have been necessary, the inhabitants moved instead.

At the mouth of the Paquita River, there is a problem of erosion of natural land, farmland and residential land. The relationship between the elongation of the sand bar at Damas and erosion of the opposite bank has become clear from maps made by the Geographical Survey Institute (Figure 13-33) and records of aerial photographs from which these maps were made (Figure 13-34) between 1947 and 1981. According to a report (Kato:1987,) which summarizes the results of these surveys, the erosion area on the shore is shifting in the direction of Quepos City at the rate of 6 meters a year (Figure 13-35). It is said that the leading edge of the erosion has already passed the mouth of the Paquita River and presently erosion is occurring at the Cocal beach on the opposite bank of the Paquita River (Figure 13-36). According to Katou, this erosion is due to the peculiar hydrozical conditions inside and outside of the Damas sand bar. He explained that the elongation of the sand bar and the erosion of the land occur hand in hand because of the migration of sand by the strong coastal current and also the energy of the water which flows in and out of the Damas inlet under the tide. A proposal was made in the past to build a structure along the beach in order to prevent this erosion.

13.2.15 Sea Area Utilization

Based on a field survey of fishermen in Quepos City, there are about 900 fishermen all of who fish in the sea area. None of them fish in the river. The current at the mouth of the Paquita River is complicated, hence the river mouth is not included in the fishing area. All fishing in this area is done offshore. No particular problem occurs during flooding because fishing is done offshore in fishing boats.

It was reported that the main kinds of fish caught are snapper, sea bass, sardine, shrimp and lobster. According to data concerning the amount of fish caught in each area in 1993 (Figure 13-37 Table 13-35), the amount of fish caught in Zone 2 was only about 1/5 of the amount caught in Zone 1 or 3.

From data showing the change in the amount of fish caught from large and small boats in each season (Table 13-36 Table 13-37), it can be seen that there is a tendency for a large

amount of fish to be caught from large boats in March, April, May and October, and from small boats in February, March, April, July, August and October. Many kinds of camaron that inhabit coastal waters are caught throughout the year, and Camaron (*Penaeus californiensis*) tend to proliferate in the dry season.

Regarding restrictions on fishing areas, the mouth of the Naranjo River is part of the national park, hence like the rest of the waters of the national park, fishing is prohibited here.

There is a 300 ha shrimp farm at the back of the Estero Damos mangrove forest, however there is also a shrimp farm (25 ha) at the mouth of the Naranjo River.

The farm between the palm plantation and the Naranjo River has a shrimp pond (25 ha), palm plantation (170 ha), rice fields (450 ha) and a ranch (1,200 animals). It is planned to enlarge the shrimp pond to 35 ha.

Water for the shrimp pond is pumped up from a water channel (Figure 13-38) that leads to Estero Negro. This water is first stored in a tank, and about 20% of the water in the tank is changed over in one day. Two pumps are used: One pump has a capacity of 300 liters/sec, and the other pump has a capacity of 900 liters/sec. These pumps operate for four hours during the day and for four hours at night. The salinity of the pond is controlled to between 12 and 22 by the operation of a gate in front of the pumps. Figure 13-37. Shows a record of the salinity of the pond. According to this record, the salinity sometimes greatly falls below 12, however according to the farm owner this causes no problem.

Figure 13-39 shows a record of the salinity together with the flow rate at Londres. In the dry season, the flow rate of the Naranjo River decreases, however even though this causes the salinity at the mouth of the river to increase, the salinity of the shrimp pond does not seem to change very much.

The kind of shrimp being farmed is *Penaeus vanamei*. Young shrimp that have been hatched artificially are used. The production volume is 1,200 kg/ha/15 weeks. Harvesting is done between two and five times a year, including the dry season.

The selling price of shrimp is between 500 and 1,000 colones/kg, and the annual turnover is about 60,000,000 colones. The turnover from rice of this farm is 120,000,000 colones, that from palm 13,000,000.

13.2.16 Tourism and Recreation

(1) Tourism Development Plan

The tourism plan for the Pacific coast area, which is based on the sustained development plan of the Costa Rica Tourist Bureau (ICT) and the EC committee (1993 to 1998; NTP), is summarized below.

This area is divided into three zones according to the features of the Pacific Ocean central coast strip and also the geographic distribution structure (Figure 13-40).

- No.I zone : From Punta Loros to Puntarenas (Puntarenas)
- No.II zone : An area that includes Isla del Golfo (Tortuga)
- No.III zone : From Plaja Naranjo to Cabo Blanco (Curu)

The main center of tourism on the Pacific Ocean side is Puntarenas City in the No.I zone which functions as a center for tourists to stay, congregate, and travel by boat. Another center of tourism in this area is Quepos region which is in the No.III zone. This region contains the cities of Tambor and Cobano which are popular places to make a sojourn.

In the No.III zone, the region between Praja Naranjo and Cabo Blanco contains two protected zones, the Curu wild animal evacuation zone and the Cabo Blanco fully protected zone. In addition, there are wetlands such as Organos, Paquera and Cabo Blanco, that satisfy the conditions necessary for protecting wildlife. This zone also contains attractive beaches such as Organos, Montezuma Cocal, Cororado, Naranjo, Gigante, Cabuya, and Tambor.

This zone is further sub-divided into No.1 and No.2 zones, from the viewpoint of their attractiveness as tourist places, tourist plans and infrastructures. The No.1 zone extends from Pogeres beach to the boundary of the Manuel Antonio National Park, and the No.2 zone extends from the boundary of the Manuel Antonio National Park to Cabo Coronado. This area is large, hence plans have been drawn up based on the two most important tourist centers and two important tourist centers.

The two most important tourist centers are located at Jaco and Quepos, respectively, and the two important centers are located at Parrita and San Isidro del General, respectively. The latter two centers are outside this area. Quepos and Manuel Antonio function as places where travelers can sojourn.

(2) Tourist Points in the Tourism Strategy

The tourist points in the No.1 zone of the No.III zone are the Carara protected zone and the Manuel Antonio National Park at the end of this area. In addition, wetlands and mangrove swamps (fishing for Damas, Paro Seco, and Palma) and Hermosa beach (surfing) have potential value as tourist spots. The Manuel Antonio National Park is the highest ranking protected zone in the Costa Rica. It is also the most popular of the national parks both among Costa Ricans and visitors from other countries.

The No.2 zone extends from the edge of the Manuel Antonio National Park to Boca Coronado. The only protected zone in this zone is the Marino Ballena (whale) National Park. This park and the ocean resources contained in it are protected.

(3) Proposed Action

The basic action is divided into two fields, the implementation of the park management plan (to avoid saturation) of the Costa Rica University Foundation, and the commencement of the coordination plan for the Quepos and Manuel Antonio areas. Development of tourism is taken into account as an important factor for dealing with the demands related to the national park and the buffer zone and also the effects exerted by these demands, in addition to the problems created by demands.

(4) Manuel Antonio National Park

The Manuel Antonio National Park has a land area of 682 ha and a sea area of 55,000 ha. The boundary of this natural park which is adjacent to the shore is the right bank of the mouth of the Naranjo River. It can be seen that the number has been increasing rapidly in recent years. Tourist of tourists come mainly in the dry season.

The tourism resources are the tropical forests and natural scenery including the beaches. The area in and around the national park is inhabited by about 2,000 small monkeys (*Saimiri oersteoi citrinellus*) which are in danger extinction, and therefore in need of protection. Five hundred of these monkeys live inside the national park. The coastline from the national park to Quepos City has many hotels for tourists, and development of tourism is going ahead.

Revenue from park entrance fees constitutes about 1.8% of the revenue of all parks in Costa Pica. Some 25% of the money that tourists spend locally is taken away by San Jose, the

capital, and 15% of the money spent is used locally for park maintenance. Recently, proposals have been made to enlarge the protected zones, including the national park, in order to promote the local tourist industry.

5) Kinds of Tourism

The area extending from the northern boundary of the park to the beaches of Quepos is used for swimming, walking and other forms of leisure. There are no tourist or hotels on the Naranjo River side.

The beaches are visited by sea turtles, and observing the turtles coming up onto land is one kind of tourism resource. There is a hatchery for sea turtles near the west end of Estero Garita (Figure 13-11), and it is said that in the spawning season between 3 and 50 sea turtles come up onto the beach. The Savegre river is popular for rafting.

According to tourist pamphlets, the following tours are available in this area.

- Isla Damas Estuary
Sea kayaking; Sightseeing by boat (\$65); Mountain biking
- Manuel Antonio National Park
Picnicking; Surfing; Dipping; Sightseeing; Snorkeling by boat (\$60); Snorkeling by kayak (\$40)
- Savegre River
Rafting (\$55 to \$75)
 - Wet season -- Seven-man U-paddle raft
 - Dry season -- Two-man inflatable kayak
 - Picnicking; Swimming; Waterfall viewing
- Shore line of Manuel Antonio National Park and the mouth of the Naranjo River
(between June and November)

Sightseeing (mangroves, topography, fauna and flora, palm plantations, pastures)
- Londres Hills
Mountainbiking (\$55)

- Naranjo River
Dipping

- Rio Naranjito Area
Mountainbiking

- Cerro Nara
Hiking

There is a firm for down-streaming at Londres in the middle reaches of the Naranjo River. Their business was off due to increased flow on September 1994 and low flow rate stopped their business from November 1995 to January 1996, based on questionnaire on people enjoying down-streaming conducted by ICE. Swimming and fishing are popular in the middle reaches of the Naranjo River in dry season replace.

The Savegre River which is to the south of the planned site flows slowly, hence it is considered suitable for boating trips down the river. At present, there are five companies that run boating trips down this river.

13.2.17 Cultural Assets

According to the data bank of the national museum which contains all records of archeological interest in Costa Rica, there is nothing of archeological interest in this area.

13.2.18 Public Sanitation

According to the results of a field survey carried out on the general hospital in the inner suburbs of Quepos, this hospital takes in patients from this area, including the planned site (excluding part of the area near San Marcos in the north). Records for the past 10 years show that there were between two and 10 malaria patients per year in the Parita region. The main maladies in this area are respiratory disorders.

13.3 Environmental Impact and Measures to be Taken

13.3.1 Physical and Biological Impact at the Stages of Land Formation and Leveling up of Project site, and Construction and Installation of Facilities, and Measures to be Taken.

(1) Outlines of Facilities and Construction Work

- a) Construction area: Figure 13-41 and 13-42 indicate the area intended for the construction work, including the construction of workers' lodgig, dam main body, its ancillary facilities, headraces, power plant, and switchyard as well as collection and disposal of aggregates.
- b) Scale of the work and materials and equipment to be used: The abale of the work is shown in Table 13-38. Principal materials and equipment to be used in the work are listed in Table 13-39.
- c) Transportation of the materials and equipment: Transportation routes of principal materials and equipment are shown in Figure 13-24.
- d) Construction process and the number of workers needed: The construction process is described in Table 13-40. The construction work in the Los Llanos Project will be carried out in 4 or 5 stages.
The number of workers to be needed in implementing the work is estimated to be at most about one thouthand workers.

(2) Environmental impact during the construction work and measures to be taken

a) Alteration of Topography

i) Collection of aggregates and disposal of waste soil

- Degree of alteration

Gravel and stone to be used as a concrete base materials in the dam construction work shall be collected from the area shown in Figure 13-41. River deposits shall be utilized for construction works of power house.

| (Unit: 1000 m3) | | |
|------------------|--------------|-----------------|
| Material | Location | Amount |
| Gravel and stone | Figure 13-41 | damsite: 125 |
| | | power site: 140 |

The number of concrete plants to be installed is 3 totally each around the dam site, power plant site and at the point located to the halfway of headrace tunnel.

The number of spoil grounds to be provided is 2 at downstream from Dam site and at the point near headrace tunnel.

• Environmental impact and countermeasures

The locations for collecting aggregates and disposing of surplus soil have neither topographic features nor geology which are deemed scientifically important. No locations have scenic excellence, either. No historic ruins which should be treated as cultural assets exist in the locations.

< Collection of aggregates >

Raw materials are to be collected mainly at the upstream area of Naranjillo River near a junction of Naranjo River and Naranjillo River.

This area to be used has comparatively poor vegetation, composed of coarse bush. Collection of rock at this location will give no particular impact onto its natural environment, since the collection work is to be conducted while avoiding destruction of forest areas. However, the extent of the collection area should be minimized to a required level by limiting the collection work to as small area as possible. Slopes along the hillside to be excavated should be protected by such measures as reinforcement of the slopes so that there may remain no fear for landslides or similar casualties.

Noises and vibration to be caused during the construction work will not generate any particular problems since the construction site is secluded from inhabited areas. However, blasting should be effected at daytime, neither at early morning nor at night.

Influences of noises and vibration upon wildlife are hardly supposed to last over a long period, though the wildlife may escape from them for a time being.

Influences of exhaust gas of construction vehicles upon inhabitants and workers should be appropriately controlled by making a utilization program of the vehicles and checking their exhaust gas.

<Collection of sand and gravel and production of concrete >

Since sand and gravel to be used for producing concrete are excavated and collected from river beds to be selected as collection site, the river water will become turbid during the excavation period.

Wildlife in water are restricted mainly to *Oryzias*, and no particular water plants have been observed. Almost all the collection sites are composed of land without particular vegetation, though bushes are found scattered around.

In this construction work, sand and gravel are to be collected from land along the river. Direct influences of the construction work upon fish are supposed to be small, because the fish can run away from the work site.

Measures against turbidity to be caused by the construction work should be determined after consultation with competent ministries and agencies. It is necessary to install a settling basin, coagulating and depositing facilities, and a neutralizing basin downstream the concrete-mixing plant so that waste water may be discharged downstream only after settling suspended materials and neutralizing the supernatant liquid of the water.

<Dumping site >

3 soil discarding yards are to be installed in the work area, but this place is in the forest and its area is narrow and its influence exerted on this area is supposed to be small, but the previous survey needs to be conducted for the existence of precious species and for the counter measure of transplantation. The protective work needs to be conducted on the houghmen of soil discarding yard in order to prevent the outflow of soil and sand because this spot is located in the area extremely much in rain fall.

ii) Material transportation routes

• Degree of alteration

Transportation of construction materials and equipment to the project site and respective construction work sites is planned as shown in Figure 13-41.

Although transportation of materials shall be secure routes as much as possible by improving existing roads, the road sections as marked in black in the figures should be newly constructed.

• Environmental impact and countermeasures

The factors which give environmental impact as a result of the above-mentioned modifications include impact upon vegetation, reduction of living space of wildlife, disposal of construction waste soil, and generation of noises and vibration.

The material transportation route passes through cultivated lands. It does not give so much impact upon the vegetation, since it is secured mainly by reinforcing or expanding existing roads. Soils distributed in this area shown high erosive characteristic, and high permeation of water. For this feature, protection of slope shall be required in order to prevent an erosion and monitoring plan shall be required to the generation of turbid water. It is necessary to minimize the construction site as much as possible to reduce environmental impact during the work.

Wildlife are subjected to such kinds of impact as reduction of living space and influences by noises and vibration.

Hence, the scope of the modifications should be minimized while no work should be effected during the nighttime, and night illumination should be reduced as much as possible.

Waste soil to be produced from the construction work should be disposed of at the spoil ground.

iii) Power plant and switchyard

• Degree of modification

The power plant is to be constructed at the point in Figure 13-41 and the switchyard is to be built at River side of Paquita River.

- Environmental impact and countermeasures

Although the power plant is to be constructed in a meadow area. Forest is located near power plant site, its vegetation is rich, precious species can not be found. However, detail study should be carried out to grasp possible influences upon the vegetation in advance to starting the construction work. The switchyard is to be constructed at the side of power plant, but the area of the work site is 3.1 ha. The natural vegetation at this construction site is not seen, and it is judged that the vegetation is hardly influenced.

iv) **Headraces**

- Degree of alteration

The headraces are to be installed underground mainly along the route as shown in Figure 13-41. A headrace to be constructed above the ground surface is occupied small area including intake mouth and outlet.

- Environmental impact and countermeasures

Environmental impact upon the underground headraces means that upon underground water. But serious influences shall not be caused by the reason of richness on the amount of underground water in this region. The headrace above the ground surface is to be installed in forest. Hence, the forest land should be leveled up and the trees should be logged. The species of trees to be logged are those which are popularly distributed in the surrounding area.

v) **Dam main body**

- Degree of alteration

The dam main body is to be constructed at the location indicated in Figure 13-41. The dam height is about 60m. The area of the construction site is estimated to be 566,000m², including a cofferdam.

- Environmental impact and countermeasures

The vegetation on both banks of the river at the construction site is extremely poorer when compared with that at the reservoir site, and the lands around the downstream of the dam are cultivated. These cultivated lands are included in the dam main body construction site. The factors which will cause environmental impact as a result of the modification of the topographic features are mainly impact on wild life in the river, the vegetation, and the cultivated land.

The vegetation study has found an important plant species of platymiscium of Pailionaceae family. In implementing the project, therefore, measures should be taken to endeavor to protect that species by conducting detail study for identifying the distribution of the species. Impact on other species is judged to be small.

Aquatic wildlife, including aquatic insects and fish, are not those whose habitat is limited to this location, and they can be found in other locations. Hence, the impact on them is small.

vi) Transmission line

• Degree of modification

Transmission route is shown in Figure 13-42, Transmission towers are to be installed in this project at an interval of 300 m.

• Environmental impact and countermeasures

The environmental impact to be caused by the transmission lines includes modification of transmission tower construction sites, impedance to flying of birds, and changes of natural landscape. Routes in Figure shall be planned passing through meadow area avoiding the houses.

b) Construction of the facilities

i) Items giving environmental impact

Those factors of the construction work which give impact to natural environment include

- making the river water turbid due to contact of excavated rock and soil with the water and/or run-off of turbid water into the river together with rain water to be fallen at the construction site
- giving impact to aquatic wildlife as a result of contamination of the river by is charging waste water from office buildings and lodging.

Construction noises and vibration as well as air pollution are also included in the main factors.

ii) Countermeasures

- **Workers' lodging and its ancillary facilities**

The land for constructing a lodging and its ancillary facilities is to be prepared by excavating and arranging the hillside downstream the dam, and it is to be returned to the initial conditions after the construction work is completed.

- **Transportation of materials**

Materials and equipment are to be transported through the roads as illustrated in Figure 13-41.

- **Construction work**

< Dam main body >

A cofferdam is to be constructed at the upstream and downstream sides of the dam construction site prior to starting the construction work so that aquatic wildlife in the downstream side may be protected from any influences of the work.

River water is to flow from the upstream side of the upper cofferdam to the downstream side of the lower cofferdam through a temporary underground conduit, thereby being protected from mixture with turbid water which will be produced during the construction work of the dam main body.

Measures should be taken to discharge into streams supernatant of both turbid water to be produced by rainfall at the work area and waste water used for mixing concrete, only after settling and neutralizing them at a temporary settling basin. Coordination concerning discharge of construction waste water will be required with a supervising agency.

The pH value of the river in issue is about 8, and the value safe for aquatic wildlife ranges from pH 6.5 to 8.5. Hence, due care should be taken in controlling the pH value of the river water. Since the river water is small in volume and high in transparency in the dry season, measures should be taken to treat turbid water and prevent its mixture. It is anticipated that no particular issues will occur as to noises and vibration to be caused by equipment and vehicles to be used in the construction work since sufficient distances are kept from inhabitants' houses. It is necessary, however, to minimize blasting during the nighttime and early in the morning as far as possible.

There are no facilities which produce air pollutants in the construction site. To minimize influences upon inhabitants and workers by exhaust gas produced by construction vehicles necessary steps should be taken in checking the vehicle conditions and arranging the efficient use of vehicles.

Since nighttime illumination gives impact particularly upon wildlife, it should be limited to a necessary level.

<Headraces >

Underground tunnels are to be excavated to construct headraces. Excavation muck is to be transported by truck to muck deposit near the dam site. To facilitate the transportation, a few surface roads are to be newly constructed and/or improved to connect more than one tunnel route to the muck deposit area. Since the land use of such a surface area has been designated to agricultural cultivation, existing roads should be utilized as far as possible, and impact upon farm lands should be minimized by the construction of new roads. Measures should also be taken to assure safety of inhabitants' movement near the construction site.

To control spring water and turbid water to be generated by the excavation work, waste water should be managed in a centralized manner and be discharged into the river only after the water is treated at a settling basin.

Influences of noises and vibration by blasting in tunnels are anticipated to be extremely small, because the tunnels are located in the underground and the routes do not involve inhabitants' houses.

<Power plant and switchyard >

These facilities are small in scale, but it is desirable to pay attention especially to the drain control, noise and vibration in executing the work.

13.3.2 Physical and Biological Impact and Measures to be Taken at the Operation Stage

(1) Reservoirs and facilities

a) Influential factor

Table 13-41 shows the operation items of facilities.

The reservoirs and the environment influential factors of facility itself are occupied by the land.

b) **Environment influence and countermeasure**

i) **Reservoirs**

• **Climate characteristics and weather**

It is sometimes said that a huge reservoir has an influence on the local weather. The functions owned by the water surface and the forest conspicuously alleviate the heat environment of ground surface. Because the area of reservoir in this project is extremely small at 11.5 km² and has the shape of river close to the current situation, the influence by the presence of this reservoir is very much small.

• **Topographical and geological characteristics**

There are no topology and geology which are precious especially in aspect of the science.

• **Hydrogeological and characteristics**

There is no utilization of underground water at this spot.

• **Soil characteristics and utilization situation**

The influence viewed from the soil characteristics and utilization situation is increase of erosion and outflow of soils from up stream area by agricultural activities. As a countermeasure for this phenomena, planning on the suitable land utilization shall be required by discussing with agriculture development organization.

• **Agricultural characteristics**

No agricultural land is included inside the reservoir.

• **Hydrological characteristics**

There is no change to the hydrological environment other than the formation of reservoir within the range shown in Figure 13-41.

- Present and under-plan utilization of surface water

The potable water in this area doesn't depend on the rivers, and moreover the traffic transportation and the inland water fishery are not utilized.

- Aquatic organisms

The river of reservoir area exists in the valleys, and the propagation of aquatic glass can not be observed. The killifish is the main fish, which is not especially precious species.

- Protection area

The reservoir is not included in the protective area. And, there exist no cultural assets.

- Forest resource

The reservoir planned area includes the mountainous forest area of 11.5 ha including the rivers and river beds.

In this area Batocarpus Costatriensis exists as the species in danger of extinction. The distribution volume needs to be surveyed including the vicinity area for this species, and the species should be transplanted for its preservation if so required.

The timber volume of mountainous forest being cut down which are worthy of economy is 279.8 m³, and its amount is 1,072,900 colones.

- Terrestrial plants and animals

<Plants>

In the spot survey of trees inside the reservoir, 16 species (2 species are unclear out of them) could be recognized, but Batocarpus contariensi is found out as the rare species.

For this species, the detailed survey must be conducted before the construction of power plant, and we must endeavor to preserve the transplantation according to the size of its importance.

<Animals >

There is no survey result in the area of reservoir, but according to the survey of dam spot in the vicinity, there are found a kind of monkey (Alouatta palliata), a kind of raccon (Nasua narica), a kind of paca (Aquouli paca), a kind of weasel (Eira barbara), a kind of parrot (Aratinga) and two kinds of Iguana (Iguana iguana, Ctenosaura similis). The formation of reservoir is shrunk against the behavior range or

distribution of these animals, but its range is small and they don't influence on the adjacent forest preservation area, the influence can be judged to be negligible. However, it is necessary to conduct the detailed survey until the execution of project to conduct the evaluation based on the fundamental data concerning the distribution volume and behavior range and also to conduct the required protective counter measure.

- Livestock resource

No pasture and grazing land exist inside the reservoir.

- Ore resource

No ore resource exists inside the reservoir.

- Location high in landscape value and recreation area

There exist no high landscape object inside the reservoir area. The reservoir in future can not be seen from the roads and has not landscape value.

ii) **Dam main body**

- Topographical and geological characteristics

There is no precious characteristics in terms of science in this spot.

- Soil characteristics and utilization situation.

The dam site exists at a narrow valley, and there is no soil that can be utilized. The farm land exists only on the down stream wide in the vicinity of dam spot.

- Hydrological characteristics

Naranjo River is divided by the dam main body, and the hydrological environments of upstream side and downstream side are formed.

- Present and under-plan utilization of ground surface water

The ground surface water is not utilized at this spot.

- Aquatic organisms

The aquatic organisms at the location where the dam main body is to be installed becomes extinct and escape. No aquatic grass exists in the dam spot. The kind of living fish is killifish and the like, and they live widely in the upper, middle and

down stream sides of Naranjo River. The living region of these fish will be divided by the dam, but they can live in the respective environments of upstream and downstream.

- Protection area

The dam site is not included in the protective area. No relics exist which need to be protected.

- Forest resource

No forest exists in the dam site.

- Terrestrial plants and animals

<Plants>

30 species of 24 families of plants can be found out at the dam spot. Out of them *Platymiscium* of *Papilionaceae* family is the plant in the danger of extinction, and it is necessary to prove the necessary counter measure after grasping and evaluating the actual situation by the survey of distribution volume of this species in performing the project.

<Animals>

9 species are recognized in mammals, and 4 species of monkey (*Alouatta palliata*), raccoon (*Nasua narica*), Paca (*Aquoti paca*) and weasel (*Eira babara*) in object of the protection are included. In the birds, the parrot (*Aratingasp.*) is to be protected. The animals and the birds are movable and have a wide movement range, and so the influence by the construction of dam main body is negligible, but in performing the project, there is the need for giving no influence on them by surveying the behavior range and feed area of these animals.

- Location high in landscape value and recreation area

The dam site is in the valley, and the farm lands, houses and traffic roads exist in the vicinity of its down stream side, but the number of spots from which the dam main body can be directly seen is limited. Further, the location high in landscape value and recreational facilities such as river shooting down and camping area don't exist in this project site.

iii) Raceway

The raceway planned route is not included in the protection area.

The raceway is an underground tunnel structure, and doesn't have any influence on the ground surface area environment. However, it is required to minimize the construction area.

The vegetation survey should be conducted in advance and care must be paid to the setting of work district before conducting the construction of raceway.

The acquisition of land should be temporarily put into the object of compensation, but the vegetation needs to be restored as soon as possible upon the end of work.

iv) Power station and switchyard

The construction spot of these facilities is not included in the protection district.

Because the power station is installed at the spot close to the human habitations, the station must be free from any hindrance to the inhabitants' life. The land should be boughtup. The plants of 107 species in 29 families are found out in the vegetation survey of this spot. The species in the danger of extinction out of them is not found out. Because no detail information is available about the animals, the counter measure needs to be drafted up by conducting the survey before the enforcement of project.

(2) Operation

a) Operation plan

The outline of operation plan of facilities is as follows.

For flood period and demand period, the water needs to bed is charged at 27 m³/sec maximum for 5 hours every day as continuous operation.

The water of Naranjo River is passed to the raceway and discharged to Paquita River via the power station which is at the upper stream side of Paquita River which is a separate water system.

The environment influence factors by the operation are the water storage and translocation, and the formation of water reduction section in the downstream from the dam site. The changes of hydrological environment, especially the river flow volume by the operation area shown in Table 13-42 and Figure 13-48.

According to it, the annual average flow volume is 27.8 m³/sec maximum monthly average flow volume is 56.0 m³/sec and minimum monthly average flow volume is 5.7 m³/sec. now at Londres in the middle stream area but they change to 13.2 m³/sec, 30.8 m³/sec and 1.4 m³/sec respectively if the project is put into practice. The annual average flow volume under the current situation at the mouth of Naranjo River is 37 m³/sec. maximum monthly average flow volume is 74.6 m³/sec. and minimum monthly average flow volume is 7.6 m³/sec, but they change to 22.6 m³/sec., 50.5 m³/sec. and 3.3 m³/sec. respectively.

Further, the low volume at the power station spot to which the flow is translocated increases, and the annual average flow volume under the current situation is 3.7 m³/sec, maximum monthly average flow volume is 7.5 m³/sec. and minimum monthly average flow volume is 0.8 m³/sec. but they increase to 18 m³/sec., 32 m³/sec. and 5 m³/sec. respectively if the project is put into practice. The current state flow volumes of Paquita River is 22.1 m³/sec., 44.9 m³/sec. and 4.6 m³/sec. respectively but increase to 36.5 m³/sec., 69.0 m³/sec., and 8.8 m³/sec.

Additional environment influence factors are the operation of facilities, the use of roads for movement and sojourn of operators and the use of lodging house.

b) Water storage

i) Hydrological characteristics

In general, the stagnancy of reservoir is greatly governed by the presence of stratification situation on water temperature distribution, and the absence of oxygen at the bottom layer comes from the accumulation of excessive nutrient substances and from the lack of perpendicular circulation due to the stratification. Since this reservoir is small in scale and its water exchanges rate is large, it doesn't stay stagnant. The water of river is clean and there is no fear for eutrophication.

The reservoir of this project has a small gross water storage capacity and the sands are unlikely to be precipitated from the aspect of its structure and operation. In other words, the crest top of flood out let gate is lower than the utilization water

level, the earth and sand are discharged together with the flood from the gate during the flood much in the inflow earth and sand.

In addition, because the reservoir has mainly the function of adjustment pond, there is a high frequency for this reservoir to become a river state, and the flushing effect can be expected at all times.

c) **Water discharge**

By the discharge of water to Paquita River, there appear the changes shown in Table 13-42 to 13-46.

i) **Topographical and geological characteristics**

In Cerritos village which is at the downstream side, the dam ages where the field are covered with water during the heavy rain and hurricane in fall season at the mountainous area have thus far been reported. At the site, they conduct the measure of harvesting the farm products previously by empirically grasping the weather forecast, but require a great deal of hard labor in the removal work of earth and sand accumulated stones after the flood.

The increase of river flow volume due to the enforcement of project is expected to be 2.4 time the current state in the annual average flow volume and to be 2.2 times in the maximum monthly average flow volume. More-over the maximum flow volume due to the rain fall during hurricane is calculated to be 260 m³/sec. in 10 year probability, 400 m³/sec in 50 year probability and 470 m³/sec in 100 year probability. Against this abnormal flood, such a measure shall be taken that the translocation to Paquita River should be stopped during the peak of flood and the water should be flown down to Naranjo River. This practice should previously be discussed with the local inhabitants for obtaining their understanding on the safety.

On the other hand, the change of seashore topography is under way at the mouth of Paquita River. The topographical change, according to Kato, is estimated to be caused by the elongation of sand bank and a great volume of water entering into and coming out of the Damas lagoon as regards the seashore erosion. Looking at the increased flow volume by the project and the water volume entering into and coming out of the creek, the former occupies 2 %, and therefore the increase of Paquita River flow volume has a small influence on the erosion phenomenon. (Figure 13-43) However, concerning the overall change of seashore topography,

the concerned ministries and diet members should discuss its prevention to urgently draft up the counter measure from the viewpoint of national land preservation.

ii) **Hydrological characteristics**

According to Table 13-5 to 13-7, the water quality of Naranjo River, Brujo River and Paquita River is clear, and it is expected that there is no aggravation in water quality due to the translocation of Naranjo River water into Paquita River. The change in discharged water volume due to the operation changes the width of river and the depth of water.

At the D/D stage, it is desirable to further survey the width of river and the change in water depth.

The water volume of Paquita River is increased by the project, and the influence range of river water is expanded to the sea area. The current situation during the maximum flow volume and the state during the enforcement of project are shown in Figure 13-44. The influence range by river water is about 9.6 km in radius with the flood of 45 m³/sec. under the current situation (the estimated value by the empirical equation). When the project is put into practice, it can be anticipated that the range of 12.5 km in radius will be included in the influence range by river water because the maximum monthly average flow volume is 69 m³/sec.

iii) **Present and under-plan utilization of surface water**

There is no present and under-plan utilization of surface water of Paquita river.

iv) **Aquatic organisms**

The major influence against the aquatic organisms is the invasion of creature species of respective water systems.

According to the fish survey of both water systems, the species living in 1,000 m area of the upper stream zone of Naranjo River is Poecilia gilli, and this species exists also in the downstream but also lives in Paquita River.

Beside it, there exist 11 species of fish from the middle to downstream of Naranjo River, and the species existing only in Naranjo River is 1 kind out of them, which is Dormitator latifrons of Eleotridae family, and this species is limited up to the

area of 30 m above the sea level, and there is no problem for this species to move to another river.

d) Formation of water reduction section.

i) Topographical and geological characteristics

The greatest problems in the river mouth area from the dam spot are generally the deformation of river mouth topography and the retreat of seashore due to the reduction of outflow earth and sand by the dam. The topography of Naranjo River mouth area belongs to the sand bank topography, and the special feature of this topography hints the presence of ocean current toward the elongation of sand bank, and it can be estimated that the formation of sand bank due to the transportation of water bottom earth and sand depends on those coming from the south east. As a matter of fact, the situation for the river water of Naranjo River flows to the west is reflected on the Landsat satellite picture, and the earth and sand of Naranjo River is dispersed and accumulated toward the offshore according to the report of CCT (1984).

According to the reports of many river sand transportation and river mouth topographies, it is known that the sand and soil being transported during flood have a great influence on the formation on topography.

As a counter measure for preventing the change of seashore topography, the present project takes such a measure to interrupt the translocation to Paquita River during the flood and to flow it down to Naranjo River in consideration of the operation plan. There fore, in operating the dam, the sufficient explanation and safety consideration must be made to the inhabitants in the local area.

ii) Hydrological and characteristics

In Londres, there is the network for supplying the potable water as shown in Figure 13-25. The source of this water derives from the spring in Cello Nara protection district and doesn't relate directly to Naranjo River. At the vicinity of spot where National Street No. 22 and Naranjo River cross with each other, there is a well for supplying the water to Quepos city and its hospital. The water level of this well is said to get lower during the dry season, and the measure for collecting the deep underground water is necessary by conducting the detailed investigation. In

addition, the well water is collected inside the palm plantation and also at the houses in the south area.

According to the survey of water level change of several wells (Figure 13-8), the water level at each spot exists at the position close to the ground surface and doesn't indicate any great fluctuation from the end of rain season to dry season.

iii) Hydrological characteristics

The river water is translocated into Paquita River by the operation of dam, and the water volume decreases at the downstream side of dam spot in project. The water volume changes are as shown in Table 13.42, 13.47 to 13.50. Because the water quality of Brujo River is clean, there is no fear for aggravation of water quality by the enforcement of project.

iv) Present and under-plan utilization of ground surface water

The river water in this area is utilized as the potable water of livestock, agricultural water and to shrimp culture at the river mouth of Naranjo River though it is not directly utilized. The major industry in this area is the palm plantation, and this facility installed TOMA water collection point at the downstream of Londres of Naranjo River and requires to collect the water of 1.8 m³/sec on average during the dry season and to collect the water of 2.0 m³/sec in the future plan.

On the other hand, the monthly minimum average flow volume of Naranjo River is 1.70 m³/sec in January, 0.71 m³/sec in February, 0.67 m³/sec in March and 1.20 m³/sec in April by the enforcement of project, and under the current situation, there is the impossibility of catering for the future water collection volume of about 2.0 m³/sec. Suppose that all this quantity should be collected, the supply of river water to the river mouth becomes zero in future. In view of the fact that the water utilization right of Naranjo River is owned by ICE and in view of securing the river water for protecting the natural environment in the downstream side, there is the need for giving the compensation to the plantation on the basis of the current utilization actual situation in enforcing the project.

There is a shrimp culture pond and small palm plantation in the vicinity of the river mouth of Naranjo River downstream. The water is pumped up and supplied into this culture pond from 1 branch stream flowing into Estero Negro, instead of taking the water directly from Naranjo River. During the site observation trip in March,

the water dripping from Queb Rastro was recognized, but the salt value from December to March during the dry season goes below 25 according to the record of salt concentration at the culture pond, and the water intake channel for agricultural water is in the dried up state during the first half of this period, and it can not be seen that the water supply depends on the ground surface water directly from the plantation.

Implementation of irrigation to small palm plantation was explained by owner from November to May by using water stored in irrigation channels in the firm. According owners' explanation, 35-40 ton/ha/year of palm fruits in harvested in irrigated area and 12-15 ton/ha/year in non irrigated area.

v) **Aquatic organisms**

Table 13-9 shows the species of fish living in the middle and downstream areas of Naranjo River. The influence factors against the organisms are the reduction of river water volume and the aggravation of water quality, but the water quality of Brujo River is identical to the water quality of Naranjo River, thus causing no problem though the water volume will be decreased than the current situation by the enforcement of project.

According to the report of CCT (1984) who investigated the river mouth area, the living of many organisms can be recognized. These organisms are living under the special environment called a brackish water but their life foundations are the physical environment conditions and the nutrition substances fused from the rivers and the nutrients contained in the suspended substance.

The mangroves grow on Estero Negro and the Manuel Antonio Park sides, but the substance flow in food chain inside the mangrove is depicted as shown in Figure 13-45, and inside the mangrove, the polychaete, shells, crustacea, fish, etc. form the food chain eating the detritus as bait by the decomposition of a part of plant body. That is to say, protecting the water, water quality and plants which become the source of nutrition is to protect the environment of living organisms.

Mangrove is the general name of plant community having the salinity tolerance. These kinds of plant have the adaptability to the salt, and therefore can grow even at the severe condition location into which the land plant can not invade, and can grow even in the fresh water. The special features of environment of mangrove growing yard are described in Figure 13-46, and one of special features is the

presence of location of limited topography which is immersed in water during the high tide level by the tide and that the exchange of water is slow by the tide and the accumulation of organic substances and the nutrients can be obtained either by fresh water or by sea water. The 2nd special feature is the supply of fresh water. The 3rd special feature is such that the soft deposit where the seeds drop down and can pierce is the foundation. And the mangrove grows throughout the year though some of them causes pseudo annual rings, and the June season is said to be most active.

- As regards the salinity tolerance, there are the reports of Table 13-51 and Figure 13-47, and the report concerning the influence of salt concentration on the growth. The salinity tolerance is up to 3 times the sea water though it varies with the kinds, and the suitable salt concentration is between 25 and 50 % the seawater concentration.

The difference of salinity tolerance by the kinds is most high between *Avicennia* genus and *Lumnitzera* genus, followed by *Cerips* genus and *Rizophora* genus, while the *Bruguiera* genus is the concentration closest to the seawater concentration. *Acrostichum* genus grow in the region around the mangrove.

- In the relation between the growth and the salt concentration, the salt concentration doesn't have an influence on the size of growth in the test for 6 months(*Avecinnia* family) as shown in Figure 13-48.
- In the model study concerning the change of nutriment volume being supplied and the biomass change obtained from Florida mangrove, there appears the difference by the supply volume of nutriments within the period, but there is no conspicuous difference in the reduction of volume for a very short period.

The seashore topography which isolate the mangrove area from the sea protect the Estero Negro in the inside. For this protection, the outflow earth and sand volume of Naranjo River must be guaranteed.

Because the outflow earth and sand volume of river is generally largest in percentage occupied during the flood, the protection will be planned in the project by stopping the translocation to Paquita River and by attempting the restoration to the downstream of Naranjo River during the heavy rain in the mountainous district.

Because the project decreases the flow volume of Naranjo River throughout the year, it is especially important to grasp the influence of Estero Negro and the like on the mangrove during the dry season. Table 13-52 show the result of salt survey at the river mouth of Estero Negro and Naranjo Rivers, and survey of the flow volume and the replenishment volume of nutrients in the water channel to Estero Negro from the plantation.

- According to the data of flow volume and replenishment volume of nutrients in the water channel leading to Estero Negro, the water of 0.4-0.7 m³/sec flows during the period when the water intake channel is dried up, and the water of 0.9 m³/sec flows even in January when the water intake is thought started. The increase of water volume started which is imagined to be the result of water intake at the end of January, and restored to the water volume at the end of March when the dry season begins. The flow volume in water channel with the water intake being stopped can be predicted by extrapolating a straight line of Figure 13-50.

According to it, the flow volume is expected to be 0.25 m³/sec in April and 0.2 m³/sec in April.

On the other hand, at least 50 % of PO₄ -P out of the nutrients are supplied from the water channel from the period when the water intake channel is dried up to the period when the water increases. The TIN suddenly decreased and reached 2 % minimum, but since then, sharply increased in April similarly to PO₄ -P. The period when the concentration of nutrients decreases is supposed to be around 1 month, which doesn't lead to the lack of nutrients for a long period of time. Even if supposing that the agricultural water doesn't flow through the water channel up to May and there is no rain fall, this is a short period, and it is supposed that there appears no special problem because the nutrients being produced inside the nutrients of mangrove and the fixation phenomenon of air nitrogen of bacteria are imagined.

- According to the records of salt value of Estero Negro and flow volume in water channel (Table 13- 53, Figure 13-51), suppose now the flow volume of water channel to be 0.25, and apply it into Figure 13-51 in the same manner, then it will be around 32 though the salt value goes up in both cases.

According to the salt survey in the mangrove area of Quepos and Savegre, the salt value of Mangrove inlet and innermost and surface layer and bottom layer proved

to be uniform at 32.6 to 32.7 during the high water in Quepos. The salt value proved to be 32.8 maximum in the surface layer and 32.9 at the water depth of 0.5 m in the mangrove of Savegre.

This value is the value and change causing no problem in view of the relation between the growth and salt which were shown previously. The salt value becomes low and its scattering becomes greater if the flow volume is less according to the data during low water of Estero Negro, and hence the blocked water inside the water channel of Estero Negro is imagined to be replaced sequentially by the tide in stead of the water supply by simple flushing from Queb Cacao.

The replacement of water of Estero Negro during this period is brought by the tidal action from outside, namely by the tidal difference close to 3m, and the stagnant conditions don't exist inside Estero Negro. Therefore, even by the water intake stop of agricultural water during the dry season, there appears no problem for the mangrove to wither in Estero Negro due to the water distribution inside the water channel and the presence of Queb Cacao under the current situation. The surface ground water that can be observed easily is shown here, but the supply of water oozing out of the underground water to Estero Negro from the plantation land can be imagined. If this should be added, the influence of project enforcement to the Estero Negro is imagined to be smaller.

- Salt change at the river mouth of Naranjo River.

Figure 13-52 shows the relationships between water flow rate and salinity obtained from Salinity survey in Naranjo river mouth. Fluctuation of Salinity values to the water flow rate seems to be originated by the tidal action. It is difficult to predict the Salinity value when water flow rate becomes small, because of lack of enough data.

Discussion related to the diffusion area and amount of water to be discharged gives effective result on the prediction of Salinity valve in the Naranjo river mouth.

vi) **Protection area**

Manuel Antonio National Park and Negro Mangrove protection area exist at the downstream of Naranjo River. The former occupies 55,000 ha of sea in the front in addition to the land area.

A part of river mouth of Naranjo River is the boundary of the east of Manuel Antonio National Park, and the location to which the influence to the park by the project enforcement possibly ranges is limited to this area and the front side sea area.

Figure 13-53 shows the predicted change of dispersion range to the sea by the river water from the current state flow volume of Naranjo River and the flow volume during the enforcement of project. The dispersion area of river water in the satellite photograph and the result by prediction equation are carried on this figure. The dispersion area in the satellite photograph is distorted toward the west than the ocean current, but the actual situation corresponds almost with the predicted situation. If the dispersion range should be predicted during the dry season when the project is put into practice according to this method, the minimum monthly average flow volume becomes about 4 m³/sec in January or in the range of about 2,200 m in radius with the river mouth as its center, about 2 m³/sec in February or in the range of about 1.4 km in radius, about 1.7 m³/sec in March or in the range of about 1.2 km, and about 2.6 m³/sec in April or in the range of about 1.7 km in radius. Even in March when the minimum monthly average flow volume becomes the least, the influence range of Naranjo River becomes the tip of peninsula of Manuel Antonio Park, and the living area of organisms liking the brackish water on the side of park subsists. Further, the Estero Negro river is similarly included in its range and the river mouth environment survives though the dispersion range of river water is narrowed. In the sea area in front of the park, the shrinkage of turbid area in the surface layer is predicted throughout the year.

vii) **Terrstrial plants and animals**

• **Plant**

<Just below the dam>

In the survey of atmospheric temperature and humidity at the spot just below the dam, any particular climate situation was found out especially in the vicinity of river, there is the less possibility for a great change to the plant environment in the block up to the confluence of Brujo river.

<Middle stream and downstream of Naranjo River>

Because the water doesn't disappear at all in the reduction of water river water, no great influence is given on the plants on the river bed.

<Manuel Antonio National Park>

The east end of park is adjacent to Naranjo river, and the mangrove is growing on the river side. This mangrove is in object of the protection. The sand and soil are supplied and the water flow conditions and salinity condition of river mouth are secured, it is supposed that there is no great influence.

<Estero Negro>

This is described in Item v) Aquatic Creatures.

• Animals

<Middle stream and downstream of Naranjo River>

The reduction of river water volume doesn't exert any influence on the animals living on the land. 12 pieces are found out as the fish in Naranjo river. However, because the water doesn't disappear according to the project, the living space of fish is temporarily narrowed in the dry season, but have no influence on the egg-laying and growing of fish. 8 species of water lizard and frog are the precious species as the amphibian, but because the water in this river and small river and water channel flowing in this river doesn't disappear, it is expected that there is a very small influence.

<Manuel Antonio National Park>

There is the precious monkey *Saimiri oerstedii* as the land animal in the park, but there is no influence because these monkeys live on the trees.

There are the sea coasts on the Naranjo river side and the west side of Park and there live the lungworm, bivalve, crustacea and fish living in water, wand or rocky area, but the brackish water area is planned to remain in front of the river mouth though the area of brackish water area decreases on the Naranjo river side during the dry season when the project is enforced. On the other hand, the west side is comparatively dense in salty content, and is the district which is not subjected to the influence of river water under the current situation, and hence it can be expected that the creatures living here and the creatures living at deep location will not be influenced.

<Estero Negro>

Many animals are living such as the birds, monkeys living in the trees, lizard, water lizard, fish, crustacea, mollusk, etc. According to the project, it is expected the salt

content of Estero Negro including the river mouth area that can be anticipated from the water volume of Naranjo river goes slightly high in the dry season.

However, it is imagined that no great influence is given on the creatures living in Estero Negro because its salt content value is within the limit that can be seen thus far, the river water exist in the future too though its expansion range becomes narrow, no great influence is given on the plants building up the mangrove, the fluidity of water can be maintained including the tide, and the nutriment can be replenished.

<Sea area>

The influence by the project enforcement against the turtle is the sand beach as its egg-laying yard, but there is no big influence because the sand supply from dam is guaranteed for the preservation of beach sand.

As regards the influence by project enforcement on the sea turtle, no great influence is anticipated because the sand supply transportation from the land is guaranteed for protecting the sandy beach as the egg-laying ground. One of the influence elements against the sea turtle is the contamination of sandy beach and the entrance of visitors by the sight-seeing development, and utmost care must be taken to the sight seeing development in Naranjo River to palm plantation districts in the future.

viii) **Location high in landscape value and recreation area**

The agricultural land and pasture land expand on the lands along the middle and downstream of Naranjo River, and they are not especially of landscape value. In the vicinity of river mouth of downstream side, a part of park forest and tropical forest and mangrove of Manuel Antonio National Park can be seen but the public people can not enter into them.

According to the sight seeing pamphlets, the landscape observation of national park and the marine leisure are the first to come. The lodging facilities for sight-seeing visitors exist around the park and inside Quepos city, but no such activities can be seen on the side of Naranjo River. Almost all the area on the Naranjo River side of National Park is the privately owned area, and the sightseers are not allowed to enter thereinto.

Lately, a foreign management started a river riding-down at Londres in the middle stream of Naranjo River, and does the business when the water volume becomes less. The business is not made during the much water volume period for

preventing the crises, and during the less water volume period because the boats can not be moved. In this neighborhood, the river swimming and fishing are done in a small scale.

The water volume of Naranjo River decreases due to the enforcement of project, but the water doesn't dry up by the presence of residual Brujo basin, and the river riding-down and river swimming can be continued.

Concerning the river riding-down, the period of water volume suitable for the river riding-down is moved forward than the conventional period, and the number of business days per year is not decreased by the enforcement of project.

e) Operation of power station

i) Noise and vibrations

Noise and vibrations are generated following the operation of power station. As this influence measure, the noise and vibrations are to be measured, and the inhabitants need to be moved to other locations as necessary.

The influence on wild animal are very small because the power station is operated for the first time.

ii) Wastes

The wastes being generated by the maintenance/control of power station and dam need to be disposed on the basis of the concerned regulations. The dangerous substance such as fuel needs to be disposed appropriately and stored and managed accordingly.

iii) Employees

The living drainage, rubbish, etc. being generated by the employees' houses need to be disposed as stipulated. The leftover food needs to be disposed adequately in order to lessen its influence to the wild animals.

iv) Traffic

The safety measure must be provided to the inhabitants when the employees move using cars.

13.3.3 Influence on Social and Economic Environments and the Countermeasure to be Taken

(1) Influence at the stage and countermeasure to be taken at the reclamation of land, leveling work of ground and installation stage.

a) Population

The towns and villages in the project area are distributed in the low land with the mountains at the background and the population density is small except for the town area.

The movement of materials and workers involved in the work becomes possible by the use of road under the current state and by the construction of small scale and new roads at the construction site. The materials are planned to move the low area, and there is no plan to pass through San Marcos which is behind it. However, the movement of workers from this area is considered, but in view of the convenience of traffic and the arrangement of population, there is a great possibility for the movement of persons from low area.

The construction work is conducted for 5 years, and the number of workers required for the work is about 1,000 persons maximum. After that, there remains a few number of controllers of facilities, but suppose that the workers are collected from the area of 25 km radius during the work period, the workers are mainly collected from the villages and towns in the vicinity, Quepos city of a central area of this district or from San Marcos city situated at the northern part.

The population density of this area is small except for Quepos city or a central area, the industry is agriculture and sight seeing, and especially the town and village annual income is low and poor except for Quepos city. Therefore, in employing the general technicians and workers, such a consideration is required to adopt the local site people with preference and with the adoption plan so that the local economy may be vitalized.

Further, the work concerned parties who can not commute from their own home need to have the lodging at the work site or the new lodging in the periphery villages and towns.

Concerning this temporal population increase or the population increase problem due to the living thereafter, there is the need for attempting the decrease of friction with the already living people and also to make the dam construction to be one aid for vitalization of commerce, etc. in the area when collecting the workers before enforcing the project.

b) Industry and economy

The project site exists in the mountainous area, and the industry in this area is a small scale agriculture at the deforested land and a feeding of livestock utilizing the slope area. The reservoir is a small in size, utilizes a part of forest in the periphery of river bed and doesn't include the agricultural land. The dam spot is mainly on rocky area and the purpose for utilizing the land is a part of natural forest and doesn't include the agricultural land in the similar way.

The power generation station and switching station are planned to be constructed near the forest, but partial agricultural land and livestock pasture will be influenced when the work is to be executed. At the same time, the area planned for the workers' office and lodging in executing the work, the concrete manufacturing plant installation spot, raw ore mountain, soil discarding yard, etc. are in the steep meadow, but there is partially the living area, they need to be acquired and the inhabitants living there need to move to another location, and therefore sufficient care must be paid to the removal destination.

For information, the road for work is catered for by expanding the existing road but the newly established road need to be acquired after fully discussing it with the landlords.

With the start of work, the workers are working at the construction site of facilities, but a great influence will be given to the inhabitants and economy in this area by the commutation from the periphery, temporary sojourn or long term sojourn.

The contents having the direct and largest influence are the increase of cash income in the area by collecting the area inhabitants as the workers, the lodging for staying by the concerned persons and workers from the periphery and the vitalization of commerce by the expansion of consumption in the area by sojourn and living.

Further, the maintenance of lodging facilities gives birth to the additional value such as the expansion of lodging facilities for sight-seeing in the area. This can also comply with the sight-seeing development strategy on the planned Pacific Ocean side.

Therefore, this project should not be ended as the electric power security by the dam construction, but needs to be enforced keeping in mind the special features of thinking against the inhabitants' economy and environment as the development in harmony with the nature and society in this area.

That is to say, this area is economically poor, and it should be considered that the overall social development is desired such as the industry, education, hygiene, infrastructure, etc.

c) Income and Unemployment

The income in Londres area which is downstream side of dam spot is 15,000 colones/family on average monthly, and in the situation where workers working away from home are many, Savegre, Naranjito and Parrita area are the poorest areas in Costa Rica.

Here, suppose the average income per dam construction worker to be 70,000 colones/average/month, about 5 times the income is to be obtained. This amount is to be applied to the consumption.

On the other hand, it is necessary to take into consideration that in the construction, the general materials are purchased from this area.

d) Land utilization

The work area is as shown in Figure 13-41. This district is mostly structured of the rough rough forest and sheep livestock pasture area, but the small scale agricultural lands are scattered partially where potatoes and achiote are cultivated. The agricultural land in conflict with the work area is quite small, and doesn't have an influence on the agriculture in the area, but compensation in acquiring the land being utilized by the inhabitants shall be required in the D/D stage.

e) Public facilities and services

Following the construction, the population increases temporarily, and the replenishment and popularization of public facilities and various services involved in it can be thought as the additional value. The education facilities of initial education are distributed in each village and town.

The large size materials and equipment to be used in the work are to be transported to the work site from Caldera port, but in performing the transportation, we need to educate and control for preventing the influence to the inhabitants along the line and to the inhabitants in the vicinity of work block due to an accident.

As the public facility, there is Manuel Antonio National Park adjacent to the river mouth of Naranjo river. The sight seeing resources of this park resides in the landscape of coast line and the tropical forest, and many visitors come to this park.

The influence given to this park involved in the execution of work is the coming and going of sight seeing but, work vehicle and inhabitants, and hence such a traffic control is requested as not giving the influence on the disturbance of traffic on the sight seeing routes.

f) River and utilization of river water

There is no change in the water volume of river during the work period. There is the possibility for turbidity of water quality due to the work, but the generation of turbid water during the period when the water is clear during dry season may possibly influence on the landscape and the inhabitants' bathing and fishing on the downstream side.

Therefore, an adequate control is required for washing of gravel and the drain of concrete plant.

g) Utilization of sea area

Because there is no change in the water volume of river, the influence to the sea area utilization during work period is understood to be small.

h) Cultural assets

There is no cultural asset in this area, and there is no problem.

i) Public sanitation

The work related workers' accident and the generation of endemic disease and contagious disease being brought about from the increase of population need to be prevented by the sufficient control. There are a less number of hospitals in this area, and the inhabitants go to the remote hospitals for treatment. The work spot exists in the middle of Quepos city having a hospital and San Marcos town, there is the need for setting up the emergency system and the sufficient acceptance system even against the occurrence of peripheral inhabitants' diseases.

(2) Influence to social economic environment in the operation stage and the countermeasure to be taken

a) Population

Only a small number of persons are engaged in the control of facilities in the administration stage, and the influence given on the population in the area is extremely small.

b) Industry and economy

The project spot has a small influence on the industry and economy in its administration stage. The generated electric power fills the demand of industry and citizens' life of Costa Rica.

c) Income and Unemployment

The dam controller and partial workers are to be working in the administration stage.

d) Land utilization

Concerning the influence after operation, a slight change in the shape of river bed of Paquita river can be expected involved in the bypass of river flow. The river bed of Paquita river and Naranjo river is not utilized so much to the agricultural land, but if the water volume of river should change, the environment relating to the edimentation and erosion must change even to the least.

Its location and change evaluation should be studied at the stage of D/D, and after the administration of facilities, the site survey should be conducted for confirming the land utilization situation, and various counter measures should be studied through the discussion with the land owner against the problematic spot.

As regards Cerritos village on the downstream of Paquita river, the reduction of influence by flood is to be attempted by the administration of facilities.

The sea coast in this area including the river mouth of Paquita river is vivid in the erosion which is judged due to the entry into and exit to the outside sea of the water of Damas harbor attributable to the tidal action.

The enforcement of project increases the water volume of Paquita river 27 m³/sec maximum, but this water volume is several % of the former and is not a great factor of erosion.

The history of land erosion in this area is read out from the record since 1974, and its situation is advancing toward Quepos city even now. Because several countermeasure plans are proposed against the advancement of this erosion phenomena, an earliest study from the overall standpoint of national land preservation by supervisory administration is desired.

e) Public facilities and services

The work roads are maintained involved in the construction of facilities. This infrastructure becomes, after the work, the route for connecting the regional inhabitants and the inland and coast line, can directly connect San Jose city with the sight seeing area of coast line and can be utilized for the invitation of sight seeing visitors. Further, for the public utilization of clinical facilities administered involved in the construction, its administration method needs to be discussed among the regional bodies.

f) River and utilization of river water

In the downstream basin of Naranjo river, there is a facility utilizing the water of Naranjo river for the purpose of irrigation of palm plantation, and the river water of nominal 1.8 m³/sec is taken from February to April during the dry season.

Concerning the utilization of river water by this plantation, there arises the difficulty in supplying the water needed for the irrigation by this project. This irrigation is done for production factory of fruit, and is required for the palm in the growth period whose production is active.

Therefore, in enforcing the project, we need compensate the producer for the loss of cultivation land where the irrigation effect comes out due to the irrigation stop under such full understanding that the water utilization right of Naranjo river for public power generation resides in ICE and that this is the project for securing the electric power for nationals in the future.

However, because the area becomes problematic due to the stop of irrigation is in a small range of palm cultivation area in this area and moreover the stop of irrigation doesn't remove the production in that area at all and doesn't deprive the occupation of workers working in that plantation, it can be thought that the stop of irrigation doesn't give a great influence on the palm fruit production and workers' living as the local industry in this area.

In the Londres, there is a trader who has a river rafting occupation. This trader makes a temporary business during a short period excluding the water increase period and water decrease period, but the business actual state such as the number of passengers per year is unclear even by the sight seeing pamphlet and by this survey. In addition, the river is utilized for the bathing, babbling and fishing.

As shown in Figure 13-42, the water volume of Naranjo river decreases only by the volume required for the electric power generation, and doesn't become nil throughout the year. As regards the river rafting, the period when the river flow becomes smooth increased by the enforcement of this project, the number of days when the business can do more than the present state can be prospected.

Further, concerning the water bathing and babbling, the shallows and deep water where they can play don't disappear, and it is understood that there appear no serious problem.

However, against the inhabitants in the area including the inhabitants utilizing Naranjo river and Paquita river, there is the need for explaining fully in advance the various changes of water volume involved in the contents of project and the operation plan in consideration of the environment counter measure and for making

them fully recognize that this is the project for clean energy development in harmony with the nature for promoting the industry including the sight seeing of this country. In other words, there is the need for explaining the inhabitants in the region the concept of optimum utilization of natural resources giving birth to new added value.

There is a well supplying water at the hospital in Quepos city near the bridge where National Road No. 22 and Naranjo river crosses with each other, and according to the record thus far it is said that the water level falls down during the dry season.

Besides it, there are several wells utilized to the inhabitants' living in the area including palm plantation which is east of Naranjo river. According to the result of surveying the water level change of wells, no remarkable water level fall was recognized even during the dry season when the water volume of Naranjo river decreases. However, in the observation result of well closer to the river mouth, the increase of slight increase of salt content is recognized.

In the vicinity of river mouth, there is the facility for breeding the shrimps, but the source of water to be utilized resides in Naranjo river, but it doesn't take the water directly from Naranjo river but takes the water from the water channel flowing into Estero Negro, and no relation can be seen to the fluctuation between the change of Naranjo river water volume and the salty content of taken water.

The long term monitoring must be done for the former, and if the water level of well should fall down and cause a problem to the water taking, such a measure is required as taking the underground water which is more deep.

g) Utilization of sea area

Off shore the Naranjo river and Paquita river, the trade fishing and sport fishing are being done, but the range of 29 km away from the park is the district where the fishing is prohibited. This is similarly applicable to the mangrove areas of Naranjo river and Paquita river mouth. The change in river water volume of Naranjo river and Paquita river dangers the diffusion and mixture area of that water, but these diffusion ranges don't reach the fishing zone.

There is the fishermen's report that the shrimp fishing is done in the sea coast to Savegre river from the river mouth of Naranjo river, The diffusion range of river water slightly expands toward Savegre along the seacoast line from the river mouth

but within a negligible range and is governed by the flow streaming to the west in the sea coast reaching the river mouth of Savegre river, and therefore it is expected that there is no big influence on the collection fishing of shrimps which like the brackish water environment.

The sight seeing resource of Manuel Antonio National Park covers the seacoast landscape as one of them but because the dispersion range of river water is slightly shrank on the Naranjo river side by the enforcement of project, the situation where the turbid water at present circumstance is diffused to the front side off-shore of park can be alleviated. On Paquita river side, the flow volume slightly increases due to the enforcement of said project, so the diffusion area is expanded, but the flow of sea area is directed toward west, and there is a small possibility for the river water to stay stagnant in front of the park more than the current situation. Therefore, it is anticipated that no great influence is given on the landscape owned by the park.

h) Cultural asset

This project have no influence on the cultural asset.

i) Public hygiene

The major disease in this area is disease of lungs, and has no special influence. The clinical facilities for the workers engaged in the facility control shall desirably be the system that can be utilized to the public welfare.

13.4 Compensation

(1) Work and Acquisition of Facility Construction Site.

The kinds of land containing the road site whose acquisition is planned in this project are three kinds of the mountains, forests, meadow and waste land (river bed area). Table 13-55 shows the areas and expenditures necessary for every work and facility. The total amount of these lands is 34,814,040 x 1,000 Colones (1995).

1) Land to be used in facilities and construction

- Land of permanent use : 9,510 x 1,000 Colones
- Land of temporary use : 5,610 x 1,000 Colones
- Total : 15,120 x 1,000 Colones

2) Transmission line

- Land to be undered by lines
22km, 9,586\$/km, 30m x 22km = 660,000 (210,892\$)
Price = 34,797,180 x 1,000 Colones (210,892\$, Ex.Rate = 165)
- Land acquisition cost for towers
30m x 30m = 900, 200 x 64 units = 57,600 Land type, Meadow
Total = 300,000 Colones x 5.8 ha = 1,740 x 1,000 Colones
- Total 34,798,920 x 1000 Colones

(2) Removal (move) of private houses and public facilities

19 houses in total need to be removed (out of them, private houses are 16 houses (estimated 96 persons work cottages are 3. and a small scale primary school is 1).

- Dam quarry spot : 4 private houses
- Dam concrete plant spot : 5 private houses
- Powerhouse, Switchyard
- Penstock Yard, Concrete
Yard spot : 4 private houses, 3 cottages, 1 primary school
- Penstock : 3 private houses

Because the unit of removal expenditure at National Bank is 3,200,000 Colons in case of the private house of 90, the expediter of 60,800 x 1,000 colones in total is necessary. For information, this expenditure is calculated with the primary school and the work cottages as

the general private houses.

(3) Compensation to the Palm Production of Palma Tica

There is the need for the compensation to the fruit production at Palma Tica Palm Plantation. This plantation utilizes the water of Naranjo river as the irrigation water to 600 ha out of the owned agricultural land. Since the enhancement of production can be attempted by the irrigation during the dry season, the compensation shall be done only for the production increase portion of that irrigation. The data of adjacent plantations shall be utilized for the irrigation effect in this calculation.

- African Palm Fruits

Irrigation agricultural land (Irrigation from November to March): 35 to 40 ton/ha/year.

Usual agricultural land: 12 to 15 ton/ha/year

Difference portion: 23 to 25 ton/ha/year

- Price of fruits of 1 ton: 11,080 Colones (1995)

- Maintained water volume of Naranjo River

The monthly average water volume 1.7 m³/sec in March at the river mouth which has been predicted from the data in the past 23 years shall be considered to the average water volume to be maintained as the minimum. The flow rate of irrigation water intake point at this time is 0.67 m³/sec. This shall be water volumes to be maintained at the spot before water intake during the dry season. With 0.67 m³/sec as the lower limit, the shortage for the irrigation water volume (maximum 1.8 m³/sec) shall be calculated from the monthly average water volume in January, February, March, April of the data for the past 23 years.

1.8 m³/sec (Monthly average water volume of Naranjo River at the spot prior to water intake - 0.67) shortage water volume (m³/sec).

With the case of 1.8 m³/sec water intake being possible as 100 %, the shortage in the past 23 years of Naranjo River becomes 57 %. (Table 13-56)

Because the production increase by the irrigation enforcement in the year is 24 ton/ha/year, the proportionate calculation (the necessary water volume of Palm and the Fruits production volume are estimated on the Sigmoide curve but is supposed here on a simple straight line (regression) results in the loss of 13.7 ton/ha/year. Since the irrigation agricultural land is 600 ha, the amount with this as the target becomes 93,072 × 1,000 Colones/year.

The estimate of actual compensation sum is calculated using the actual production volume of Palm Fruits of the year, but the total amount for 35 years can be calculated as 3,257,520 x 1,000 Colones because the Fruit production if 35 years for one generation of Palm as the commerce based on the expenditure of said single year.

The compensation amount of actual Palm Fruits needs to be calculated for every year, using the said method, by the river water, water intake possibly (actual record) during the dry season, and the Palm production amount (actual record) of that year.

For information ad another method from the monetary compensation, the is the water intake in the deep layer undergroundwater as an alternative water source of the water volume in shortage, but in this case, there is the needs for estimating the installation expense of facilities and the electric charge.

(4) Total of Compensation Cost

The total of compensation cost is 38,132 x 10⁶ Colones.

13.5 Cost Benefit of Environment

(1) Basic Concept

The basic concept equation of C/B analysis is shown below:

$$NPV=Bd+Be-CD-CP-CE$$

where NPV: Pure present value

Bd: Direct value form the project.

- Value of generated electricity
- National land preservation value

Be: External benefit (including the environmental benefit)

- Plus effect of improvement such as environment amenity
- Economical value of secondary benefit

Cd: Direct expenditure imposed on the project.

Cp: Cost needed for the environment preservation measure

Ce: External expenditure(including the environment cost)

- Expense for inhabitant removal, estimated amount of dam age suffered by the persons who lost the chance of leisure.

In the actual calculation, the life span of dam is supposed to be 50 years, each of item being calculated and the costs being compared with one another, But in this report, comparing the costs among Be, Cp and Ce, the benefit obtained with the contents of development plan and the side of necessitated environment measure are compared.

(2) Influence on the natural and social environments.

In this project, the minimization of environment influence is planned to be attempted by studying the operation plant concerning the environment influence being called by the contents of this plan. Table 13-57 shows the danger of environment influence obtained by the environment survey and the contents of evaluation against it.

Therefore, in this project, the following two negative environment influence items are extracted:

- Influence on the fruit production by the irrigation of Palm plantation.
- Acquisition of land and removal of private houses at the work spot.

(3) External Benefit (Be)

As the secondary benefit by the enforcement of project, considered are the employment of general laborers and technicians involved in the work, maintenance of lodging facilities, maintenance of infrastructures at the project spot and the peripheral area, maintenance of local clinics, and the vitalization of regional economy by the preparation of high school education facilities, Concerning the foodstuffs, daily necessities, general material and consumed good being used in the work, and the other products that can be supplied the local area, the counter measure consider in the local area will be possible as satisfying the demands preferentially inside the local area when conducting the project.

Together with the agricultural and turistic foundation maintenance of this area which are said to be poorest in Costa Rica, the positioning as a of national and overall regional promotion is important.

The economy effect of these secondary benefits can be said to be extremely great and precious to the focal area.

On the other hand, Paquita river has the special feature of its flow rage being decreased during the dry season similar to Naranjo River, Because the water volume of Paquita river increases by enforcing the project, such a benefit can be imagined as utilizing this water to the agricultural use.

There is the idea of releasing the source to the dam facilities and the reservoir but the reservoir of this project is of a small scale of flow-in system and is located at the location which can not be seen by the sight seeing visitors and inhabitants, and therefore the benefit in the sight seeing can not be expected.

(4) Expenses necessary for the environment preservation measure (CP)

There are following expenses necessary for the environment preservation measure of this project.

a) Under construction

There is no special measure compared with the measure in other hydraulic development under the construction.

As regards the turbid water and change of water quality by the work, their appearance preventions are planned.

The washing of raw ores and gravels, the grain treatment at the concrete production, the protective work of inclination face at the improvement/change of land are planned but a hundred million is appropriated including the drain water quality monitoring cost for the said expenditures.

b) Operation

Environment monitoring is planned involved in the operation of facilities. The survey expenditure of river water volume, water quality, living organisms, etc., shall be counted as the personnel expenses and consumed goods cost, and the necessary amount is comparatively small.

(5) External expenditure(Ce, including the envelopment cost)

The total of production compensation to the inhabitants removal, the acquisition of land and Palm plantation is $38,132 \times 10^6$ Colones.

13.6 Monitoring

(1) Before performing the project

What is important that should be conducted before performing the project is the detailed survey of environment considering the environment preservation of down streams basins of Naranjo River and Paquita River and Paquita River after conducting the project, and the record of environment is necessary.

Because there exists the mangrove which is said to be the protective region in the downstream basin of Naranjo River, and this river mouth is adjacent to the National Park, we have to grasp the living environment of organisms and all to the actual situation of organisms. Further because there is the management of Palm Plantation which is important in the regional, economy utilizing the river water of Naranjo River as its irrigation, there is especially the need for monitoring the water river rate and irrigation water volume during the dry season.

a) Flow rate, irrigation water volume of Naranjo river and Palm production volume

The flow rate of Naranjo River is predicted to decrease by the enforcement of project. The river water flow rate decreases especially during the dry season on account of the irrigation utilization at the downstream side. In connection with the compensation to the Palm plantation, the observation point should be provided at the up-stream side of irrigation water intake point of Naranjo River, and the water intake measurement and the continuous survey are required. There is also the need for monitoring the fluctuation of palm production volume. The result obtained here is used as the basic data for compensation amount involved in the enforcement of project. This survey is continued during the works and after the work, and utilized to the discussion of actual compensation amount before and after the project enforcement.

Naranjo River is also utilized to the river rafting and inhabitants water playing at Londres spot. Therefore, it is important to grasp in details the water volume during the utilization period, the range of utilization spot, the water level of river and the topographical situation of river and also to monitor the local inhabitants activities.

b) Topography of river mouth

The function of sand/soil supply during the flooding is considered into the dam facility for maintaining the topography in the river mouth region, and the present situation maintenance of river mouth topography is anticipated even after the enforcement of project. However, it is also the fact that the topography is changed by the accumulation of slight fluctuations over a long period of time. For this reason, we have to monitor the topographical fluctuation of river mouth region of Naranjo River including the outlet of Estero negro of Naranjo River including the outlet of Estero negro from the long term view in preparation for grasping the change even after the enforcement of project.

c) Flow rate observation of major water channel inside Plantation and the water quality and creatures in Mangrove region including the river mouth region.

The river water guided to the Palma Tica Plantation is absorbed into the Palm, or the excessive water is finally vaporized or flows out via the Mangrove of Estero Negro of Naranjo River mouth region as the surface water or underground water. In this survey, it was grasped that during the dry season or even during no water intake period of irrigation water, the living environment of Mangrove can be maintained by the existence of outflow water.

Moreover, it is expected that even if the irrigation should be stopped during the dry season, the Mangrove environment can be maintained. Because this survey is the investigation for a short period of time, it is necessary to accumulate the data by carrying out the continuous survey.

The preservation of living environment of plants constituting the Mangrove invites the preservation of creature community living there. As earlier mentioned, it is anticipated that no serious environmental influence will happen to the Mangrove area after the enforcement of project, but the detailed survey of environment through the D/D stage if necessary also for confirming the influence after the enforcement of project and for drafting up the counter measure is necessary. Especially requested is the continuation of survey of flow rate and water quality in addition to the record of creature community.

For information the Mangrove of Estero Negro experienced the deforestation into the agricultural land by the land owner in the past, and its area is said to become smaller. At present, the Mangrove is in object of protection by the law, but it is heard that its effect can not be seen as a matter of fact as regards the Mangrove owned by individuals, and hence we must watch their developments and positively promote the protection of Mangrove.

The concrete survey item are the flow ratter, water quality, bottom quality, topography, vegetation, aquatic organisms, living animal, etc.

e) **Dispersion actual circumstance and landscape of river water.**

Such an actual situation can be seen that the river water of Naranjo River disperses offshore of National Park. By the enforcement of project, the reduction of river water volume and the contraction dispersion area are predicted. The water quality of Naranjo River during the rainy season is characterized by the turbid water quality, and an additional landscape improvement must be invited by the reduction of that water volume. The landscape of water area is one of important factors to the sight seeing and leisure at the seashore, so its record from the current situation is necessary. For information, the method utilizing the satellite picture is effective for the actual situation of dispersion.

The situation of river mouth area during the dry season can be confirmed by the satellite picture and salinity survey.

f) **Utilization of underground water**

Quepos Hospital utilizes the undergroundwater from the spot with Naranjo River crossing with National street No.20. It is reported that this well falls in this water level during the dry season. On the other hand, the water level of wells distributing in the fan area at the downstream side of Naranjo River don't change so much during the dry season, but the water level fall, though not so conspicuous is recorded in the vicinity of the irrigation water intake channel to the Palm plantation. The monitoring should be continuously conducted on the well of Quepos Hospital before and after the enforcement of project, and if the function of well aggravates due to the fall of water level, there is the need for taking water from the deeper layer or seeking an all tentative well at another spot.

g) Fishing

In the present survey, it is predicted that no great influence is given on the catch volume from the fishing pattern in this area. However, the fishing is governed only by the natural environment but also by the social environment and tangled with many other elements, so the daily contact with the fishermen and the collection of fishing information are necessary toward the enforcement of project.

h) Prawn cultivation

The shrimp cultivation yard exists adjacent Estero Negro. This cultivation pond takes the water from the water channel leading to Estero Negro, but from the fluctuation of measured value of salt value of this pond, it is predicted that no great influence will be caused in the enforcement of project. However, because the fishing is structure of many factors as described above, it is necessary to monitor the prawn cultivation actual record by the daily contact with the management. For information, the catch fishing in the Mangrove area including Estero Negro is prohibited for the sake of protecting the natural environment and fishing resources, so there is the need for supervising the fishing in Estero Negro region.

i) Sea turtle

In general speaking, the environmental problem at sea turtle egg-laying ground attributes to the development and contamination of sea coast. The present project isn't of on contents aggravating the water quality, so it doesn't have any great influence on the sea turtle. In addition, this area is not the central area of sea turtle egg-laying ground.

At this spot, it is recorded that a few number of turtles come, but the dam of this project of the contents and administration that the sand can be supplied concerning the topographical change of sea coast, and it can be judged that the sea beach of Savegre River from Nartanjo River is under the influence of Savegre River, so the present project can be predicted to have no big environmental influence the sea turtle similarly to the pollution problem. However, because the sight seeing development from Naranjo River mouth to the Savegre River mouth sea coast area and the sea turtle visit can be seen the direct relationship in other cases, it is necessary to grasp the situation of sight seeing development and also to monitor the sea turtle by the specialist.

j) Vegetation including the reservoir and facility construction planned area

The distribution of precious plants are found in the reservoir and dam spot according to this survey confirming their kinds. Detailed survey shall be needed to grasp the detailed actual situation in the future including the living animals. If living spot is extremely limited, positive protection measures will be demanded.

k) Flow rate and topography of Paquita River

The problem in the downstream side is extremely important after all concerning Paquita River. That is to say, the detailed study of current situation is necessary for predicting the river flow rate and river course and the topographical change of river mouth area or for confirming then after the enforcement of project.

The erosion problem of sea coast has happened from the past in Paquita River mouth area. Its great factor is said to be the movement of erosion site due to the change of sea coast topography which is being caused by the natural phenomena.

The enforcement of this project increased the water volume of inherent Paquita River and Cana River by a few percents, and it is predicted that this project gives no great artificial influence. However, the data of correct flow rate change and topography are very much important in the future too and necessitated, and so they need to be monitored.

The topographical change of river source in the downstream side is also important similarly to the river mouth area. According to the project, the conversion of Naranjo River water to Paquita River is to be limited during the natural food which have the possibility of bringing about a big topographical change, and the occurrence of environment influence can be prevented. However, there is the need for monitoring into details the actual situation of water volume during the natural flood like the case of Canas River.

The dispersion state of Paquita river water needs to be monitored just like that of Naranjo River.

l) Paquita River water quality and biological survey

The detailed and prior environment survey is necessary for grasping the environment change after the enforcement of project. The survey items cover the water quality and aquatic organisms.

2) During the enforcement

During the enforcement, it is necessary to monitor the sand/soil, noise and vibration being caused by the work together with the continuation of survey before the enforcement of said project, Especially concerning the appearance of turbidity during the work and the problem of pH during the dry season, care must be taken such as installing a monitoring spot, etc.

3) After the enforcement

Because there is the need for grasping the environment change and conducting its evaluation after the enforcement of project, the continuation of monitoring is necessary.

13.7 Overall Evaluation

- (1) The project site is positioned at the area where the tropical rain forest has already been developed into the agricultural land for feeding the livestock, and a large scale of deforestation of natural forest is not being planned. The vegetation in this area is poor by the agriculture land development but there exists the forest in the vicinity of reservoir planned area and power station planned area.

Because some precious kinds of plants exist at the reservoir planned area and dam spot according to this survey, their distribution volume should be investigated before enforcing the project, and if its distribution should be limited, the positive protection measure is desired.

- (2) The present project is to generate the electric power by converting the river water of Naranjo River into Paquita River or by utilizing its head or water level. Therefore, in the downstream area from the dam spot of Naranjo River to its river mouth, the water volume decreases and the reduced water situation appears. The Mangrove protected by the law exists at the river mouth of Naranjo River downstream side, and the National Park is adjacent to the right bank of that river mouth.

Surveying the influence on them involved in the enforcement of this project, it was grasped that the current state Mangrove environment can be maintained even by the enforcement of this project and moreover that the project doesn't have any serious influence on the National Park.

- (3) Following the water reduction of Naranjo River, the water volume of Paquita River increases. At the creek existing in the river mouth of Paquita River, the erosion of land which is on the opposite side is conspicuous by the natural growth at the tip of sandbank positioned at the outlet of said creek, it was understood that the influence on the erosion phenomena by the water increase portion of this project doesn't conspicuously promote the natural topographical change process of current situation.

Against this, the enforcement of prompt measure by the organization relating to the national land preservation of Costa Rica is desired together with the re-evaluation of erosion history from the past.

- (4) Aquatic organisms are living in Naranjo River and Paquita river, but the organisms which is judged to be precious is not especially found out, Many survey data revealed that many organisms are living in the brackish water area including the water decreasing Mangrove area.

In the this evaluation, environment survey and environment evaluation from were conducted at the standpoint of preservation of living environment of organisms, but there is the need for monitoring the survey of detailed living organisms in the future and for leaving the records. For preserving the precious environment of Mangrove, etc. which are protected by the sandbank, the this project, considering the supply of sand and earth from Naranjo River, expects to protect it by the enforcement of measure where the contrivance is added to the dam facility and administration.

- (5) The water volume of Paquita river is increased by the conversion of Naranjo River. Paquita river has a history that a flood happened at the curved area in its middle stream by the heavy rain in the up stream side, Concerning the fear for promoting the flood during a heavy rain, the conversion of river water into the Paquita River will be stopped during an emergency case, and the present project previously prevents the said fear by the enforcement of administrative measure.

- (6) Small villages sporadically exist around the project spot, and the livestock feeding and small scale agriculture are being done. The economy in this area depends on the primary economy and the people are very much poor and many of them are tenant farmers under a large scale land owner. On the other hand, the survey result reveals that the satisfaction degree concerning the living of access, infrastructure, clinics, education, etc. of inhabitants as the social capital is low, and

this area is positioned at the low rank among the areas in Costa Rica nation.

Therefore, the jobs for obtaining the income are less and moreover the individuals' incomes are extremely less, thus the enhancement of quality of regional economy and the renovation of society are said to bear the future of this area.

In the downstream of dam spot, large scale Palm Plantations are developed under a few number of managements as the regional industry, but because a part of agriculture land utilizes the water of Naranjo River as the irrigation water especially during the dry season, this conflicts with the present project only during the limited period of dry season. there is the need for compensate for the water shortage during the dry season, but the irrigation agriculture land is only a small range of Palm Fruits production area in this region and thus it is understood that no serious influence is given on the area industry.

In compensating for the irrigation water, there is the need for fully discussing it with the agricultural managements, and mutually discuss the effective utilization of underground water for the water shortage portion in addition to the selection of payment method of compensation money.

- (7) About less than 100 persons and one primary school need to be removed following the enforcement of project, but there is the need for sufficiently explaining the project to the inhabitant for making the compensation in conducting these removal.
- (8) This project is for generating the electric power but the correspondence considering the actual situation of society and economy in this area is requested. That is to say, the project needs to coexist with the area in the future too in such that it employs preferentially the inhabitants in this area as the laborers involved in the work in this area, the local traders are utilized for the general materials required for the work and that the clinics and infrastructure arrangement is for enhancing the level of area. In addition, fostering the leisure and sight seeing industry in what is desired by the inhabitants, the up-stream spot utilization of dam spot needs to be released to the people utilizing a part of river, and it is desired that the project is in forced under the sufficient explanation to the regional inhabitants.
- (9) With the said result kept in mind, it can be thought that this project can be enforced without having any especially serious negative influence to the nature, society and economic environment in this region.

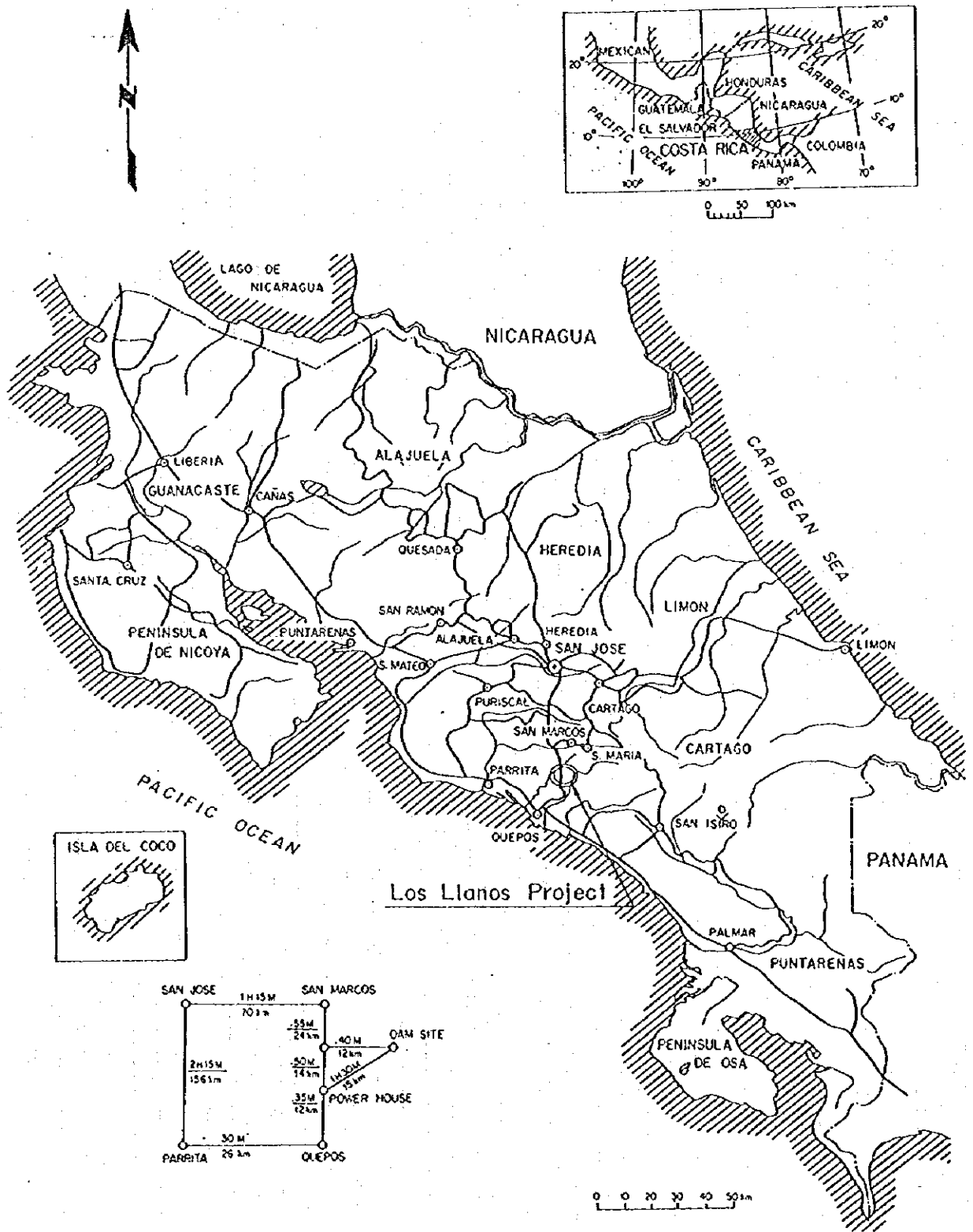


Fig. 13-1 Location of Project Area

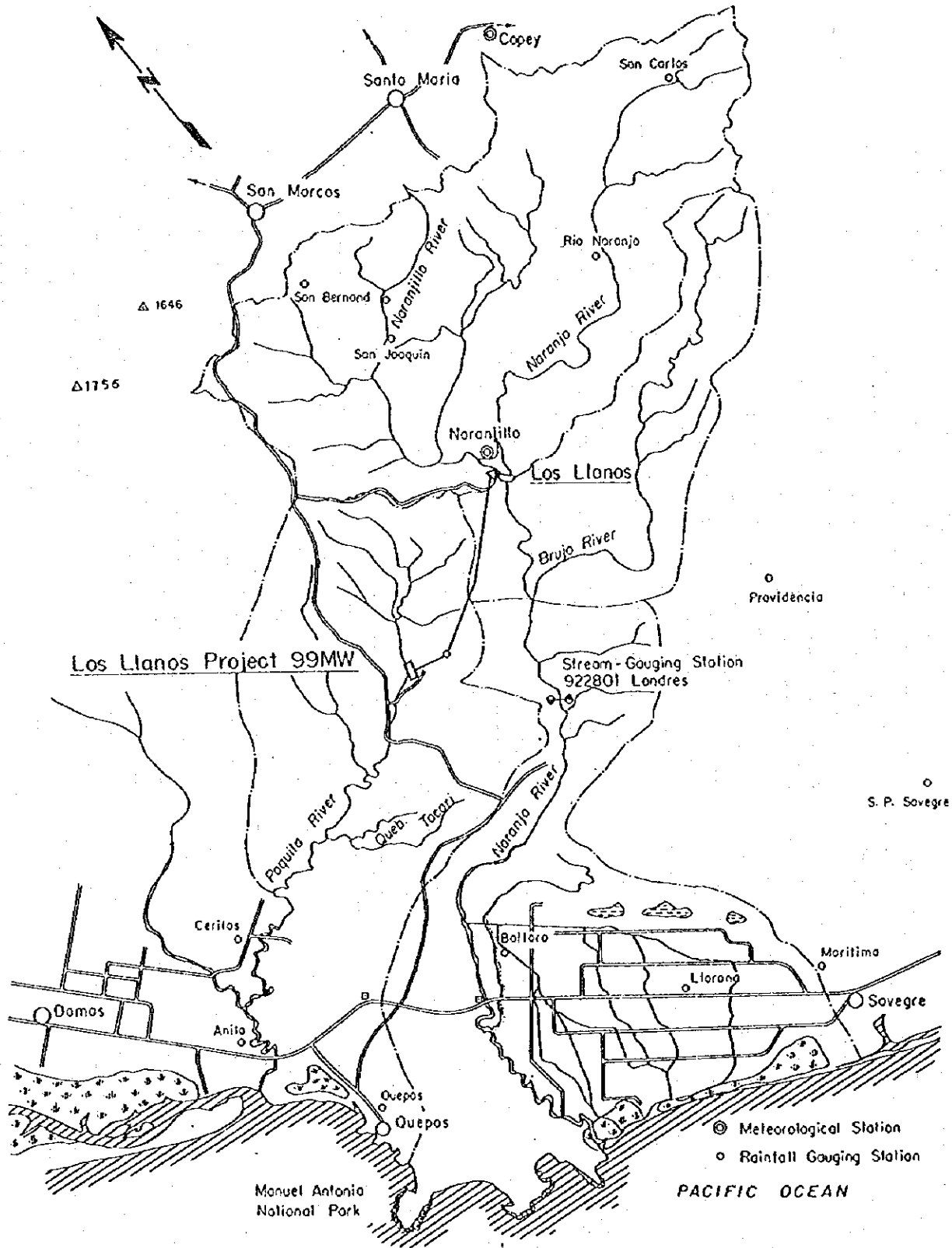


Fig. 13-2 Basins of Naranjo and Paqueta River

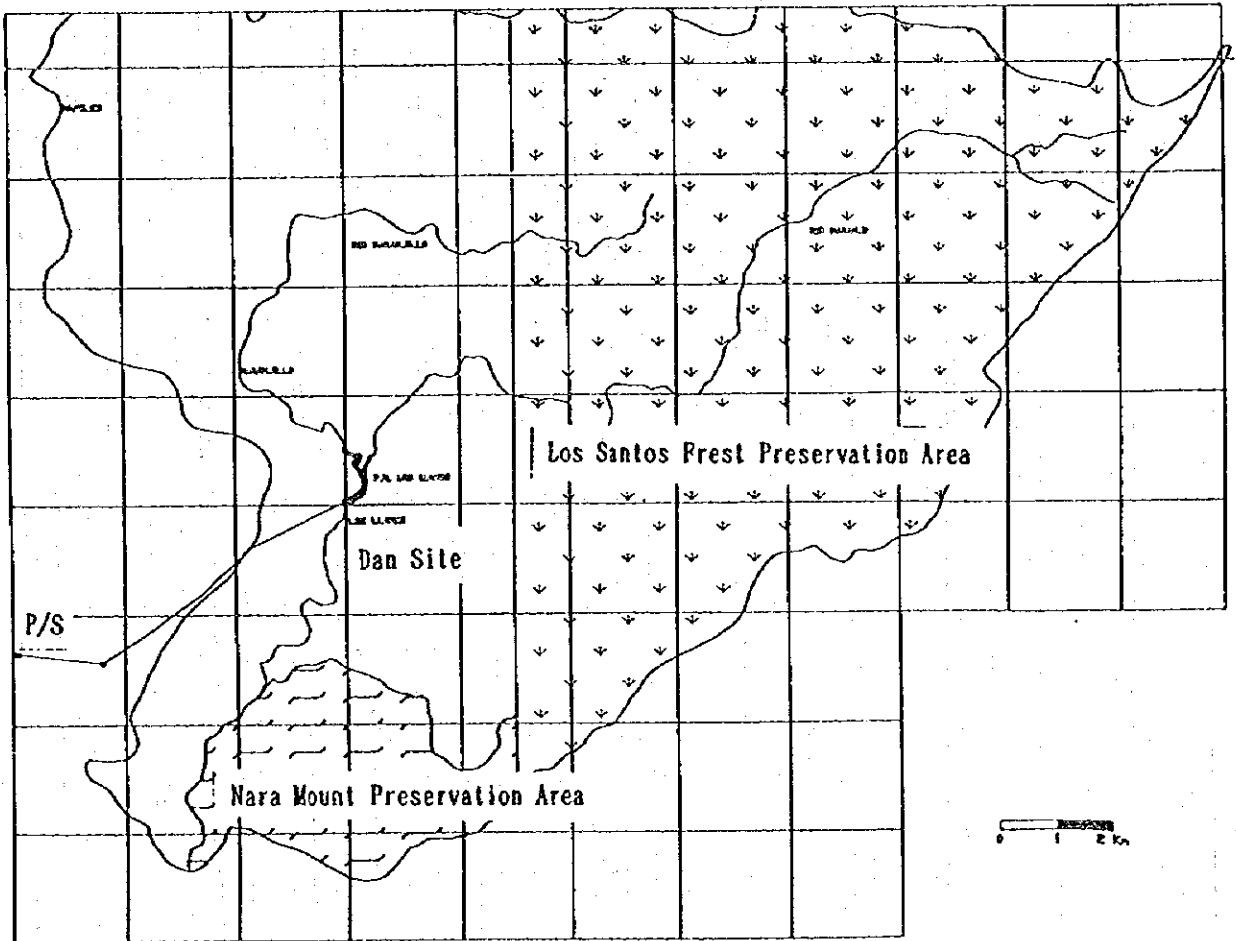


Fig. 13-3 Location of Forest Protection Area

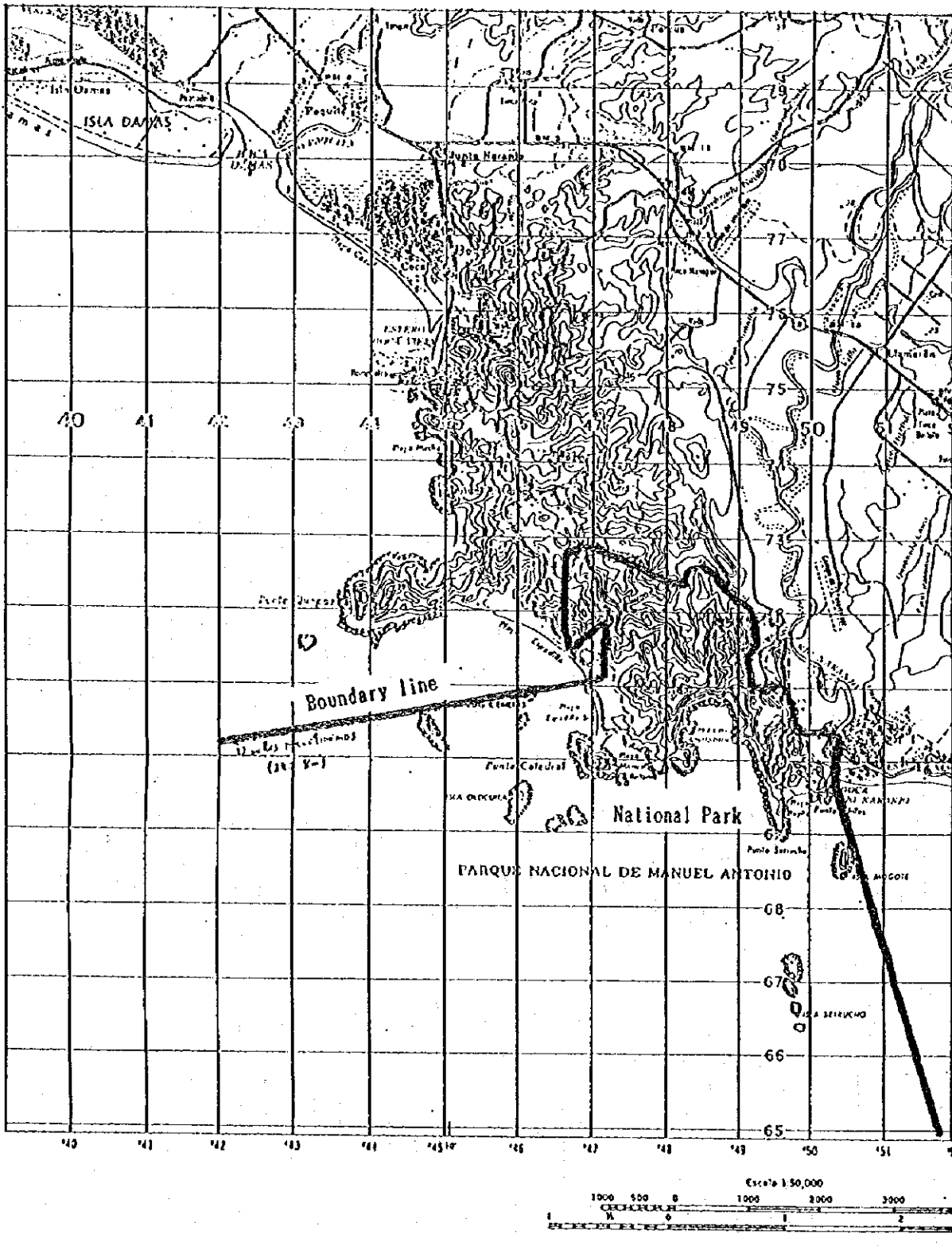


Fig. 13-4 Location of Manual Antonio National Park

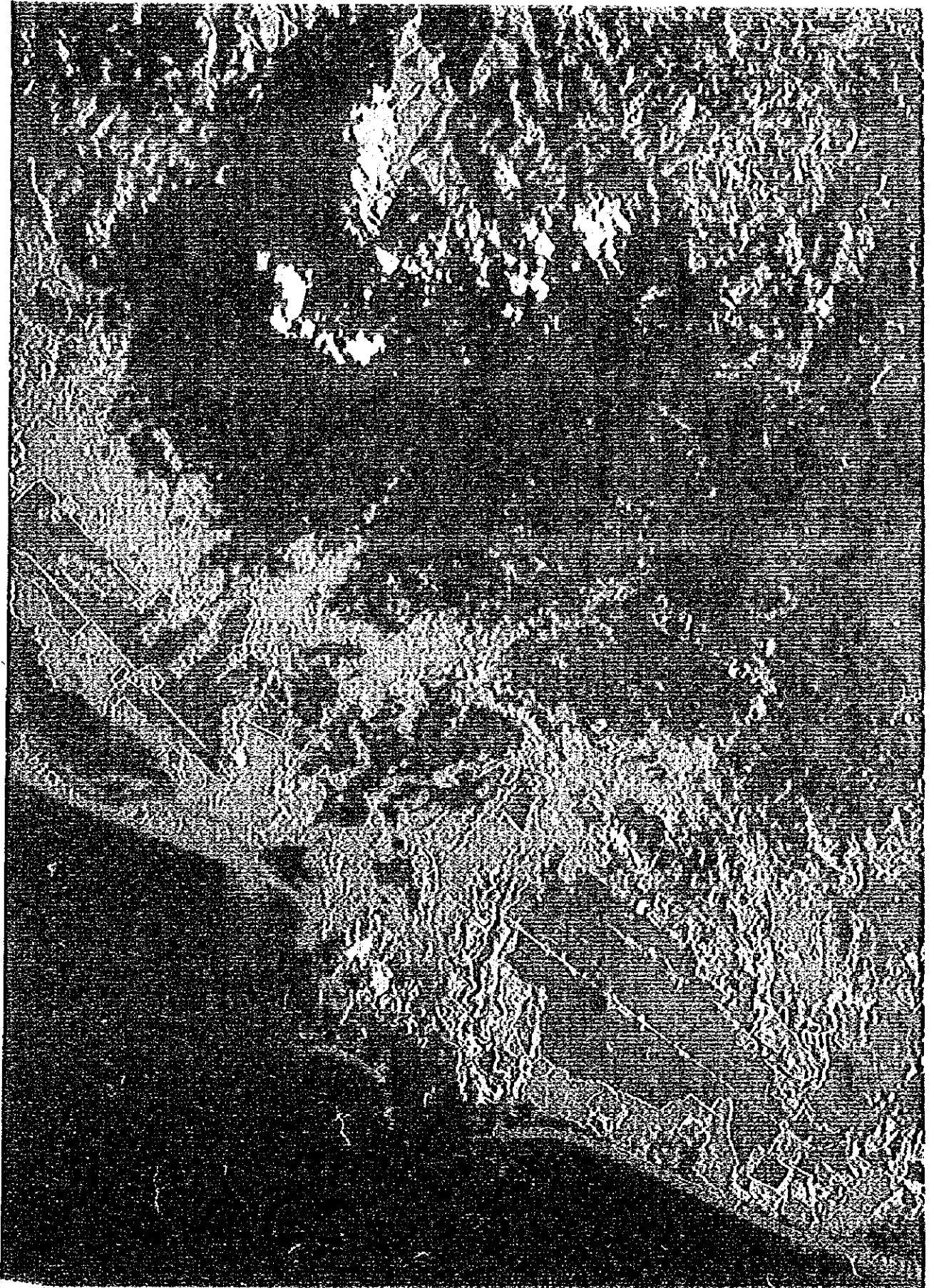


Fig. 13-5 Landsat Image of Project Area (April 3, 1992)

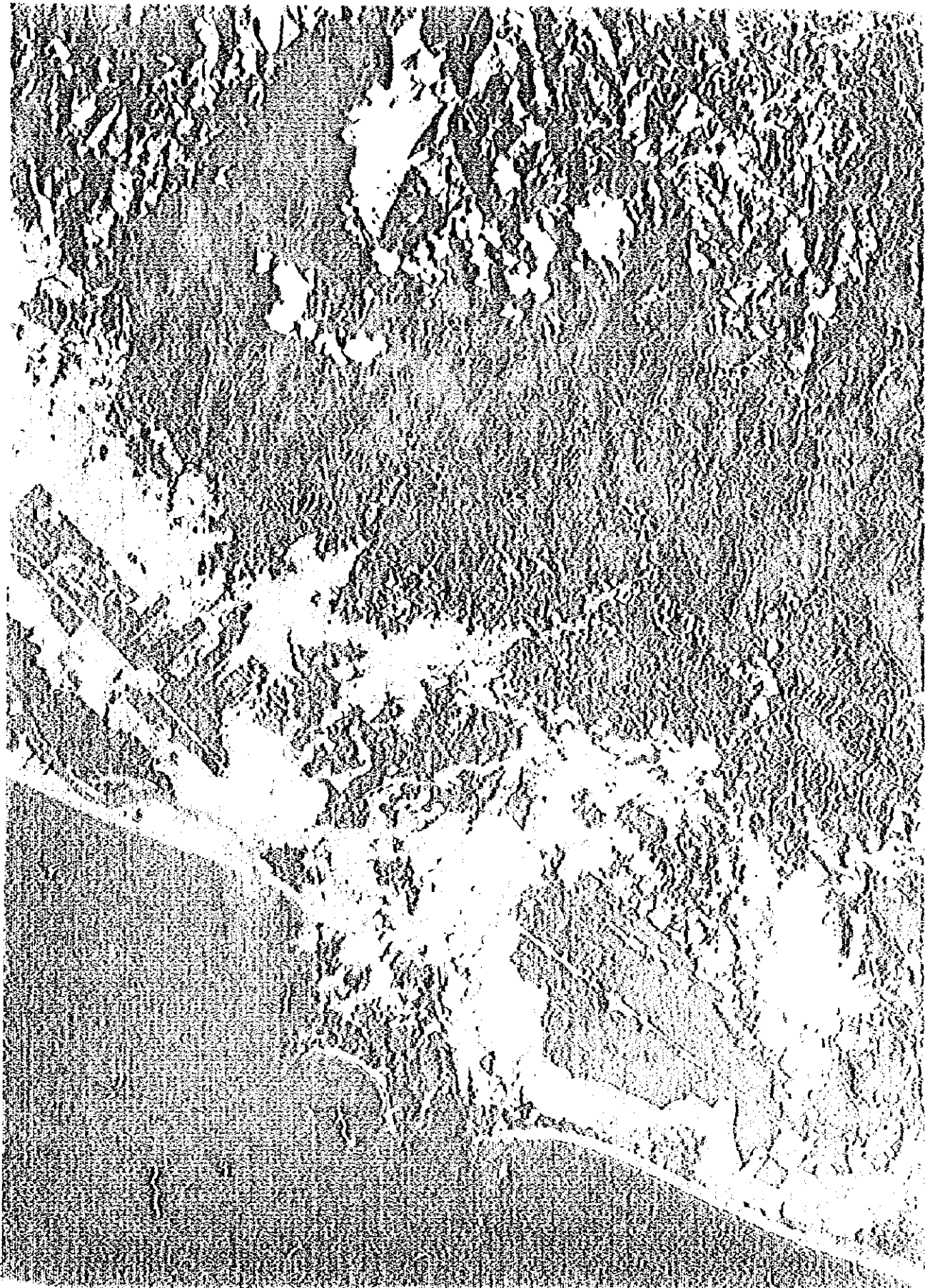


Fig. 13-5 Landsat Image of Project Area (April 3, 1992)

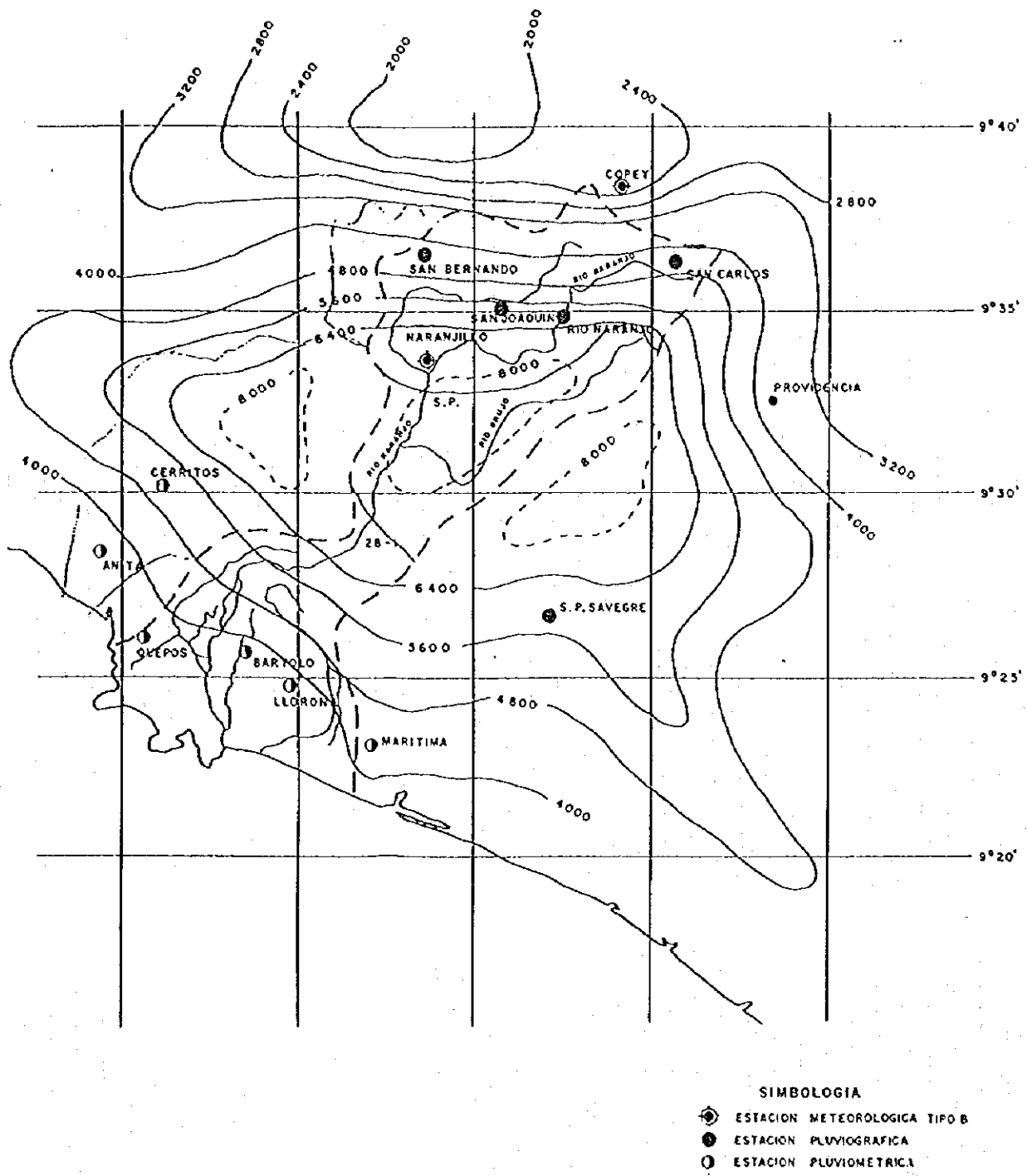


Fig. 13-6 Distribution of Annual Precipitation



Fig. 13-7 Location of Ground Water Level Measurements

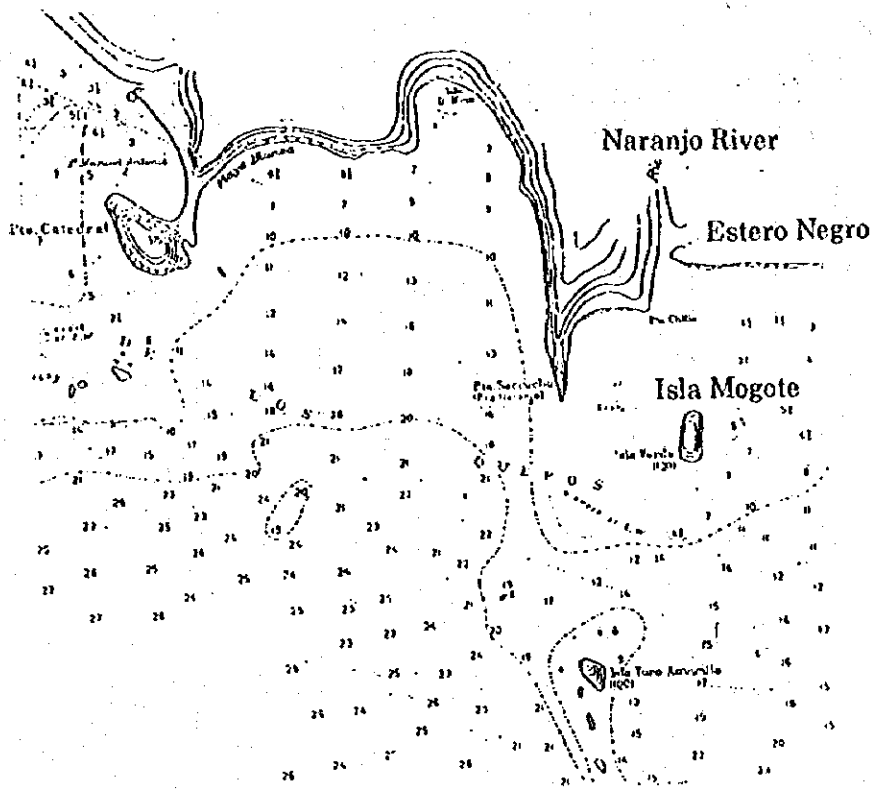


Fig. 13-8 Depth Distribution (m)

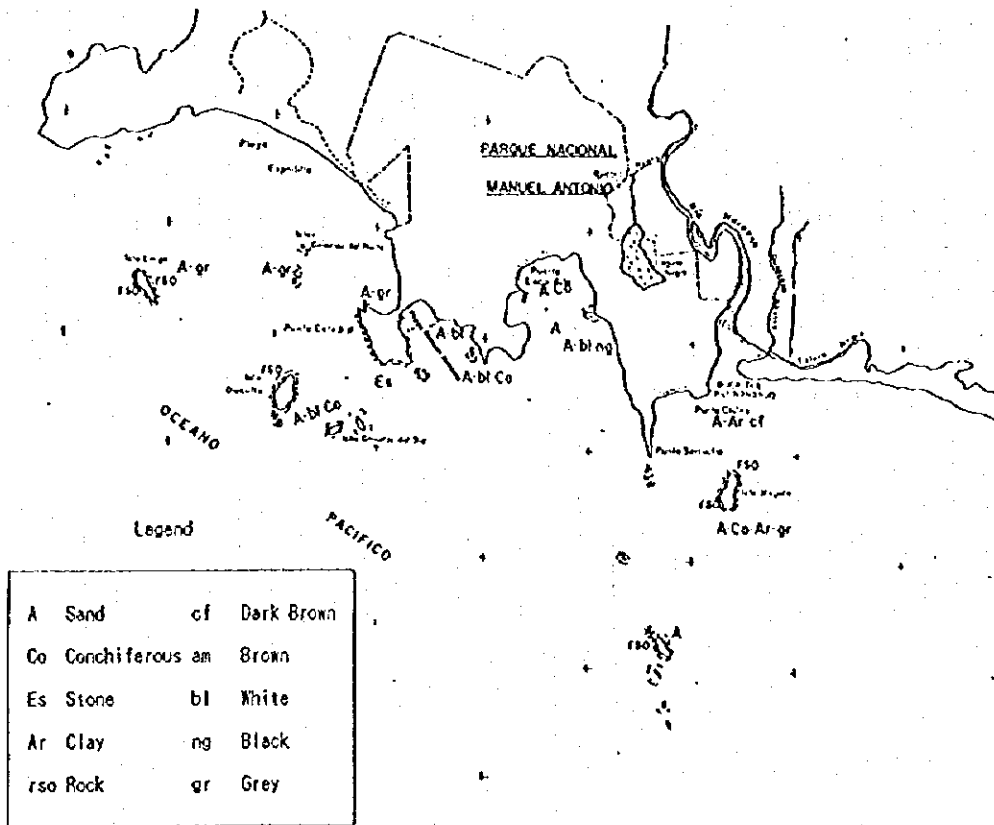


Fig. 13-9 Characteristics of Sediment

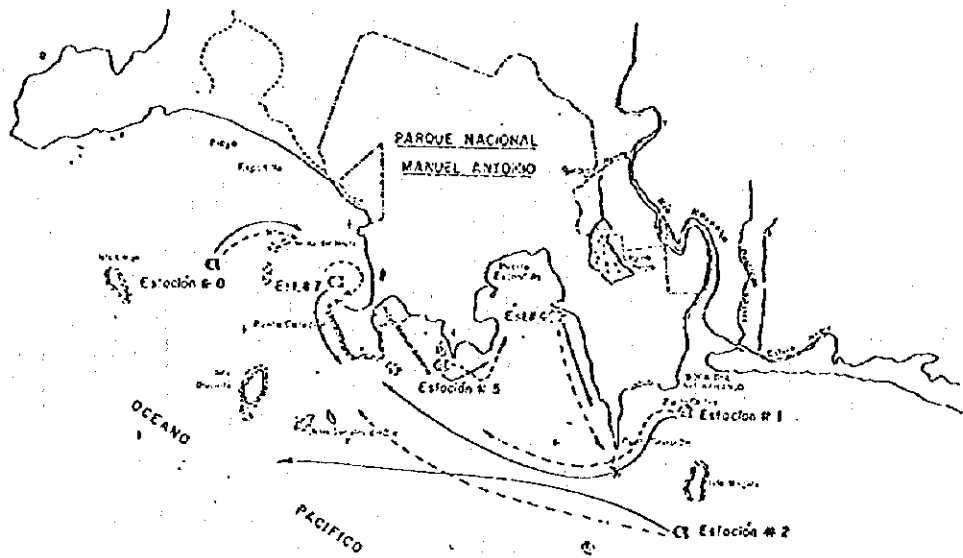
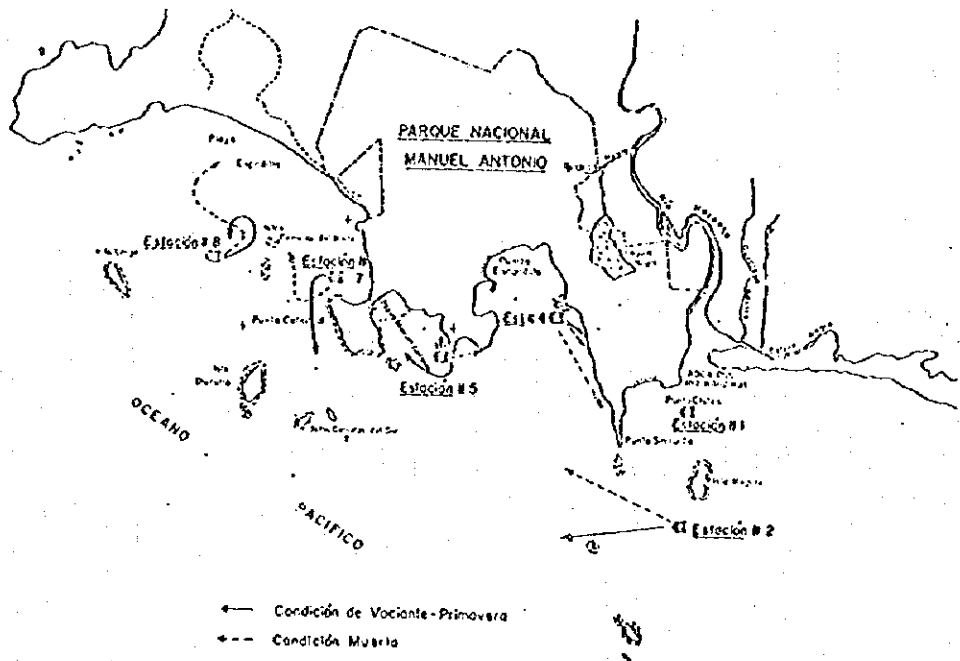


Fig. 13-10 (a) Flow Condition of Surface Water (Ebb Tide)

← Ebb Tide
- - - Low Water

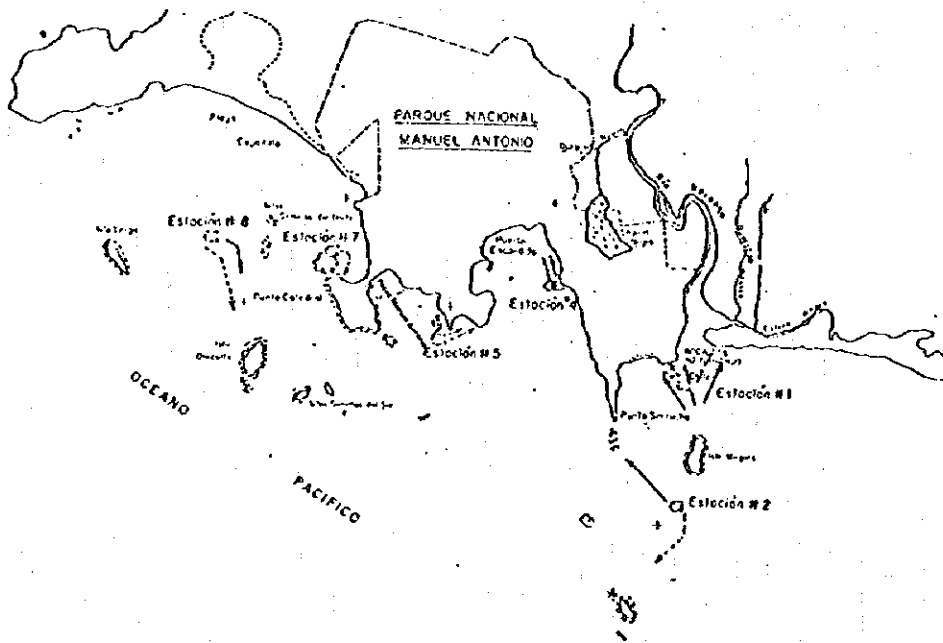
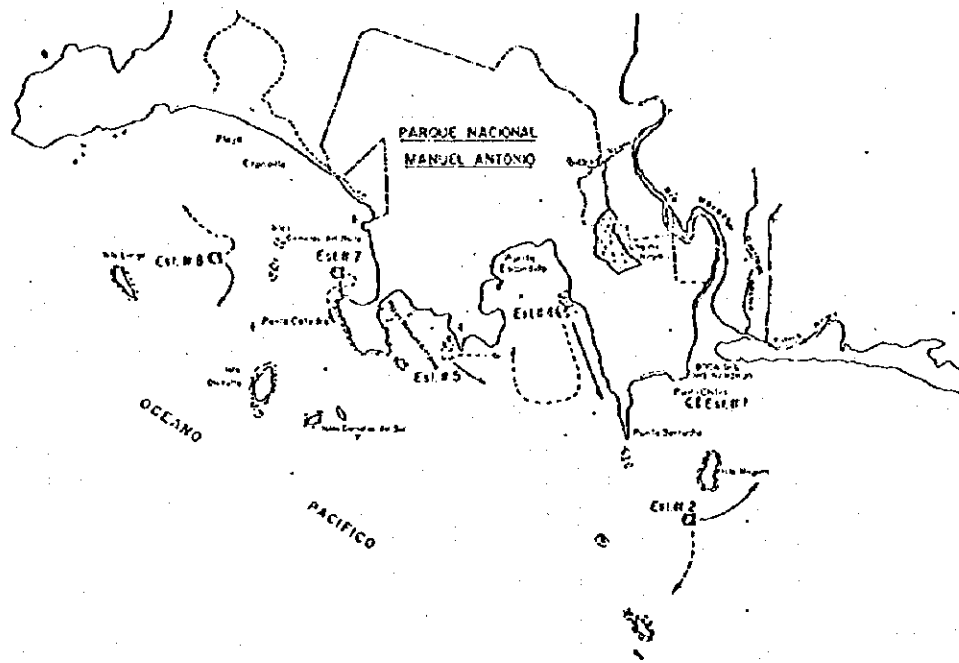
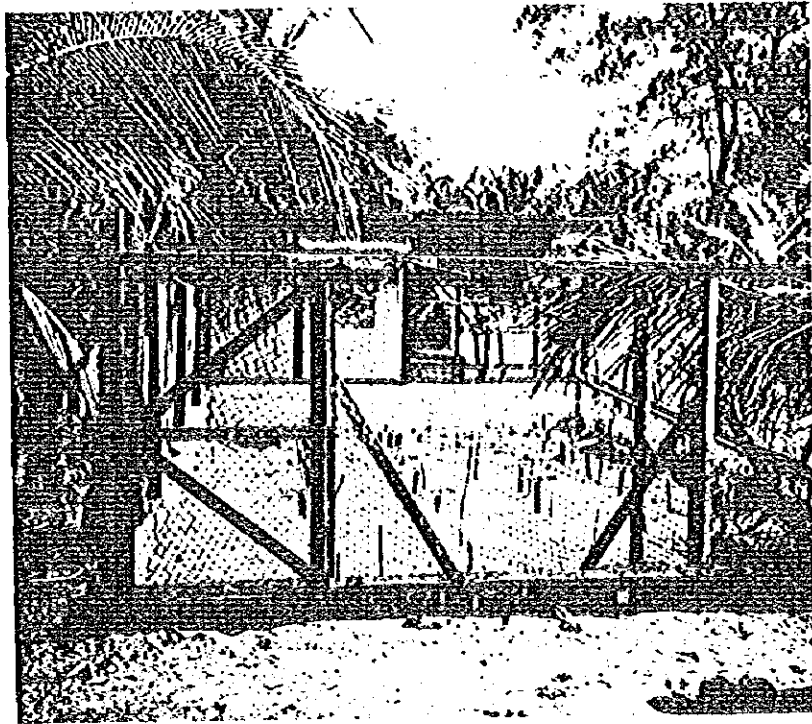


Fig. 13-10 (b) Flow Condition of Surface Water (Rising Tide)

- Rising Tide
- High Water



**Artificial Hatching Facility
near Naranjo River Mouth**

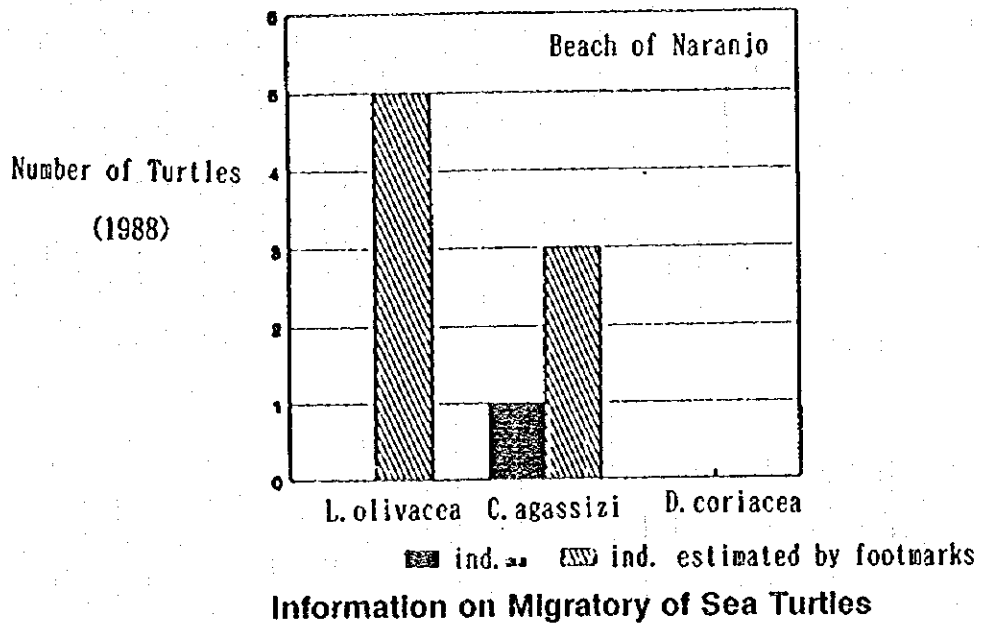
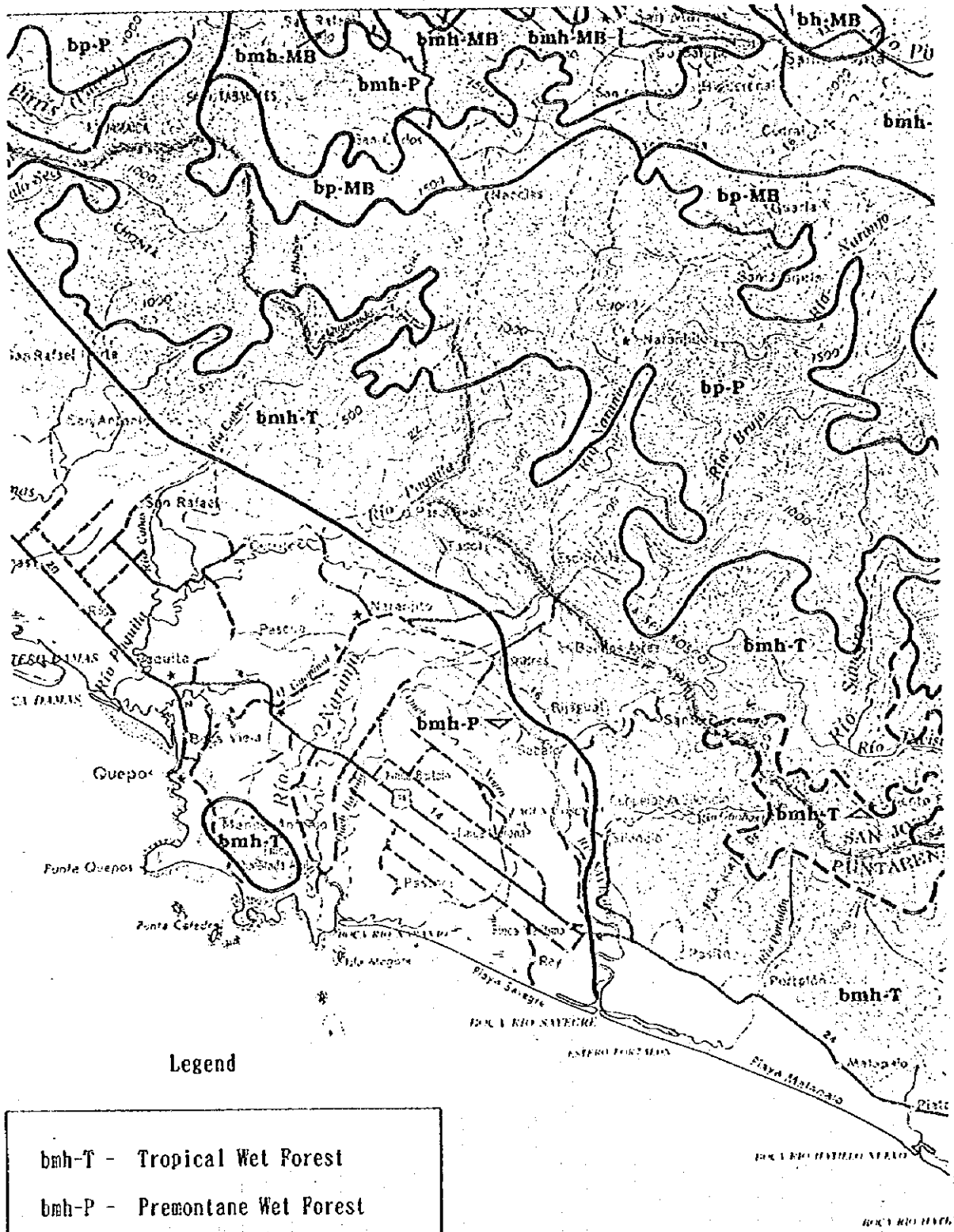


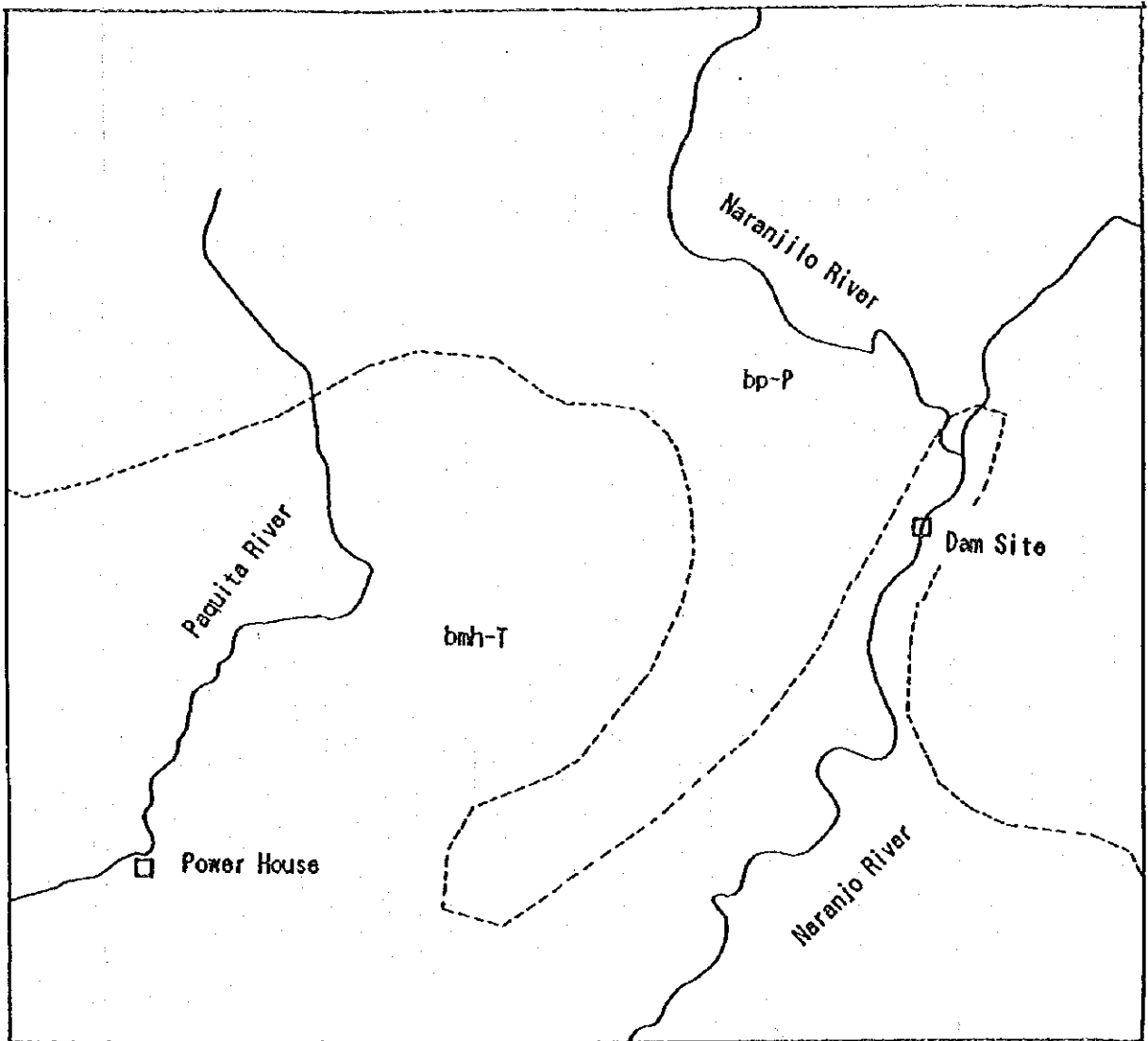
Fig. 13-11 Artificial Hatching Facility of Sea Turtles near Naranjo River Mouth



Legend

| | |
|--------|-----------------------------|
| bmf-T | - Tropical Wet Forest |
| bmf-P | - Premontane Wet Forest |
| bp-P | - Premontane Rain Forest |
| bp-MB | - Lower Montane Rain Forest |
| bmf-MB | - Lower Montane Wet Forest |

Fig. 13-12 Ecological Map of Project Area (CCT-1988)



bp-P : Premontane Rain Forest

bnh-T: Tropical Wet Forest

Fig. 13-13 Detailed Ecological Map in the Project Area

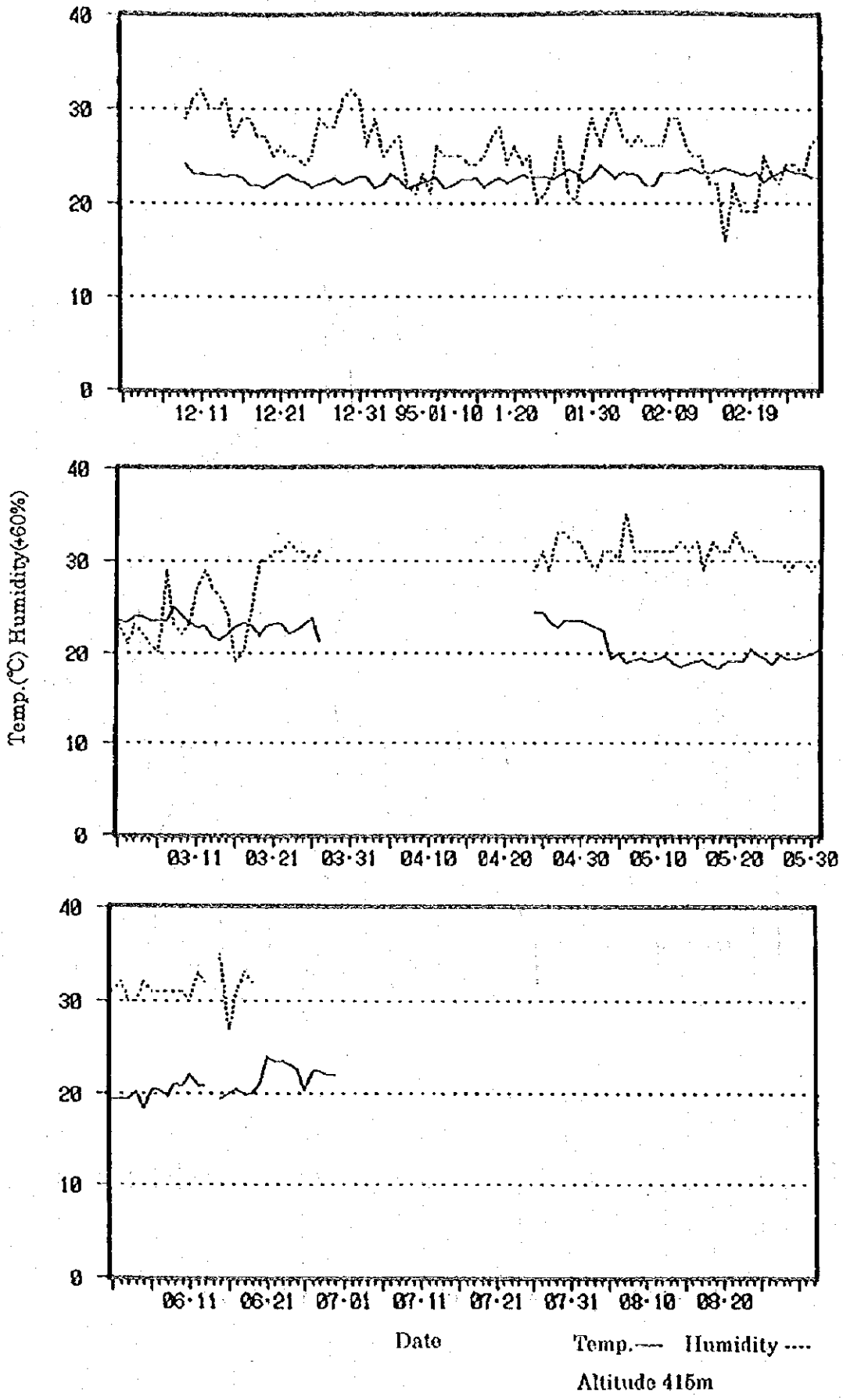


Fig. 13-14 (a) Change of Air Temperature and Humidity

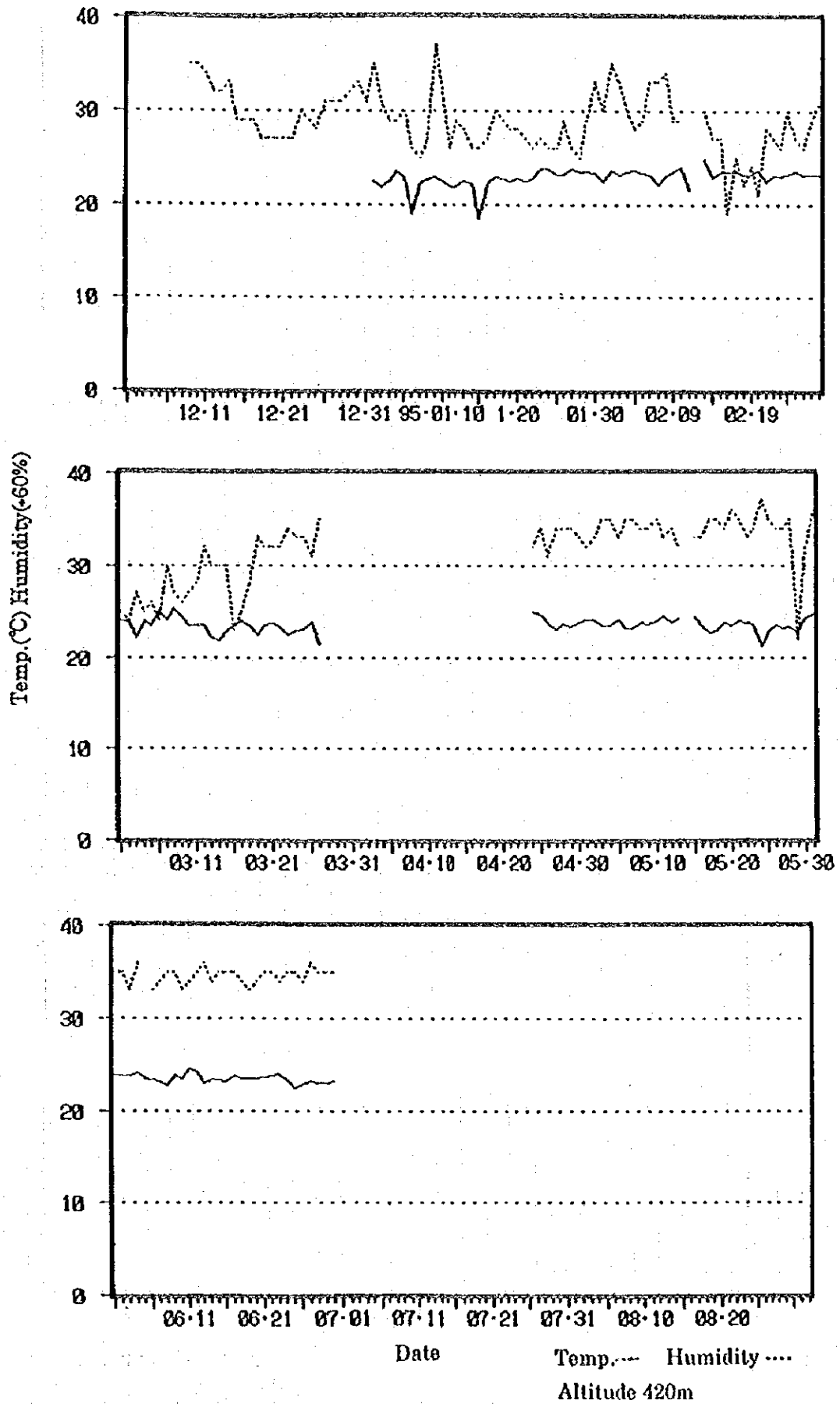


Fig. 13-14 (b) Change of Air Temperature and Humidity

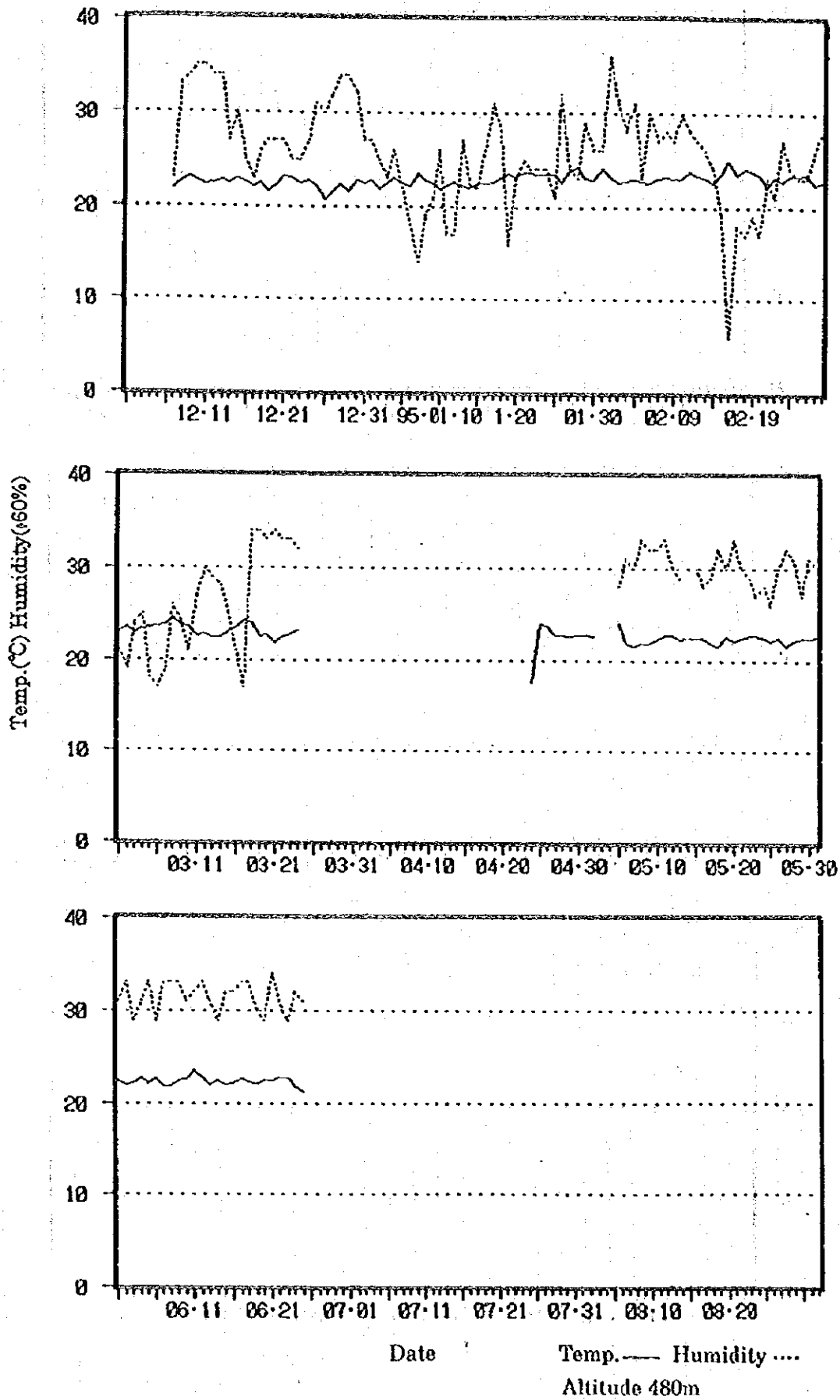


Fig. 13-14 (c) Change of Air Temperature and Humidity

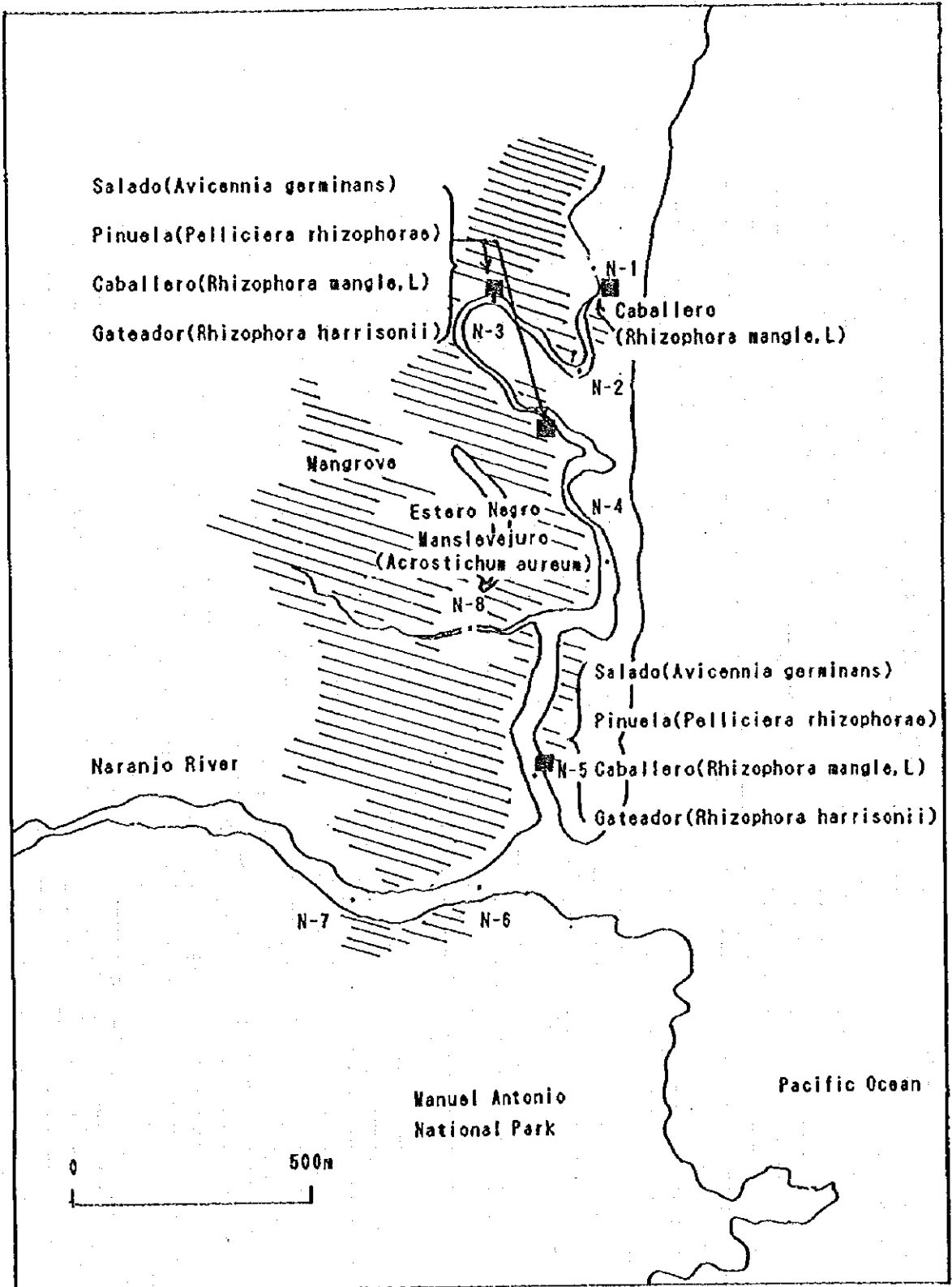


Fig. 13-15 Distribution of Mangrove Trees in Estero Negro

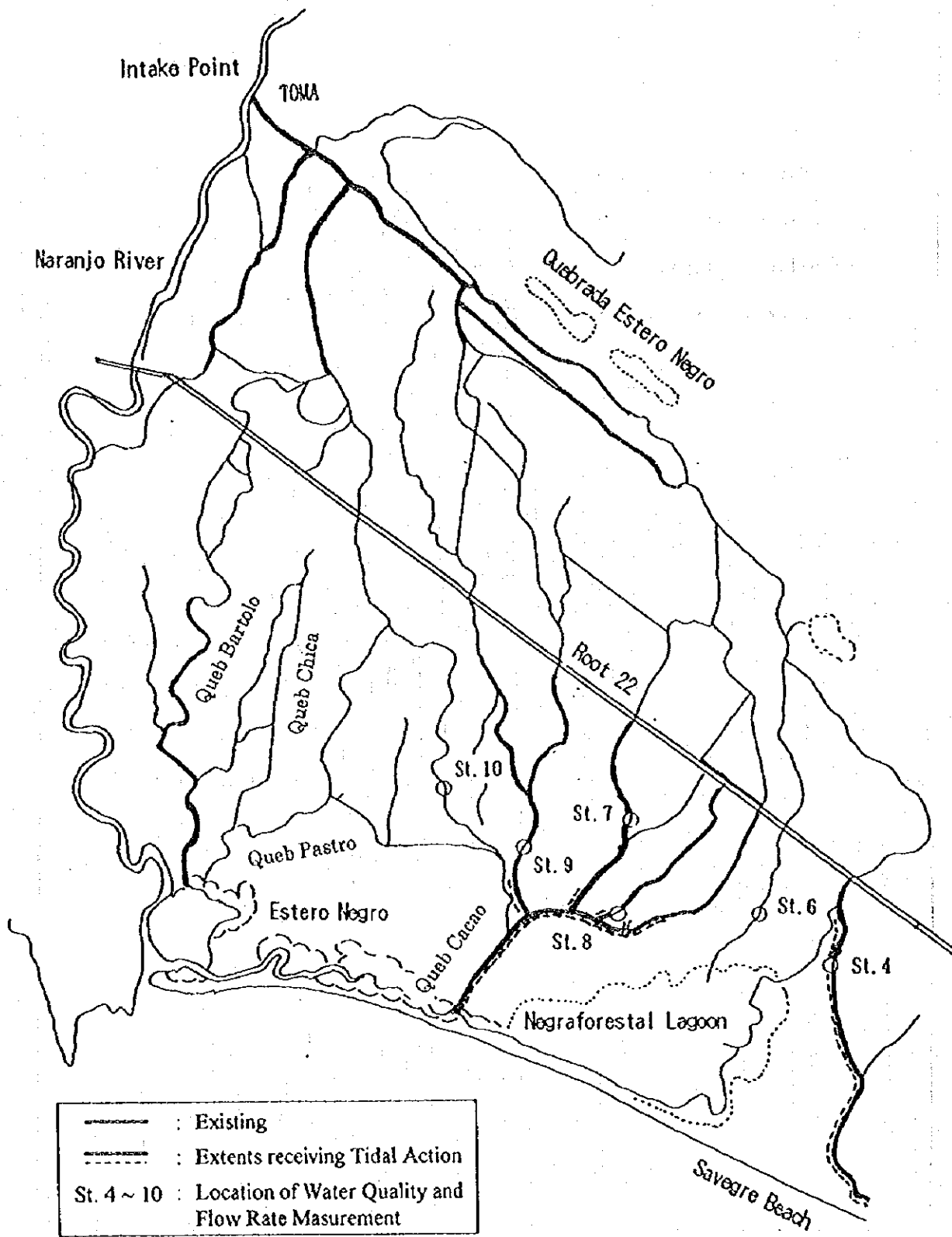


Fig. 13-16 Distribution of Channel Water

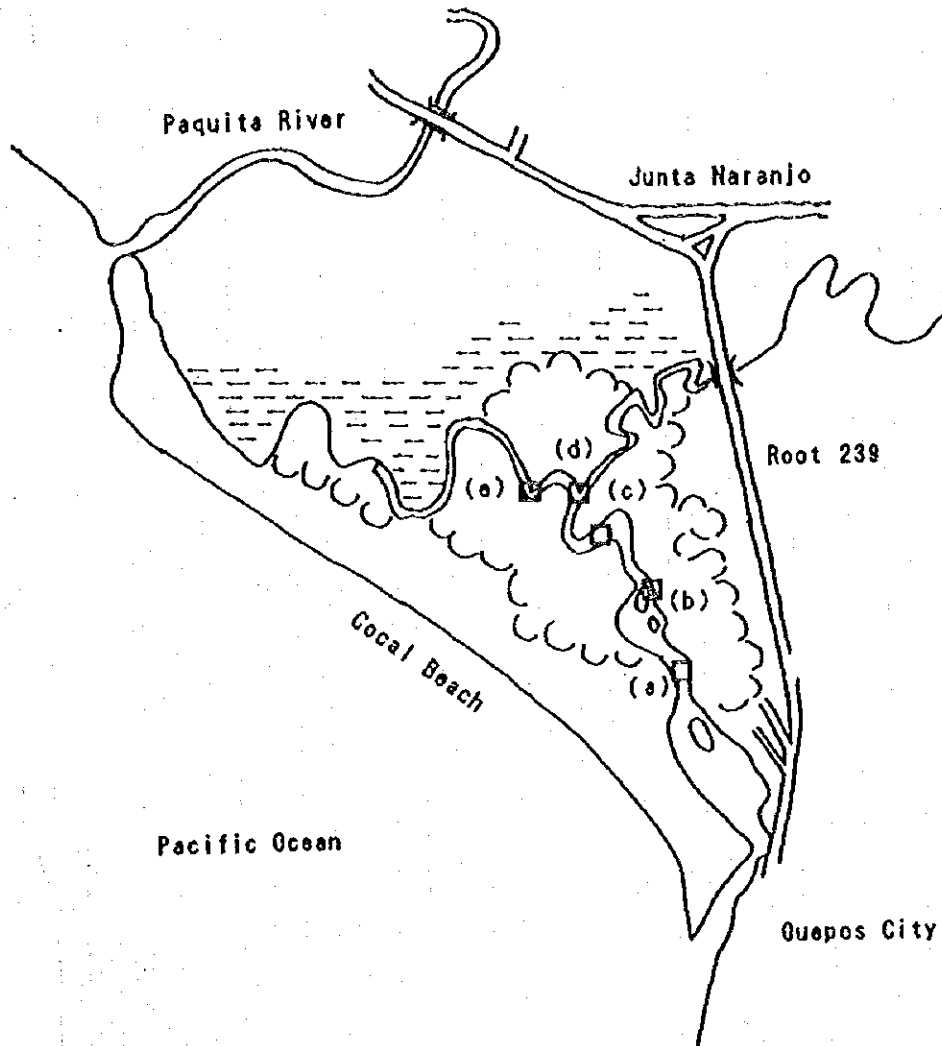


Fig. 13-17 **Location of Salinity Observation at Quepos Mangrove Area**

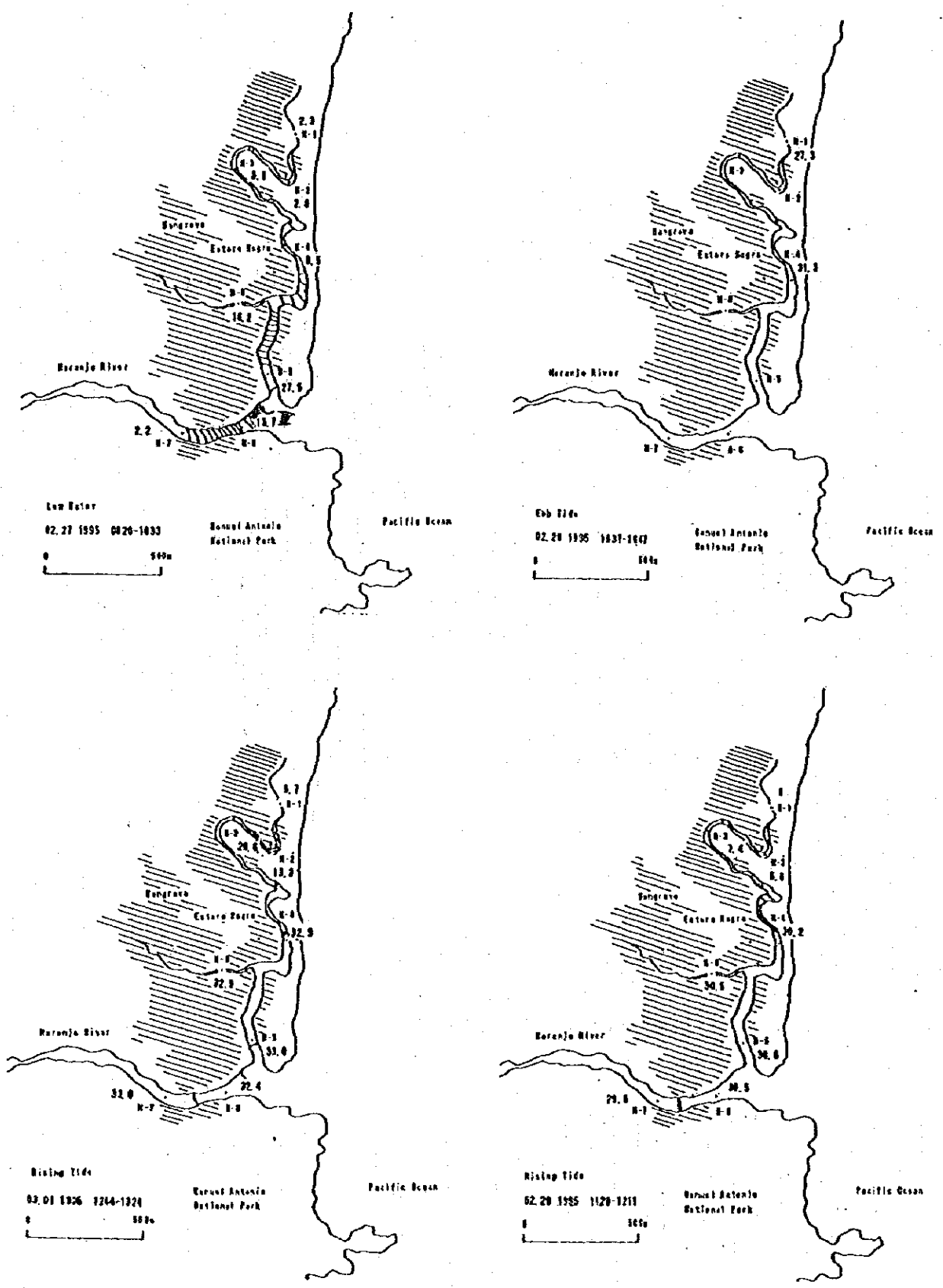


Fig. 13-18 (a) Horizontal Distribution of Salinity in Estero Negro and Naranjo River Mouth

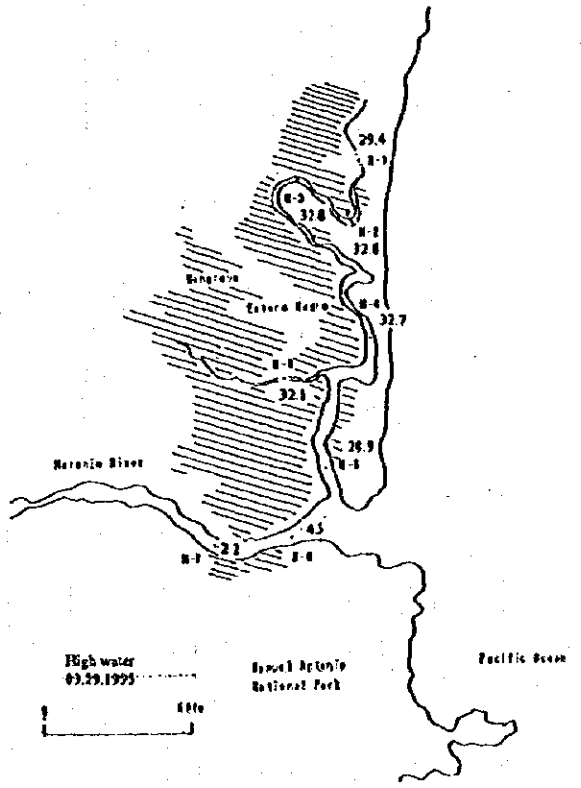
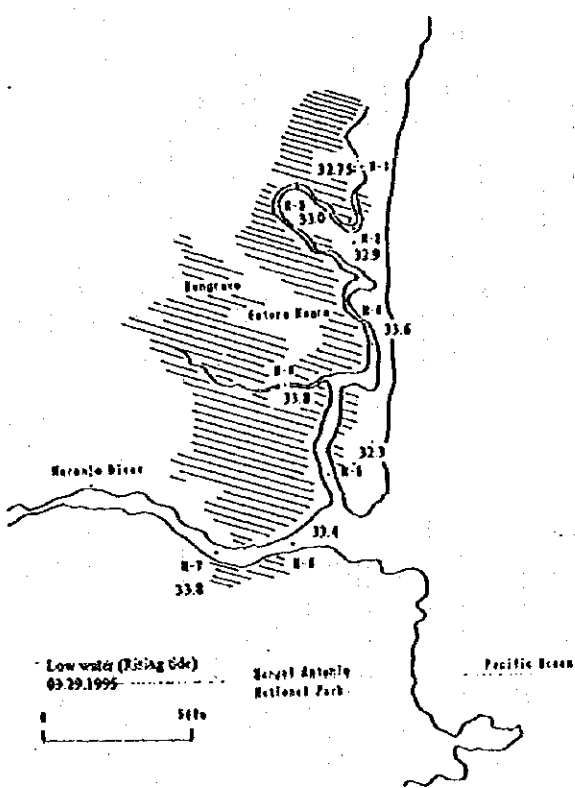
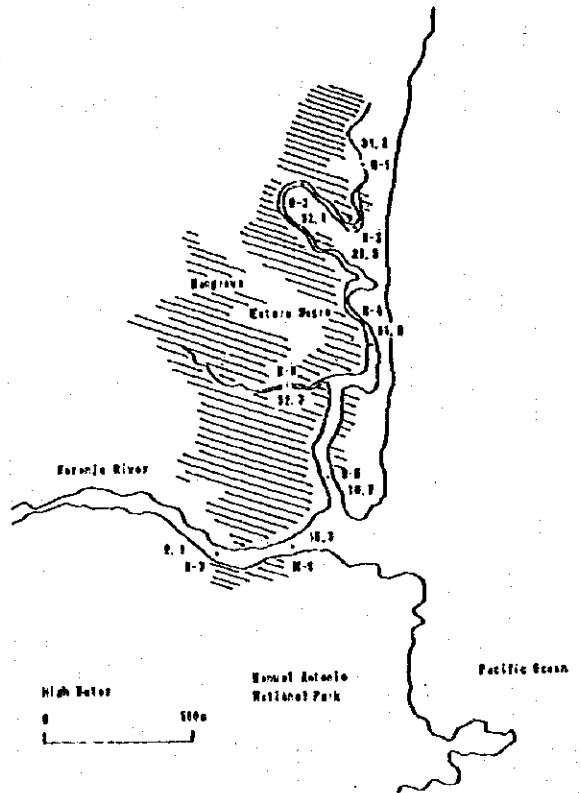
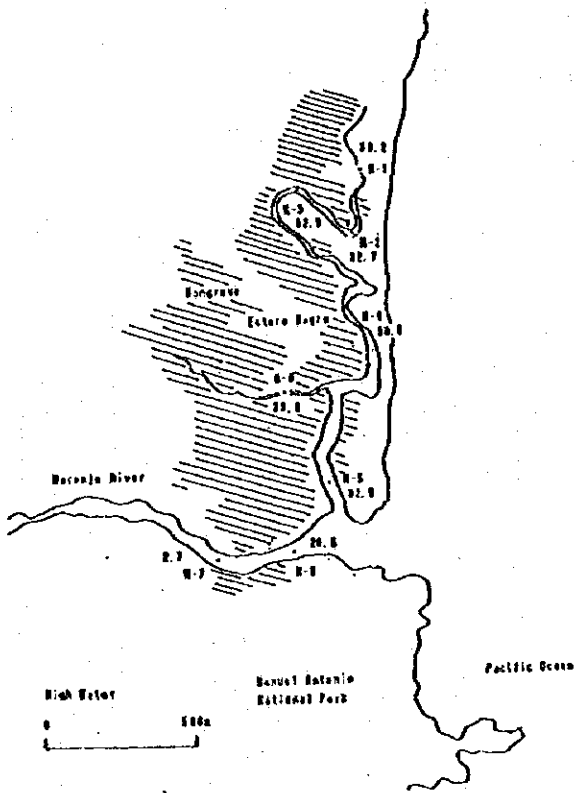


Fig. 13-18 (b) Horizontal Distribution of Salinity in Estero Negro and Naranjo River Mouth

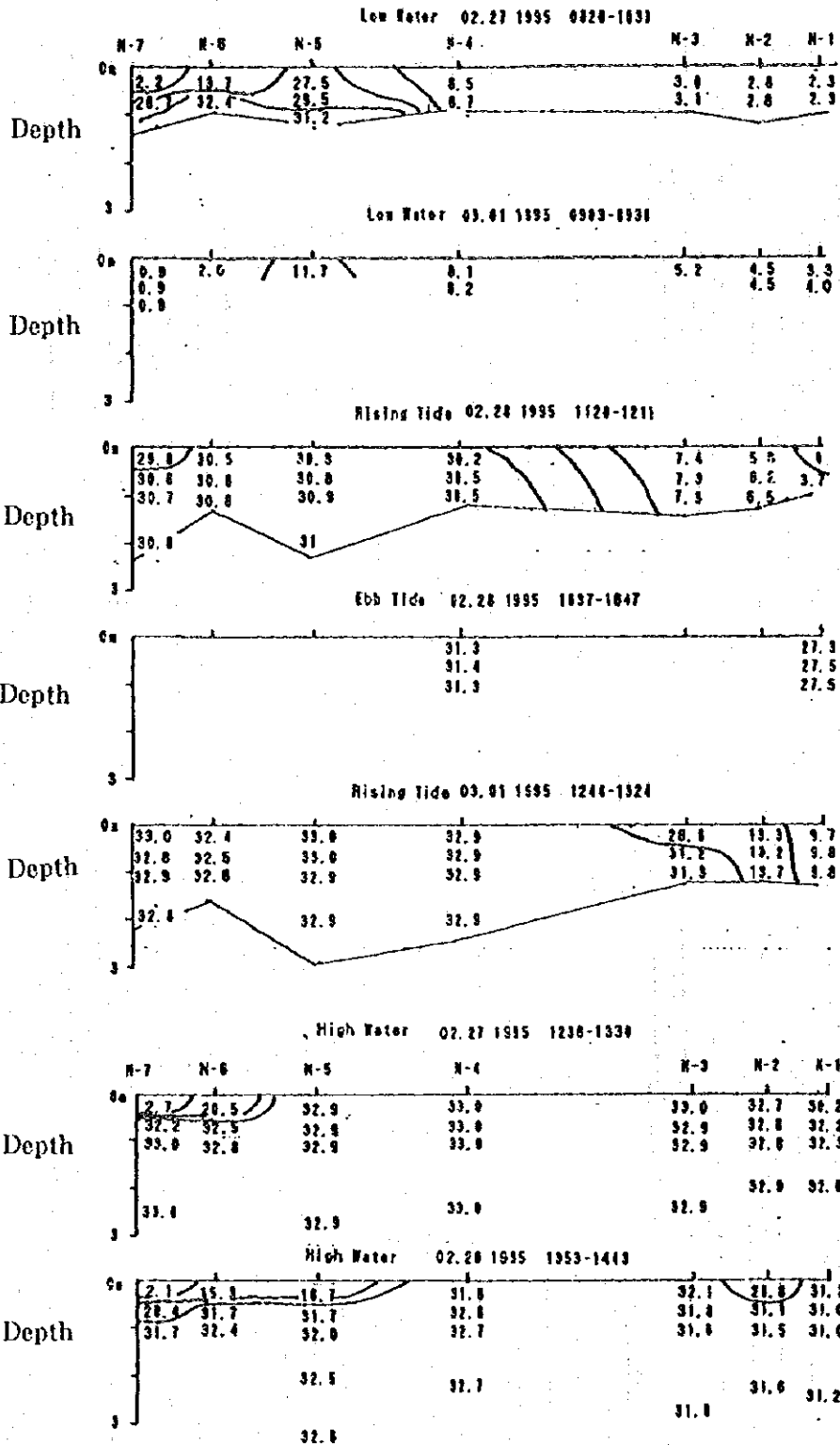


Fig. 13-19 Vertical Distribution of Salinity in Estero Negro and Naranjo River Mouth

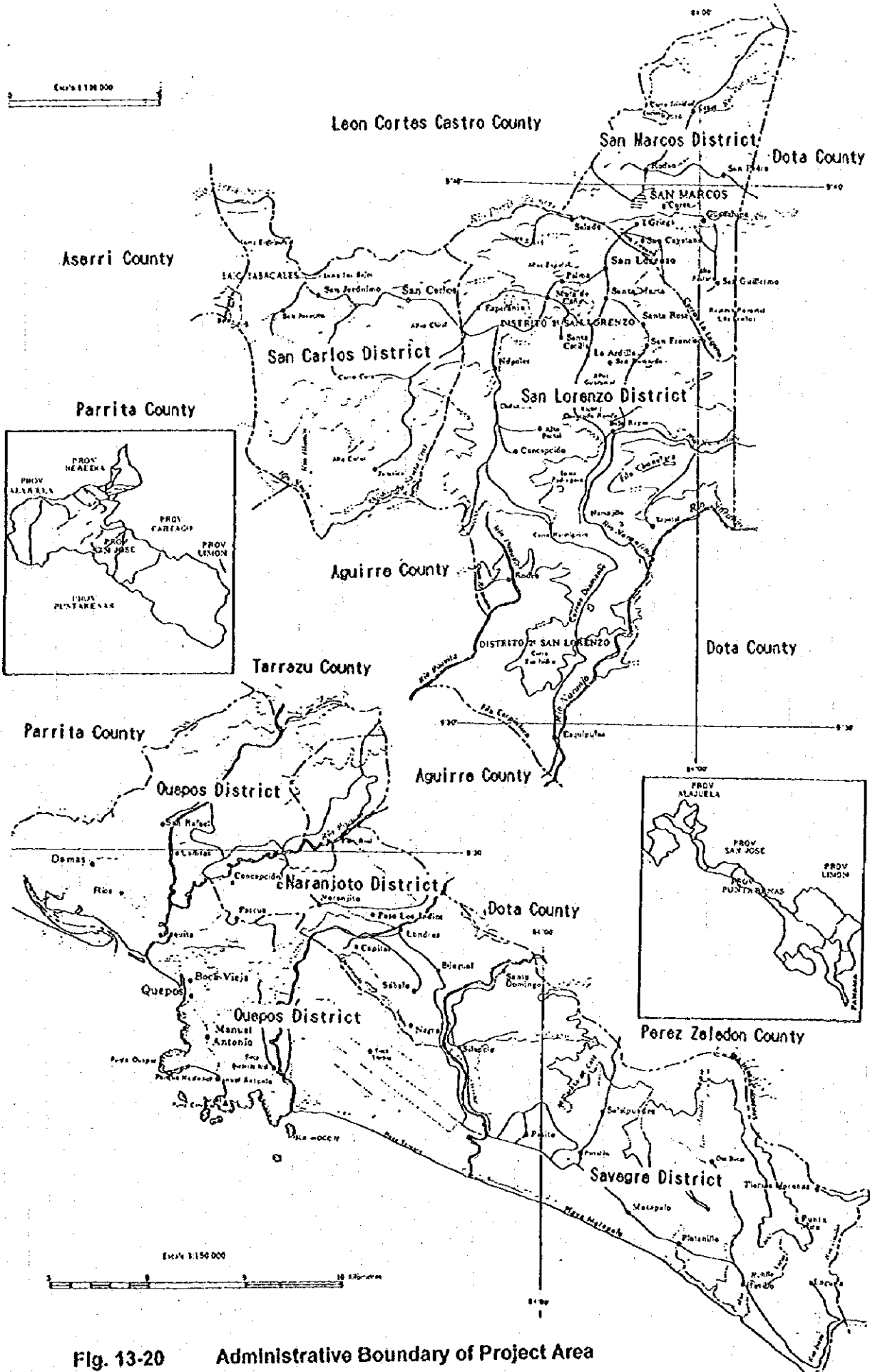


Fig. 13-20 Administrative Boundary of Project Area

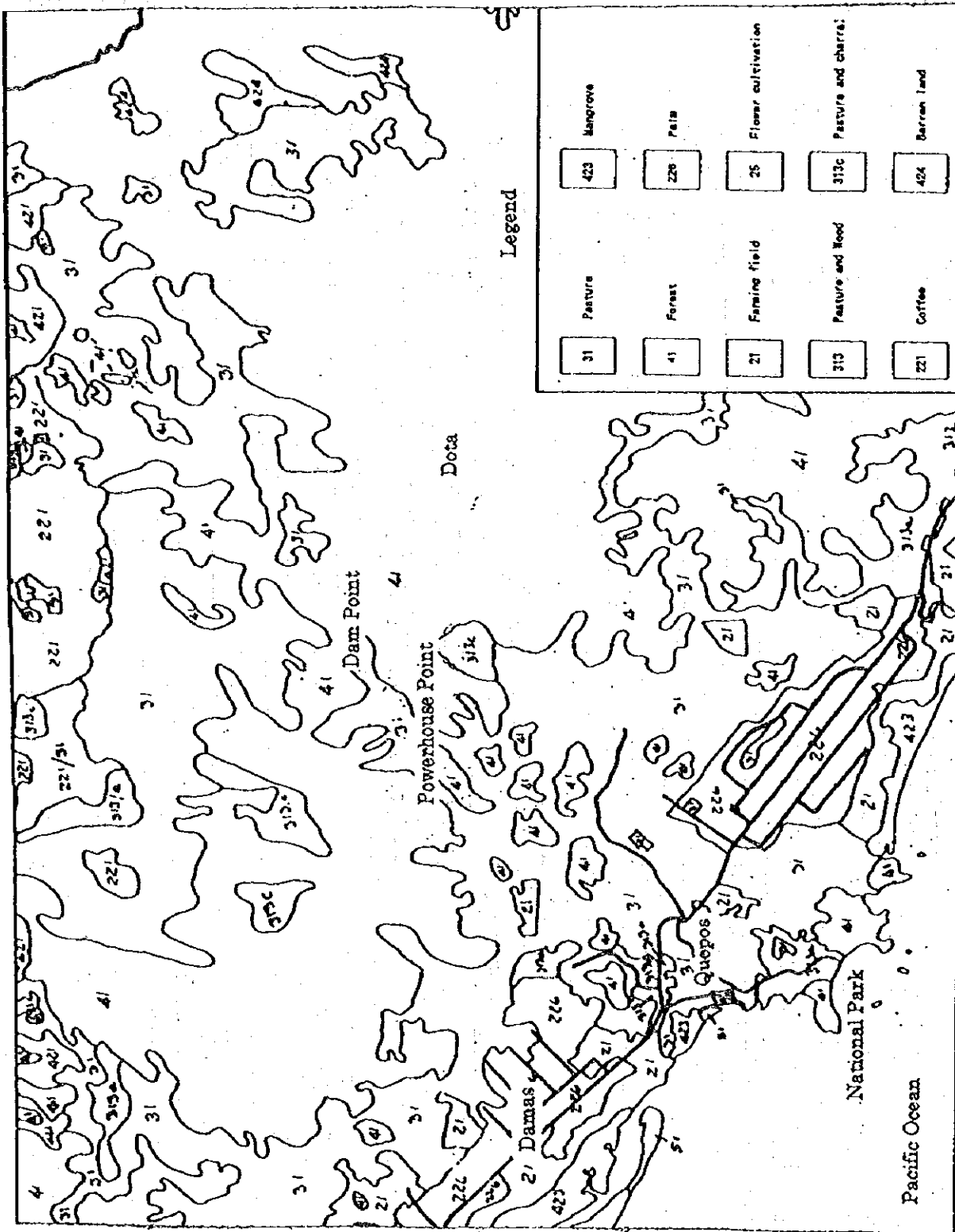


Fig. 13-21 Land Utilization Map